Baltimore Tree species in a changing climate:

Generating a list of climate-informed tree species projections for the GBWC

USDA

Forest Service U.S. Department of Agriculture

Michigan Technological University 1885

NIACS Northern Institute of Applied Climate Science

Agenda

- Who we are and what we do
- Tools that can help for Baltimore
    - Tree Atlas
    - Heat and Hardiness Zone data

Northern Institute of Applied Climate Science

Climate

Carbon

The Northern Institute of Applied Climate Science (NIACS) develops synthesis products, fosters communication, pursues science, and provides technical assistance in climate change adaptation and carbon management.

Multi-institutional collaborative chartered by USDA Forest Service, universities, and non-profit and tribal conservation organizations

NIACS Northern Institute of Applied Climate Science

Forest Service U.S. Department of Agriculture

American Forests™

The University of Vermont

Great Lakes Indian Fish & Wildlife Commission

NCASI

University of Minnesota

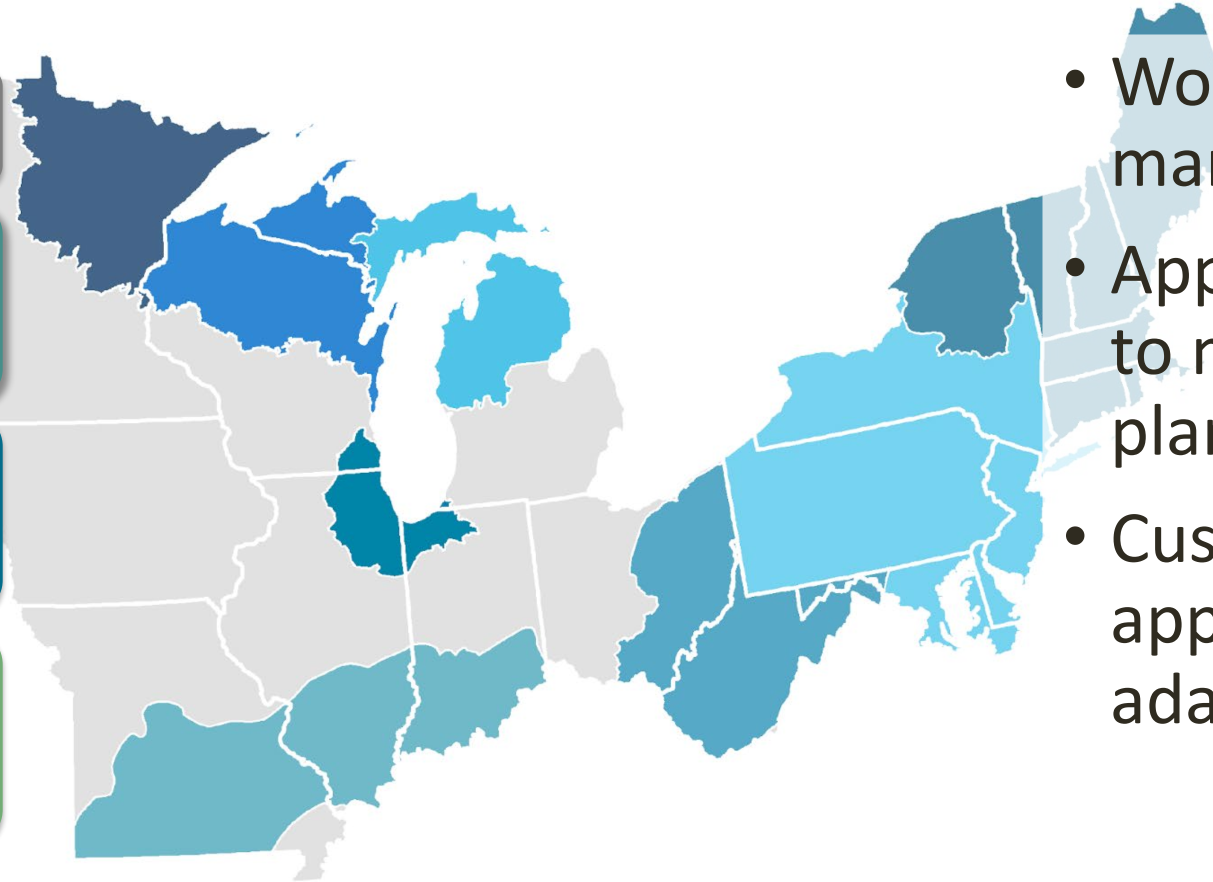
Michigan Technological University 1885

Michigan State University

Climate Change Response Framework

4 COMPONENTS:

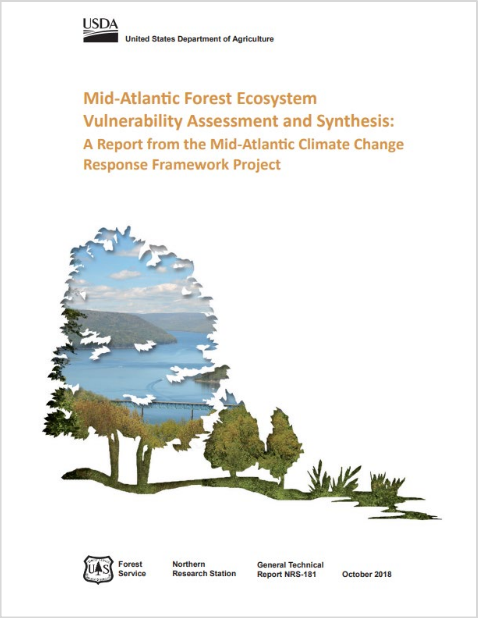
- Partnerships
- Vulnerability Assessments
- Forest Adaptation Resources
- Adaptation Demonstrations



- Work with land managers
- Apply climate-lens to management planning
- Customize approaches for adaptation

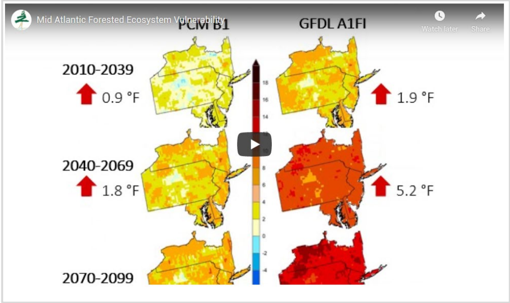
forestadaptation.org

We create practical tools you can use!

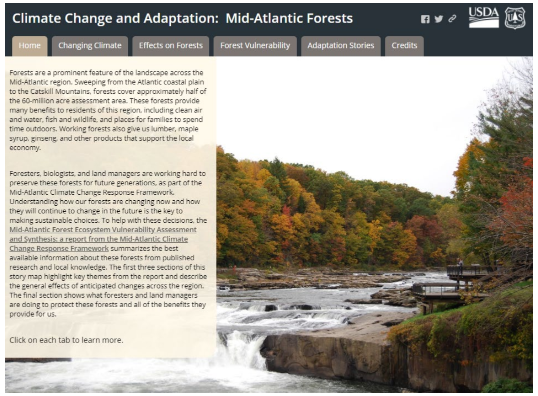


Vulnerability Assessment for Forested Ecosystems

Video presentations

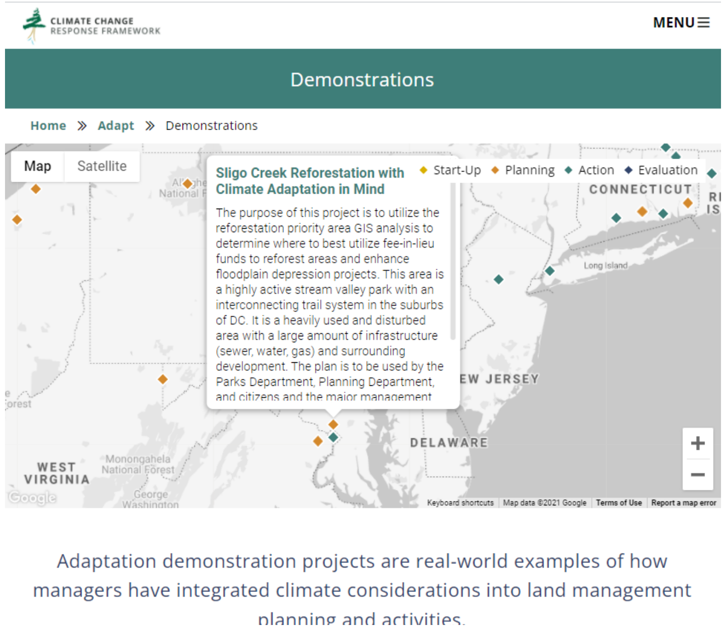


Story Map



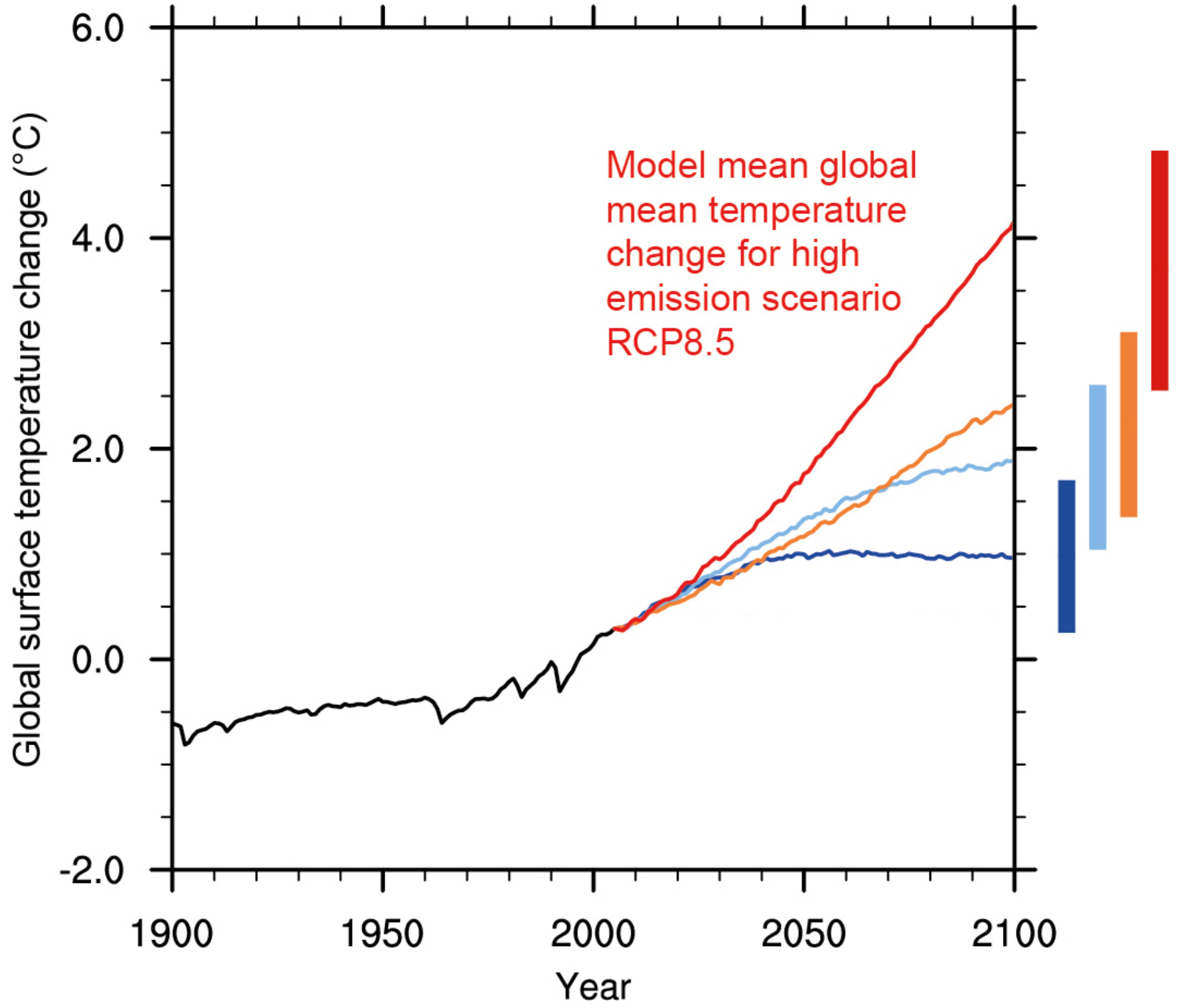
Tree projections & Adaptation tools

Real stories of people making climate-informed decisions



ForestAdaptation.org/Mid-Atlantic

Representative Concentration Pathways (RCPs)



Climate Change Projections

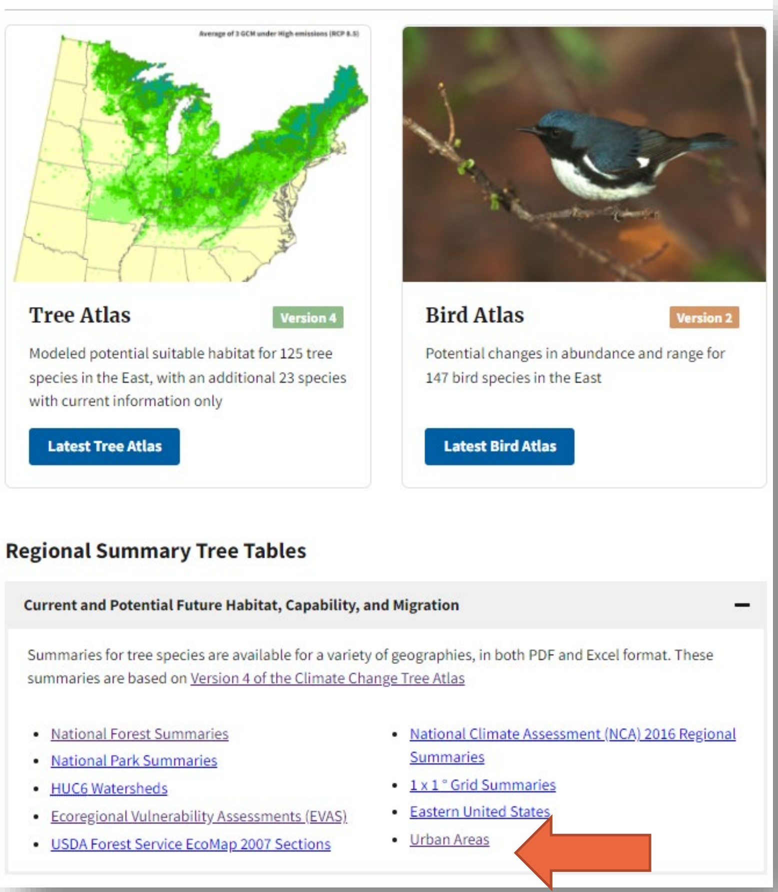
*2009 vs. 2099

	Low Climate Change RCP 4.5	High Climate Change RCP 8.5
Average Temperature	↑ 3.7 °F	↑ 10.4 °F
Growing Season (May-Sept) Temperature	↑ 3.7 °F	↑ 11.5 °F
Total Precipitation	↑ 7 inches	↑ 5.1 inches
Growing Season (May-Sept) Precipitation	↑ 5.3 inches	↓ -0.3 inches

Tools to inform Baltimore tree planting

USFS Tree Atlas

Baltimore, MD



Tree Atlas Version 4

Modeled potential suitable habitat for 125 tree species in the East, with an additional 23 species with current information only

Latest Tree Atlas

Bird Atlas Version 2

Potential changes in abundance and range for 147 bird species in the East

Latest Bird Atlas

Regional Summary Tree Tables

Current and Potential Future Habitat, Capability, and Migration –

Summaries for tree species are available for a variety of geographies, in both PDF and Excel format. These summaries are based on Version 4 of the Climate Change Tree Atlas

- National Forest Summaries
- National Park Summaries
- HUC6 Watersheds
- Ecoregional Vulnerability Assessments (EVAS)
- USDA Forest Service EcoMap 2007 Sections
- National Climate Assessment (NCA) 2016 Regional Summaries
- 1 x 1 ° Grid Summaries
- Eastern United States
- Urban Areas

Heat & Hardiness Zones

Washington, DC

CLIMATE CHANGE VULNERABILITY OF URBAN TREES

WASHINGTON, D.C.

rjones0856/Flickr

This list was developed to aid Washington, D.C. community forestry practitioners in selecting trees to reduce climate change vulnerability of their urban forests. It is meant to be a complement to other tree selection resources. Other factors may also need to be considered, such as aesthetics, local site conditions, wildlife value, or nursery availability. It is also important to note that some species may have climate benefits but may not be suitable for planting for other reasons, such as having invasive potential or susceptibility to pests or pathogens.

Vulnerability: Trees can be vulnerable to a variety of climate-related stressors such as intense heat, drought, flooding, and changing pest and disease patterns. Climate vulnerability is a function of the impacts of climate change on a species and its adaptive capacity. Species with negative impacts on habitat suitability and low adaptive capacity will have high vulnerability and vice versa. The following factors were used to determine climate vulnerability:

Urban adaptability: Adaptability scores were generated for each species based on literature describing its tolerance to disturbances such as drought, flooding, pests, and disease, as well as its growth requirements such as shade tolerance, soil needs, and ease of nursery propagation. Scores were assigned to species using methods developed in an urban forest vulnerability assessment for Chicago for trees planted in developed sites. A positive score indicates that a species is tolerant to a wide range of disturbances and can be planted on a variety of sites. A negative score indicates a species is highly susceptible to disturbances and/or is limited to specific planting sites.

Hardiness and heat zone suitability: Tree species ranges were recorded from government, university, and arboretum websites. Species tolerance ranges were compared to current and projected heat and hardiness zones for Washington, D.C. using downscaled climate models under low emissions (RCP 4.5) and high emissions (RCP 8.5) scenarios for changes in greenhouse gases. Trees were considered to have suitable zone suitability if the species' tolerance was within the range of current and projected hardiness and heat zone through the end of the 21st century.

NOTE: This list was primarily created for species planted in developed sites, such as streets, yards, boulevards, and parks. If you are interested in projected changes in habitat suitability for native species in natural areas, see the Climate Change Tree Atlas at www.fs.fed.us/nrs/atlas/.

Current and projected USDA Hardiness Zones and AHS Heat Zones for Washington, D.C. Hardiness zone is determined by the average lowest temperature over a 30 year period. Heat zones are determined by the number of days above 86°F.

Time Period	Hardiness Zone Range		Heat Zone Range	
1980–2010	7		7	
	Low Emissions	High Emissions	Low Emissions	High Emissions
2010–2039	7	8	7 to 8	8
2040–2069	7 to 8	8	8	9
2070–2099	8	8 to 9	8	9 to 10

SOURCE: Adaptability scores were assigned using methods developed in an urban forest vulnerability assessment for Chicago by Brandt et al. 2017 (https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs168.pdf). Future heat and hardiness zone information were provided from: https://usfs.maps.arcgis.com/apps/MapSeries/index.html?appid=96088b1c086a4b39b3a75d0fd97a4c40.

NIACS

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Climate Change Tree Atlas: About

- A tool used to describe tree habitat distribution and colonization under changed climate.
- Model results for 125 species (and relative abundance for 24 species)
- Information about colonization potential (SHIFT) and overall ability to tolerate future conditions (Capability)
- **New tutorials** and explanations throughout the site.

Regional Summary Tree Tables

Current and Potential Future Habitat, Capability, and Migration –

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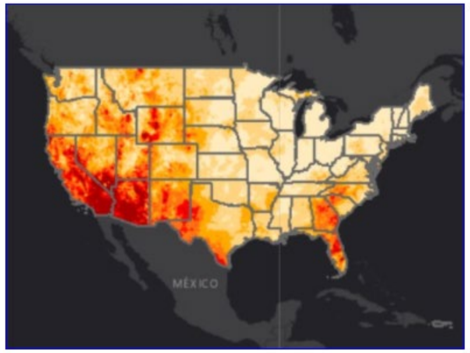
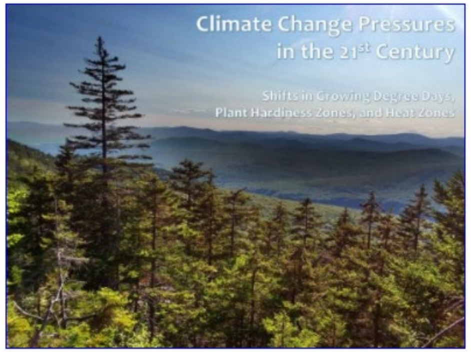
Other Products



Story Map: Drought Over Time



Story Map: Climate Change Pressures in the 21st Century: Shifts in Growing Degree Days, Plant Hardiness Zones, and Heat Zones

www.fs.fed.us/nrs/atlas

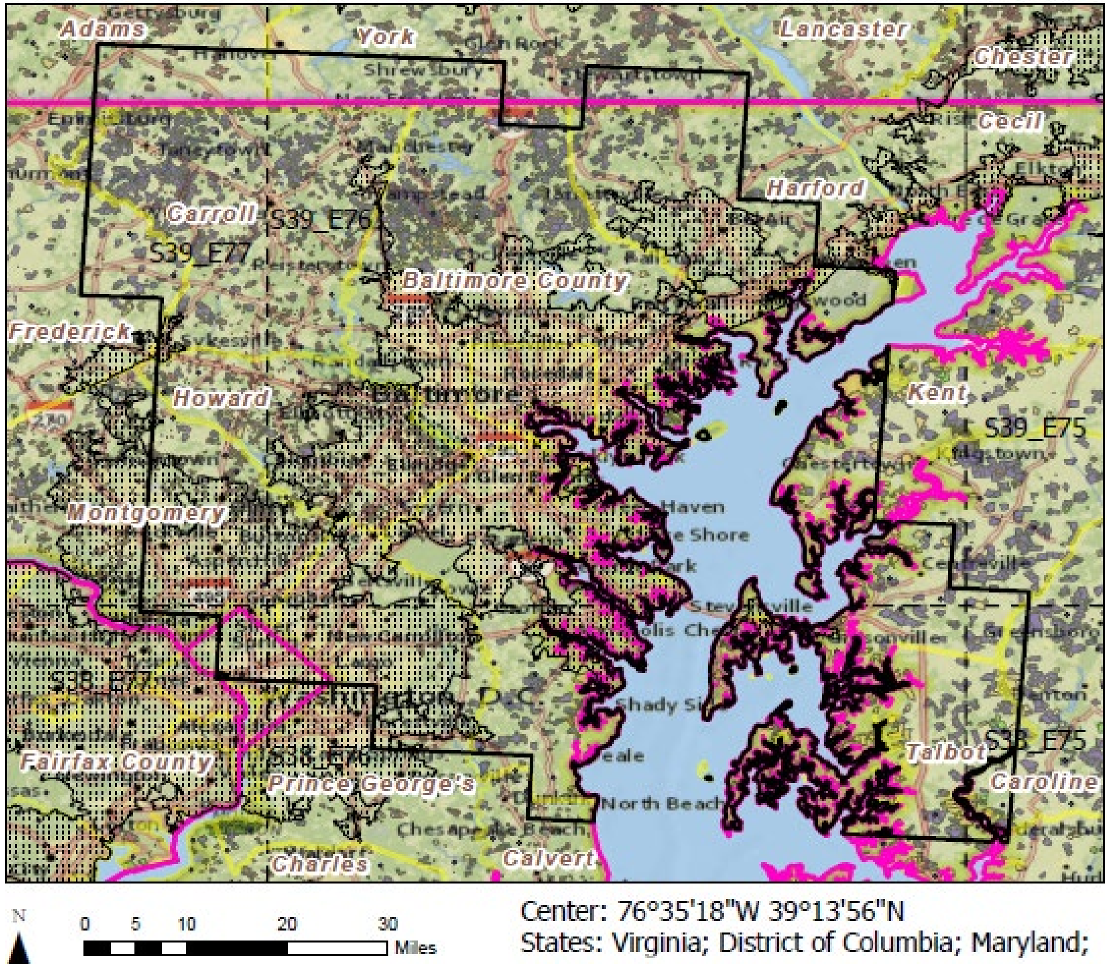
Climate Change Tree Atlas: Baltimore

Results describe trends across the greater Baltimore area

- Urban area (sq. km) = 1,922
- Urban buffer area (sq. km) = 9,137
  - 90 tree species modeled
  - 22% urban land cover

Rare, nonnative, or cultivar species are likely not modeled.

- These species may have vulnerability ratings based on projected heat and hardiness zones.



Center: 76°35'18"W 39°13'56"N
States: Virginia; District of Columbia; Maryland;

www.fs.fed.us/nrs/atlas/combined/resources/summaries/urban/

Climate Change Tree Atlas: Baltimore

- Common and scientific names
- Range
- Model reliability
- FIA sum
- Habitat change class
- Adaptability
- Capability
- SHIFT

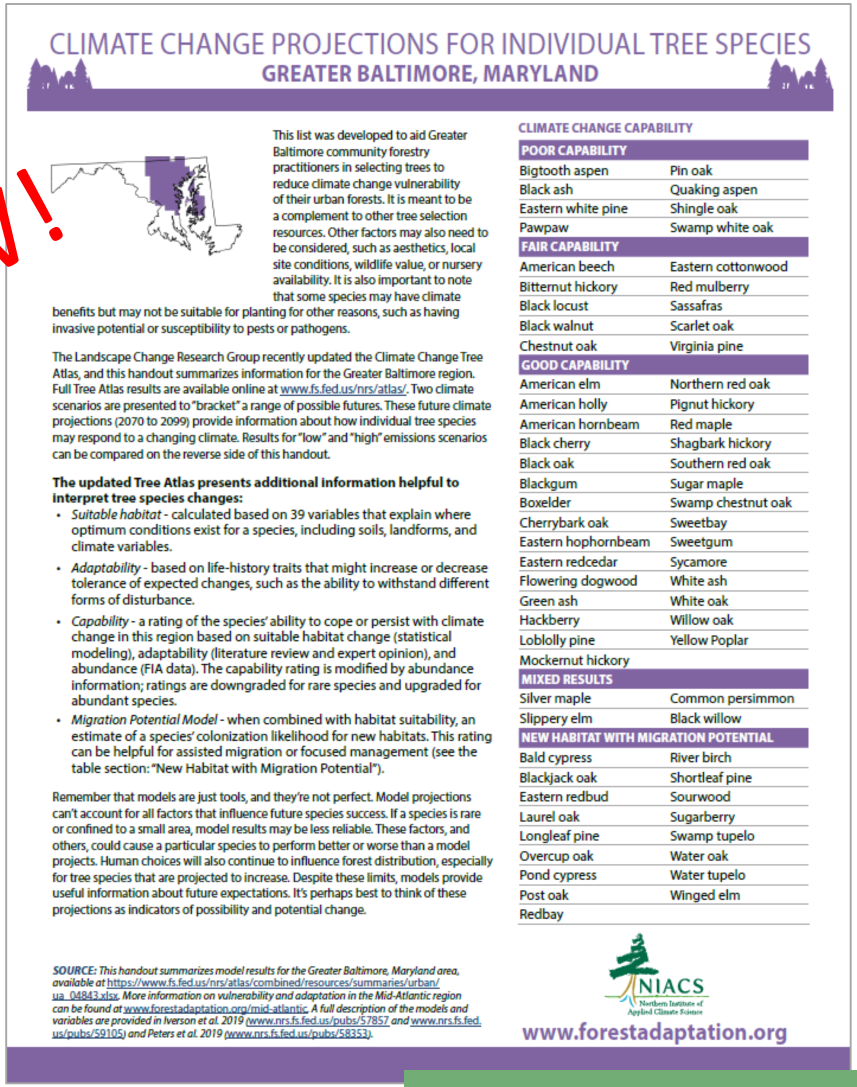
F19 91.61

	Scientific Name	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO	N
14	Quercus rubra	WDH	Medium	37.1	117.6	6.5	No change	No change	High	Common	Good	Good	Infill ++	Infill ++	1	13
15	Quercus coccinea	WDL	Medium	27.6	113.9	6.8	Sm. dec.	Sm. dec.	Medium	Common	Fair	Fair	Infill +	Infill +	1	14
16	Carya glabra	WDL	Medium	31.4	112.2	6.9	No change	No change	Medium	Common	Good	Good	Infill ++	Infill ++	1	15
17	Fraxinus americana	WDL	Medium	25.6	104.4	7.7	No change	No change	Low	Common	Good	Good	Infill ++	Infill ++	1	16
18	Sassafras albidum	WSL	Low	35.9	100.5	5.0	Lg. dec.	Sm. dec.	Medium	Common	Fair	Fair	Infill +	Infill +	1	17
19	Juglans nigra	WDH	Low	20.4	91.6	6.8	Sm. dec.	Sm. dec.	Medium	Common	Fair	Fair	Infill +	Infill +	1	18
20	Pinus taeda	WDH	High	12.7	84.5	15.7	Lg. inc.	Lg. inc.	Medium	Common	Very Good	Very Good	Infill ++	Infill ++	2	19
21	Platanus occidentalis	NSL	Low	16	81.1	9.5	Sm. inc.	Sm. inc.	Medium	Common	Very Good	Very Good	Infill ++	Infill ++	2	20
22	Acer negundo	WSH	Low	19.5	77.2	6.0	No change	No change	High	Common	Good	Good	Infill ++	Infill ++	1	21
23	Populus deltoides	NSH	Low	2.8	68.6	28.0	Sm. dec.	Sm. dec.	Medium	Common	Fair	Fair			0	22
24	Picea abies	NSH	FIA	1.1	61.3	50.0	Unknown	Unknown	NA	Common	NNIS	NNIS			0	23
25	Quercus pagoda	NSL	Medium	1	61.3	45.9	No change	No change	Medium	Common	Good	Good			2	24
26	Pinus strobus	WDH	High	1.1	44.9	36.7	Lg. dec.	Lg. dec.	Low	Rare	Poor	Poor			0	25
27	Ulmus rubra	WSL	Low	3.4	42.0	11.4	Sm. dec.	No change	Medium	Rare	Poor	Fair	Infill +	Infill +	2	26
28	Quercus falcata	WDL	Medium	12.5	37.4	6.6	Lg. inc.	Lg. inc.	High	Rare	Good	Good	Infill ++	Infill ++	2	27
29	Acer saccharinum	NSH	Low	6.8	35.0	13.9	Sm. dec.	No change	High	Rare	Poor	Fair		Infill +	2	28
30	Quercus palustris	NSH	Low	4.5	33.8	6.9	Sm. dec.	Sm. dec.	Low	Rare	Poor	Poor	Infill +	Infill +	2	29
31	Ailanthus altissima	NSL	FIA	8	31.4	6.5	Unknown	Unknown	NA	Rare	NNIS	NNIS			0	30
32	Carya cordiformis	WSL	Low	6.6	29.6	7.2	No change	No change	High	Rare	Fair	Fair	Infill +	Infill +	2	31
33	Ulmus americana	WDH	Medium	15.8	24.3	7.7	Sm. inc.	Lg. inc.	Medium	Rare	Good	Good			2	32
34	Cornus florida	WDL	Medium	16.6	19.5	1.6	Sm. inc.	Sm. inc.	Medium	Rare	Good	Good	Infill ++	Infill ++	1	33
35	Carpinus caroliniana	WSL	Low	7.4	19.1	2.6	Sm. inc.	Sm. inc.	Medium	Rare	Good	Good	Infill ++	Infill ++	1	34
36	Fraxinus pennsylvanica	WSH	Low	4	18.7	5.2	Sm. inc.	Sm. inc.	Medium	Rare	Good	Good			2	35
37	Quercus phellos	NSL	Low	3.8	16.6	4.5	Sm. inc.	Sm. inc.	Medium	Rare	Good	Good			2	36
38	Acer platanoides	NSL	FIA	7.9	14.1	3.9	Unknown	Unknown	NA	Rare	NNIS	NNIS			0	37
39	Quercus imbricaria	NDH	Medium	2.3	12.7	5.2	Sm. dec.	Sm. dec.	Medium	Rare	Poor	Poor			0	38
40	Morus alba	NSL	FIA	10.4	10.7	5.5	Unknown	Unknown	NA	Rare	NNIS	NNIS			0	39
41	Asimina triloba	NSL	Low	6.4	9.8	2.8	Sm. dec.	Lg. dec.	Medium	Rare	Poor	Poor			0	40
42	Ilex opaca	NSL	Medium	13.1	9.0	2.4	Lg. inc.	Lg. inc.	Medium	Rare	Good	Good	Infill ++	Infill ++	1	41

www.fs.fed.us/nrs/atlas/combined/resources/summaries/urban/

Climate Change Tree Atlas: Results for Greater Baltimore

NEW!



CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES
GREATER BALTIMORE, MARYLAND

This list was developed to aid Greater Baltimore community forestry practitioners in selecting trees to reduce climate change vulnerability of their urban forests. It is meant to be a complement to other tree selection resources. Other factors may also need to be considered, such as aesthetics, local site conditions, wildlife value, or nursery availability. It is also important to note that some species may have climate benefits but may not be suitable for planting for other reasons, such as having invasive potential or susceptibility to pests or pathogens.

The Landscape Change Research Group recently updated the Climate Change Tree Atlas, and this handout summarizes information for the Greater Baltimore region. Full Tree Atlas results are available online at www.fs.fed.us/nrs/atlas/. Two climate scenarios are presented to "bracket" a range of possible futures. These future climate projections (2070 to 2099) provide information about how individual tree species may respond to a changing climate. Results for "low" and "high" emissions scenarios can be compared on the reverse side of this handout.

The updated Tree Atlas presents additional information helpful to interpret tree species changes:

- *Suitable habitat* - calculated based on 39 variables that explain where optimum conditions exist for a species, including soils, landforms, and climate variables.
- *Adaptability* - based on life-history traits that might increase or decrease tolerance of expected changes, such as the ability to withstand different forms of disturbance.
- *Capability* - a rating of the species' ability to cope or persist with climate change in this region based on suitable habitat change (statistical modeling), adaptability (literature review and expert opinion), and abundance (FIA data). The capability rating is modified by abundance information; ratings are downgraded for rare species and upgraded for abundant species.
- *Migration Potential Model* - when combined with habitat suitability, an estimate of a species' colonization likelihood for new habitats. This rating can be helpful for assisted migration or focused management (see the table section: "New Habitat with Migration Potential").

Remember that models are just tools, and they're not perfect. Model projections can't account for all factors that influence future species success. If a species is rare or confined to a small area, model results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change.

SOURCE: This handout summarizes model results for the Greater Baltimore, Maryland area, available at https://www.fs.fed.us/nrs/atlas/combined/resources/summaries/urban/ua_04843.xlsx. More information on vulnerability and adaptation in the Mid-Atlantic region can be found at www.forestadaptation.org/mid-atlantic. A full description of the models and variables are provided in Iverson et al. 2019 (www.nrs.fs.fed.us/pubs/57857 and www.nrs.fs.fed.us/pubs/59105) and Peters et al. 2019 (www.nrs.fs.fed.us/pubs/58353).

CLIMATE CHANGE CAPABILITY

POOR CAPABILITY	
Bigtooth aspen	Pin oak
Black ash	Quaking aspen
Eastern white pine	Shingle oak
Pawpaw	Swamp white oak
FAIR CAPABILITY	
American beech	Eastern cottonwood
Bitternut hickory	Red mulberry
Black locust	Sassafras
Black walnut	Scarlet oak
Chestnut oak	Virginia pine
GOOD CAPABILITY	
American elm	Northern red oak
American holly	Pignut hickory
American hornbeam	Red maple
Black cherry	Shagbark hickory
Black oak	Southern red oak
Blackgum	Sugar maple
Boxelder	Swamp chestnut oak
Cherrybark oak	Sweetbay
Eastern hophornbeam	Sweetgum
Eastern redcedar	Sycamore
Flowering dogwood	White ash
Green ash	White oak
Hackberry	Willow oak
Loblolly pine	Yellow Poplar
Mockernut hickory	
MIXED RESULTS	
Silver maple	Common persimmon
Slippery elm	Black willow
NEW HABITAT WITH MIGRATION POTENTIAL	
Bald cypress	River birch
Blackjack oak	Shortleaf pine
Eastern redbud	Sourwood
Laurel oak	Sugarberry
Longleaf pine	Swamp tupelo
Overcup oak	Water oak
Pond cypress	Water tupelo
Post oak	Winged elm
Redbay	

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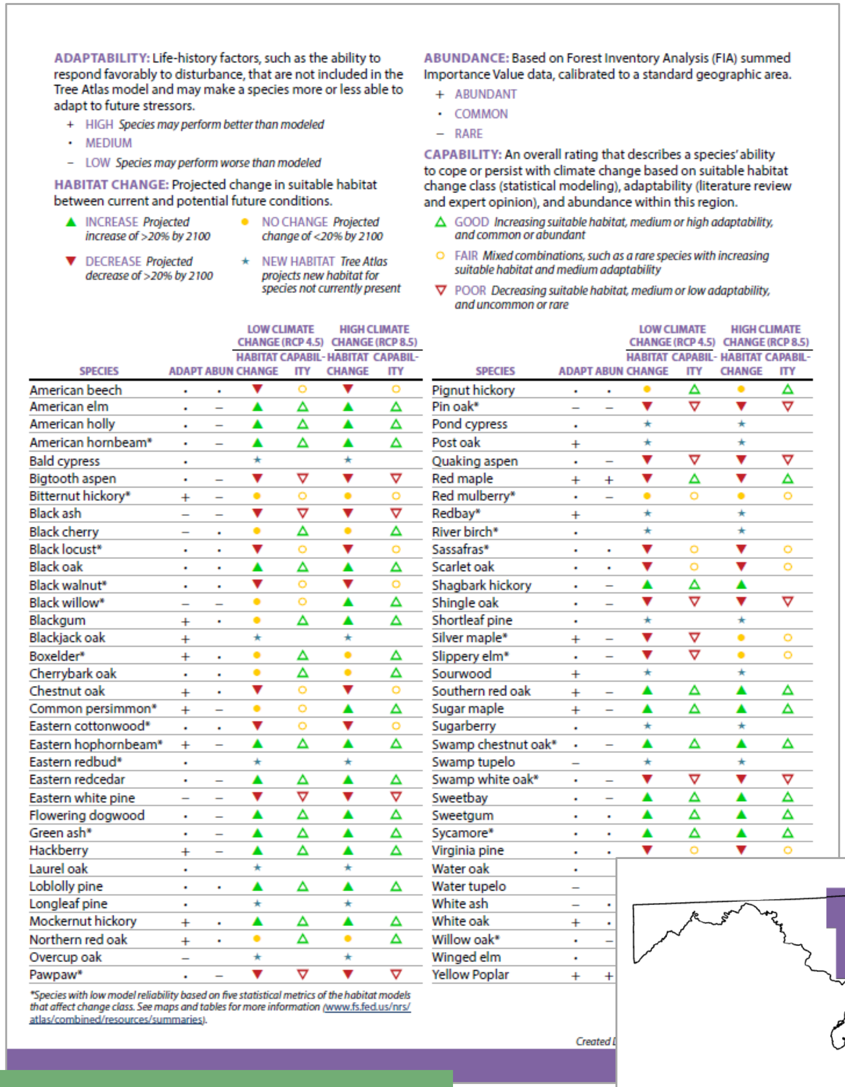

ADAPTABILITY: Life-history factors, such as the ability to respond favorably to disturbance, that are not included in the Tree Atlas model and may make a species more or less able to adapt to future stressors.

- \+ HIGH *Species may perform better than modeled*
- • MEDIUM
- – LOW *Species may perform worse than modeled*

HABITAT CHANGE: Projected change in suitable habitat between current and potential future conditions.

- ▲ INCREASE *Projected increase of >20% by 2100*
- ● NO CHANGE *Projected change of <20% by 2100*
- ▼ DECREASE *Projected decrease of >20% by 2100*
- ★ NEW HABITAT *Tree Atlas projects new habitat for species not currently present*

ABUNDANCE: Based on Forest Inventory Analysis (FIA) summed Importance Value data, calibrated to a standard geographic area.

- \+ ABUNDANT
- • COMMON
- – RARE

CAPABILITY: An overall rating that describes a species' ability to cope or persist with climate change based on suitable habitat change class (statistical modeling), adaptability (literature review and expert opinion), and abundance within this region.

- △ GOOD *Increasing suitable habitat, medium or high adaptability, and common or abundant*
- ○ FAIR *Mixed combinations, such as a rare species with increasing suitable habitat and medium adaptability*
- ▽ POOR *Decreasing suitable habitat, medium or low adaptability, and uncommon or rare*

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	ADAPT	ABUN	HABITAT CHANGE	CAPABILITY	HABITAT CHANGE	CAPABILITY
American beech	•	•	▼	○	▼	○
American elm	•	–	▲	△	▲	△
American holly	•	–	▲	△	▲	△
American hornbeam*	•	–	▲	△	▲	△
Bald cypress	•		★		★	
Bigtooth aspen	•	–	▼	▽	▼	▽
Bitternut hickory*	+	–	●	○	●	○
Black ash	–	–	▼	▽	▼	▽
Black cherry	–	•	●	△	●	△
Black locust*	•	•	▼	○	▼	○
Black oak	•	•	▲	△	▲	△
Black walnut*	•	•	▼	○	▼	○
Black willow*	–	–	●	○	▲	△
Blackgum	+	•	●	△	▲	△
Blackjack oak	+		★		★	
Boxelder*	+	•	●	△	●	△
Cherrybark oak	•	•	●	△	●	△
Chestnut oak	+	•	▼	○	▼	○
Common persimmon*	+	–	●	○	▲	△
Eastern cottonwood*	•	•	▼	○	▼	○
Eastern hophornbeam*	+	–	▲	△	▲	△
Eastern redbud*	•		★		★	
Eastern redcedar	•	–	▲	△	▲	△
Eastern white pine	–	–	▼	▽	▼	▽
Flowering dogwood	•	–	▲	△	▲	△
Green ash*	•	–	▲	△	▲	△
Hackberry	+	–	▲	△	▲	△
Laurel oak	•		★		★	
Loblolly pine	•	•	▲	△	▲	△
Longleaf pine	•		★		★	
Mockernut hickory	+	•	▲	△	▲	△
Northern red oak	+	•	●	△	●	△
Overcup oak	–		★		★	
Pawpaw*	•	–	▼	▽	▼	▽
Pignut hickory	•	•	●	△	●	△
Pin oak*	–	–	▼	▽	▼	▽
Pond cypress	•		★		★	
Post oak	+		★		★	
Quaking aspen	•	–	▼	▽	▼	▽
Red maple	+	+	▼	△	▼	△
Red mulberry*	•	–	●	○	●	○
Redbay*	+		★		★	
River birch*	•		★		★	
Sassafras*	•	•	▼	○	▼	○
Scarlet oak	•	•	▼	○	▼	○
Shagbark hickory	•	–	▲	△	▲	
Shingle oak	•	–	▼	▽	▼	▽
Shortleaf pine	•		★		★	
Silver maple*	+	–	▼	▽	●	○
Slippery elm*	•	–	▼	▽	●	○
Sourwood	+		★		★	
Southern red oak	+	–	▲	△	▲	△
Sugar maple	+	–	▲	△	▲	△
Sugarberry	•		★		★	
Swamp chestnut oak*	•	–	▲	△	▲	△
Swamp tupelo	–		★		★	
Swamp white oak*	•	–	▼	▽	▼	▽
Sweetbay	•	–	▲	△	▲	△
Sweetgum	•	•	▲	△	▲	△
Sycamore*	•	•	▲	△	▲	△
Virginia pine	•	•	▼	○	▼	○
Water oak	•					
Water tupelo	–					
White ash	–	•				
White oak	+	•				
Willow oak*	•	–				
Winged elm	•					
Yellow Poplar	+	+				

**Species with low model reliability based on five statistical metrics of the habitat models that affect change class. See maps and tables for more information (www.fs.fed.us/nrs/atlas/combined/resources/summaries).*

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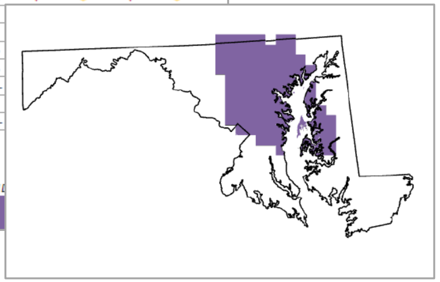


forestadaptation.org/baltimore

Climate Change Tree Atlas: Results for Greater Baltimore

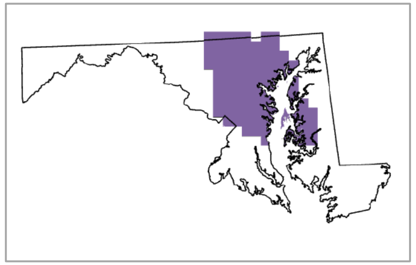
POOR CAPABILITY	
Bigtooth aspen	Pin oak
Black ash	Quaking aspen
Eastern white pine	Shingle oak
Pawpaw	Swamp white oak

FAIR CAPABILITY	
American beech	Eastern cottonwood
Bitternut hickory	Red mulberry
Black locust	Sassafras
Black walnut	Scarlet oak
Chestnut oak	Virginia pine

GOOD CAPABILITY	
American elm	Northern red oak
American holly	Pignut hickory
American hornbeam	Red maple
Black cherry	Shagbark hickory
Black oak	Southern red oak
Blackgum	Sugar maple
Boxelder	Swamp chestnut oak
Cherrybark oak	Sweetbay
Eastern hophornbeam	Sweetgum
Eastern redcedar	Sycamore
Flowering dogwood	White ash
Green ash	White oak
Hackberry	Willow oak
Loblolly pine	Yellow Poplar
Mockernut hickory	

MIXED RESULTS	
Silver maple	Common persimmon
Slippery elm	Black willow

NEW HABITAT WITH MIGRATION POTENTIAL	
Bald cypress	River birch
Blackjack oak	Shortleaf pine
Eastern redbud	Sourwood
Laurel oak	Sugarberry
Longleaf pine	Swamp tupelo
Overcup oak	Water oak
Pond cypress	Water tupelo
Post oak	Winged elm
Redbay	



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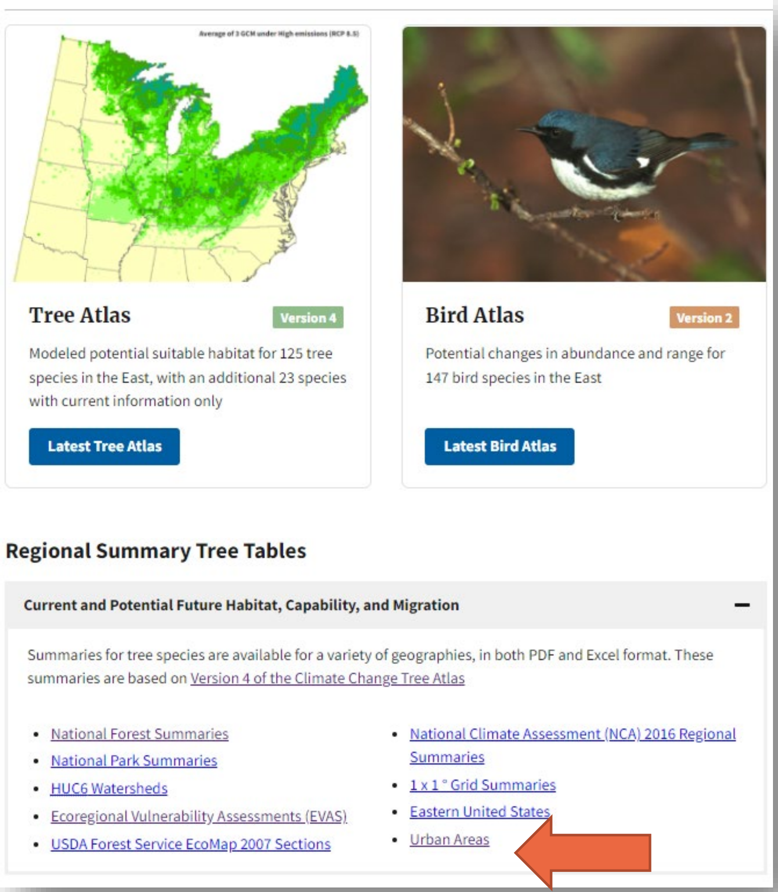
Tools to inform Baltimore tree planting

USFS Tree Atlas

Baltimore, MD



Heat & Hardiness Zones

Washington, DC

CLIMATE CHANGE VULNERABILITY OF URBAN TREES

WASHINGTON, D.C.

rjones0856/Flickr

This list was developed to aid Washington, D.C. community forestry practitioners in selecting trees to reduce climate change vulnerability of their urban forests. It is meant to be a complement to other tree selection resources. Other factors may also need to be considered, such as aesthetics, local site conditions, wildlife value, or nursery availability. It is also important to note that some species may have climate benefits but may not be suitable for planting for other reasons, such as having invasive potential or susceptibility to pests or pathogens.

Vulnerability: Trees can be vulnerable to a variety of climate-related stressors such as intense heat, drought, flooding, and changing pest and disease patterns. Climate vulnerability is a function of the impacts of climate change on a species and its adaptive capacity. Species with negative impacts on habitat suitability and low adaptive capacity will have high vulnerability and vice versa. The following factors were used to determine climate vulnerability:

Urban adaptability: Adaptability scores were generated for each species based on literature describing its tolerance to disturbances such as drought, flooding, pests, and disease, as well as its growth requirements such as shade tolerance, soil needs, and ease of nursery propagation. Scores were assigned to species using methods developed in an urban forest vulnerability assessment for Chicago for trees planted in developed sites. A positive score indicates that a species is tolerant to a wide range of disturbances and can be planted on a variety of sites. A negative score indicates a species is highly susceptible to disturbances and/or is limited to specific planting sites.

Hardiness and heat zone suitability: Tree species ranges were recorded from government, university, and arboretum websites. Species tolerance ranges were compared to current and projected heat and hardiness zones for Washington, D.C. using downscaled climate models under low emissions (RCP 4.5) and high emissions (RCP 8.5) scenarios for changes in greenhouse gases. Trees were considered to have suitable zone suitability if the species' tolerance was within the range of current and projected hardiness and heat zone through the end of the 21st century.

NOTE: This list was primarily created for species planted in developed sites, such as streets, yards, boulevards, and parks. If you are interested in projected changes in habitat suitability for native species in natural areas, see the Climate Change Tree Atlas at www.fs.fed.us/nrs/atlas/.

Current and projected USDA Hardiness Zones and AHS Heat Zones for Washington, D.C. Hardiness zone is determined by the average lowest temperature over a 30 year period. Heat zones are determined by the number of days above 86°F.

Time Period	Hardiness Zone Range		Heat Zone Range	
1980–2010	7		7	
	Low Emissions	High Emissions	Low Emissions	High Emissions
2010–2039	7	8	7 to 8	8
2040–2069	7 to 8	8	8	9
2070–2099	8	8 to 9	8	9 to 10

SOURCE: Adaptability scores were assigned using methods developed in an urban forest vulnerability assessment for Chicago by Brandt et al. 2017 (https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs168.pdf). Future heat and hardiness zone information were provided from: https://usfs.maps.arcgis.com/apps/MapSeries/index.html?appid=96088b1c086a4b39b3a75d0fd97a4c40.

NIACS

www.forestadaptation.org

NIACS Washington DC climate change resources

Tree species projections (simplistic):

Tree characteristics

+

Climate informed habitat projections

Disturbance Factors

Tolerance to: Pests, diseases, drought, flood, wind, ice, salt, air and urban pollution, heat, browsing, invasive species

Biological Factors

Shade tolerance, edaphic specificity, invasive potential, habitat specificity, nursery propagation, maintenance required, planting establishment, restricted rooting conditions

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NIACS Washington DC climate change resources

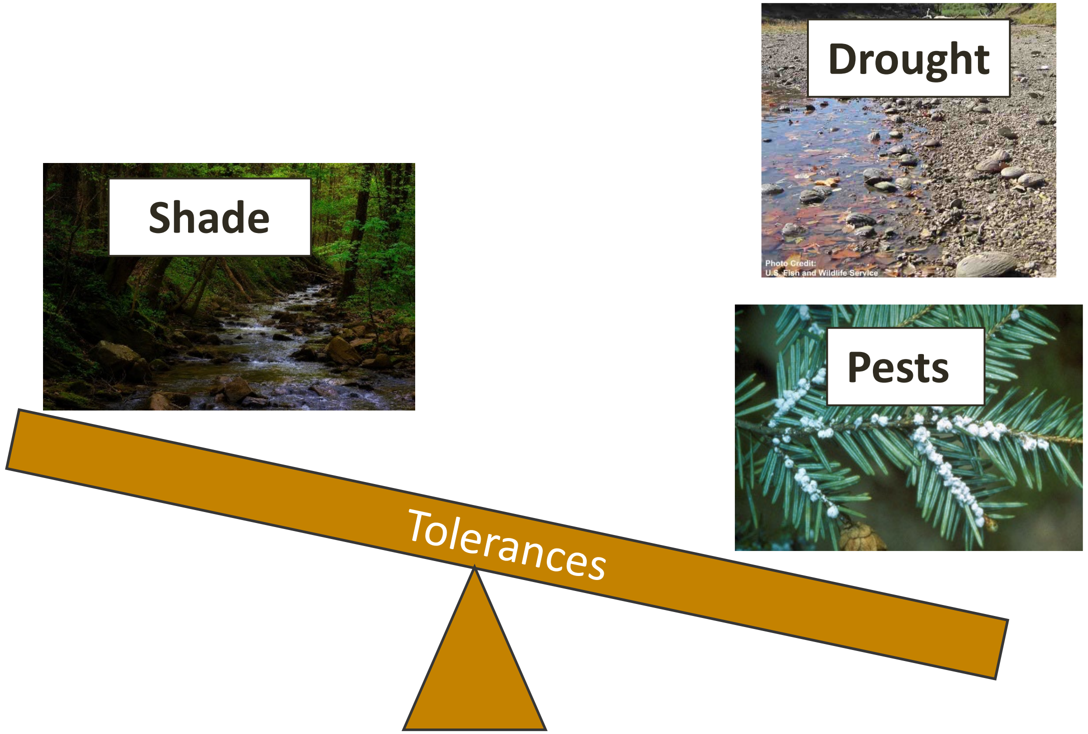
Tree species projections (simplistic):

Tree characteristics

Adaptive capacity scoring

\+

Climate informed habitat projections

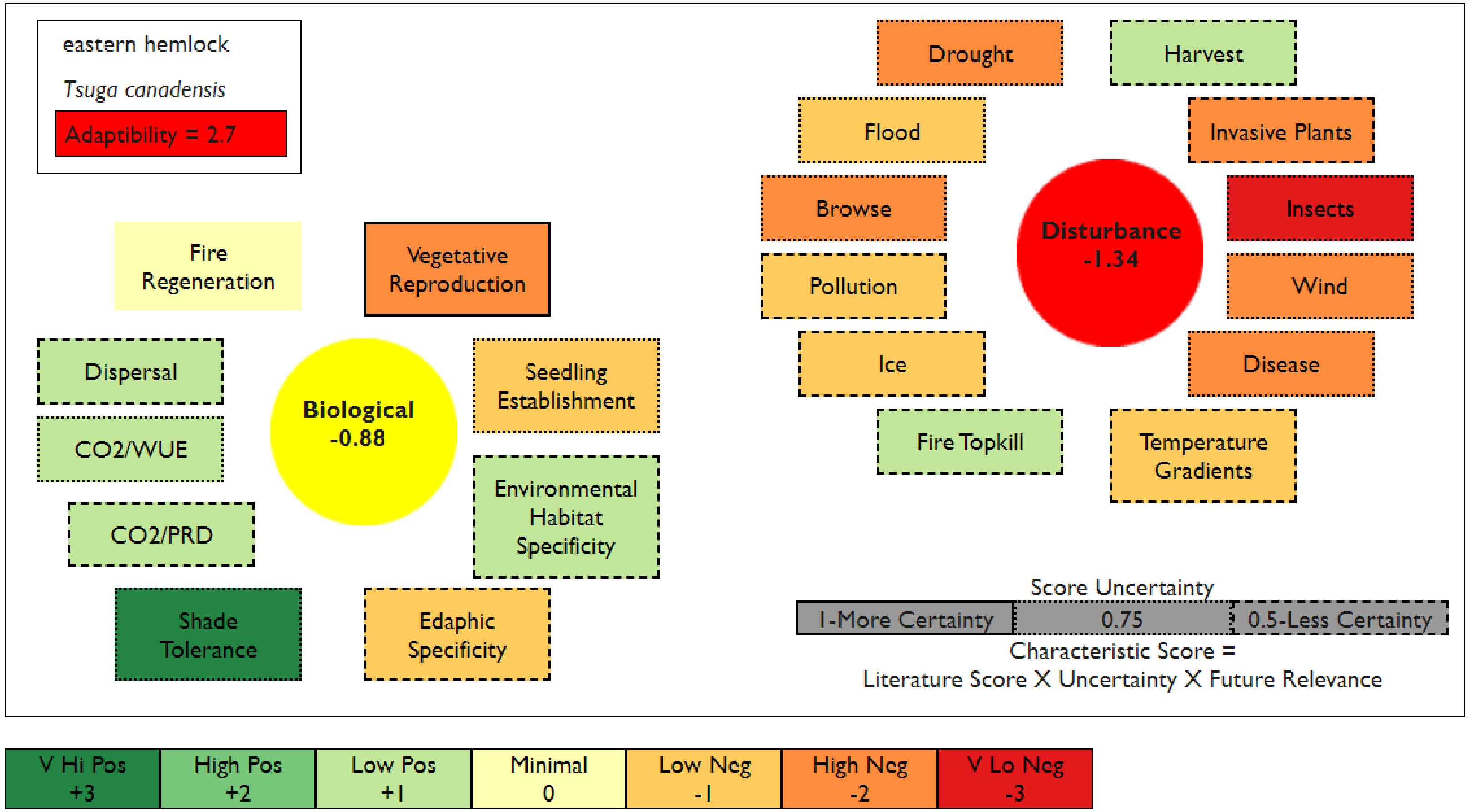


Eastern hemlock

forestadaptation.org/washington-dc

How do we determine vulnerability of individual trees? Adaptive Capacity Scoring

Example of Planted Modification Factor Scores Generated for the Species **Eastern hemlock**.



This image is available on the Tree Atlas website!

Matthews, S. N., Iverson, L. R., Prasad, A. M., Peters, M. P., & Rodewald, P. G. (2011). Modifying climate change habitat models using tree species-specific assessments of model uncertainty and life history factors. Forest Ecology and Management, 262, 1460-1472.

How do we determine vulnerability of individual trees? Adaptive Capacity Scoring

Example of Planted Modification Factor Scores Generated for the Species **Boxelder**.

Matthews, S. N., Iverson, L. R., Prasad, A. M., Peters, M. P., & Rodewald, P. G. (2011). Modifying climate change habitat models using tree species-specific assessments of model uncertainty and life history factors. Forest Ecology and Management, 262, 1460-1472.

Factor Type	ModFactor	Score	Uncert	FutureRelevance	Weighted
Disturbance	Disease	-1	0.75	2	-1.50
Disturbance	Insect Pests	-3	0.5	5	-7.50
Disturbance	Browse	-1	0.75	1	-0.75
Disturbance	Invasive Plants	0	0.5	2	0.00
Disturbance	Drought	3	0.75	3	6.75
Disturbance	Flood	2	0.75	3	4.50
Disturbance	Ice	-1	0.5	2	-1.00
Disturbance	Wind	-1	0.75	2	-1.50
Disturbance	Salt	1	0.5	1	0.50
Disturbance	Temperature Gradients	3	0.75	3	6.75
Disturbance	Air Pollution	-2	0.75	3	-4.50
Disturbance	Soil & Water Pollution	-2	0.5	1	-1.00
Biological	Competition-Light	2	0.5	1	1.00
Biological	Edaphic Specificity	2	0.75	2	3.00
Biological	Land Use & Planting Site Specificity	1	0.75	3	2.25
Biological	Restricted Rooting Conditions	1	0.75	3	2.25
Biological	Nursery Propagation	-1	0.75	4	-3.00
Biological	Planting Establishment	2	0.75	2	3.00
Biological	Maintenance Required	-1	0.75	2	-1.50
Biological	Invasive Potential	-3	0.75	3	-6.75
	Adapt Score				4.41
	Adapt Class				Medium

NIACS Washington DC climate change resources

Tree species projections (simplistic):

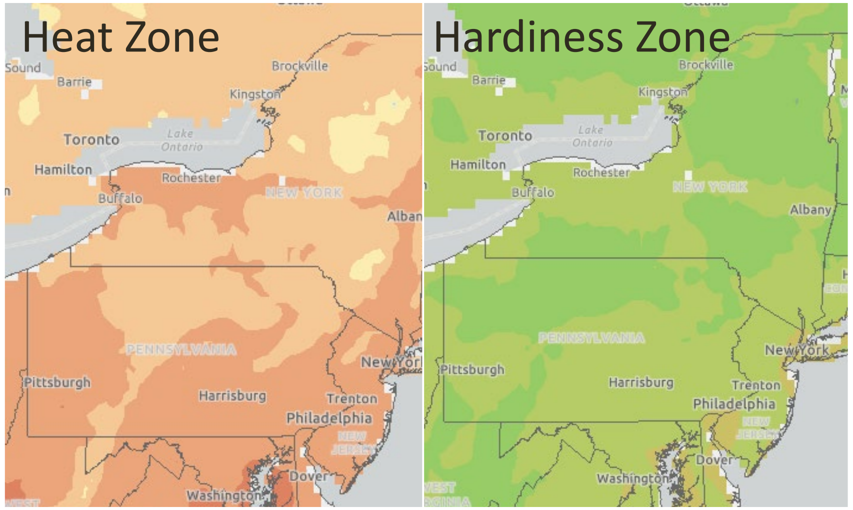
Tree characteristics

Adaptive capacity scoring

+ **Future heat zone and hardiness zone projections**

Climate informed habitat projections

High Climate Change Scenario (RCP 8.5)



Time Period	Hardiness Zone Range		Heat Zone Range	
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Current and projected USDA Hardiness Zones and AHS Heat Zones for Washington, D.C. Hardiness zone is determined by the average lowest temperature over a 30 year period. Heat zones are determined by the number of days above 86°F.

forestadaptation.org/washington-dc

NIACS Washington DC climate change resources

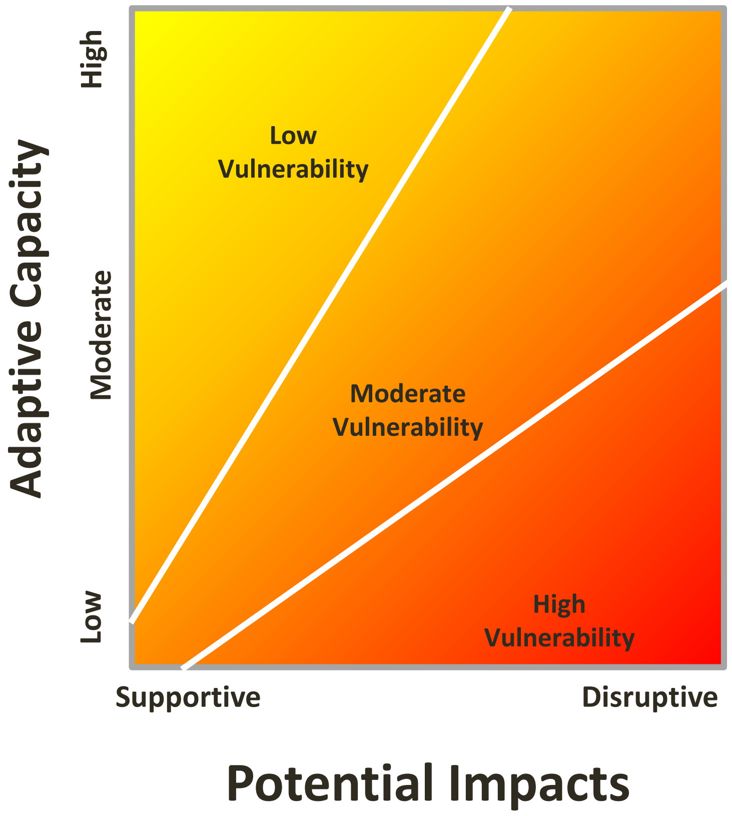
Tree species projections (simplistic):

Tree characteristics

Additional vulnerability considerations

\+ Future heat zone and hardiness zone projections

Climate informed habitat projections



ZONE SUITABILITY:

- ✔ ***Suitable***
- ✕ ***Not Suitable***

VULNERABILITY:

- ▼ ***Low:*** *Suitable zone, high adaptability*
- ● ***Low-moderate:*** *Suitable zone, medium adaptability*
- ⊖ ***Moderate:*** *Suitable zone, low adaptability or zone not suitable, high adaptability*
- ○ ***Moderate- high:*** *Zone not suitable, medium adaptability*
- △ ***High:*** *Zone not suitable, low adaptability*

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NIACS Washington DC climate change resources

URBAN ADAPTABILITY:

- \+ ***High:*** *Species may perform better than modeled*
- · ***Medium***
- – ***Low:*** *Species may perform worse than modeled*

ZONE SUITABILITY:

- ✓ ***Suitable***
- ✗ ***Not Suitable***

VULNERABILITY:

- ▼ ***Low:*** *Suitable zone, high adaptability*
- ● ***Low-moderate:*** *Suitable zone, medium adaptability*
- ⊖ ***Moderate:*** *Suitable zone, low adaptability or zone not suitable, high adaptability*
- ○ ***Moderate- high:*** *Zone not suitable, medium adaptability*
- △ ***High:*** *Zone not suitable, low adaptability*

**Invasive species*

		LOW EMISSIONS		HIGH EMISSIONS	
		ZONE		ZONE	
COMMON NAME	ADAPT	SUIT	VULN	SUIT	VULN
Alleghany serviceberry	+	✓	▼	✗	⊖
American linden, Basswood	·	✓	●	✗	○
American sweetgum, fruitless	+	✓	▼	✓	▼
American beech	·	✓	●	✓	●
American elm	·	✓	●	✓	●
American sycamore	·	✓	●	✓	●
Amur corktree*	+	✗	⊖	✗	⊖
Amur maackia	+	✗	⊖	✗	⊖
Amur maple*	·	✗	○	✗	○
Bald cypress	+	✓	▼	✓	▼
Bipinnate goldenrain tree	+	✓	▼	✓	▼
Black alder	·	✗	○	✗	○
Black locust	·	✓	●	✗	○
Black oak	·	✓	●	✗	○
Black tupelo, Black gum	+	✓	▼	✓	▼
Black walnut	–	✓	⊖	✓	⊖
Blackjack oak	–	✓	⊖	✓	⊖
Boxelder	·	✓	●	✗	○

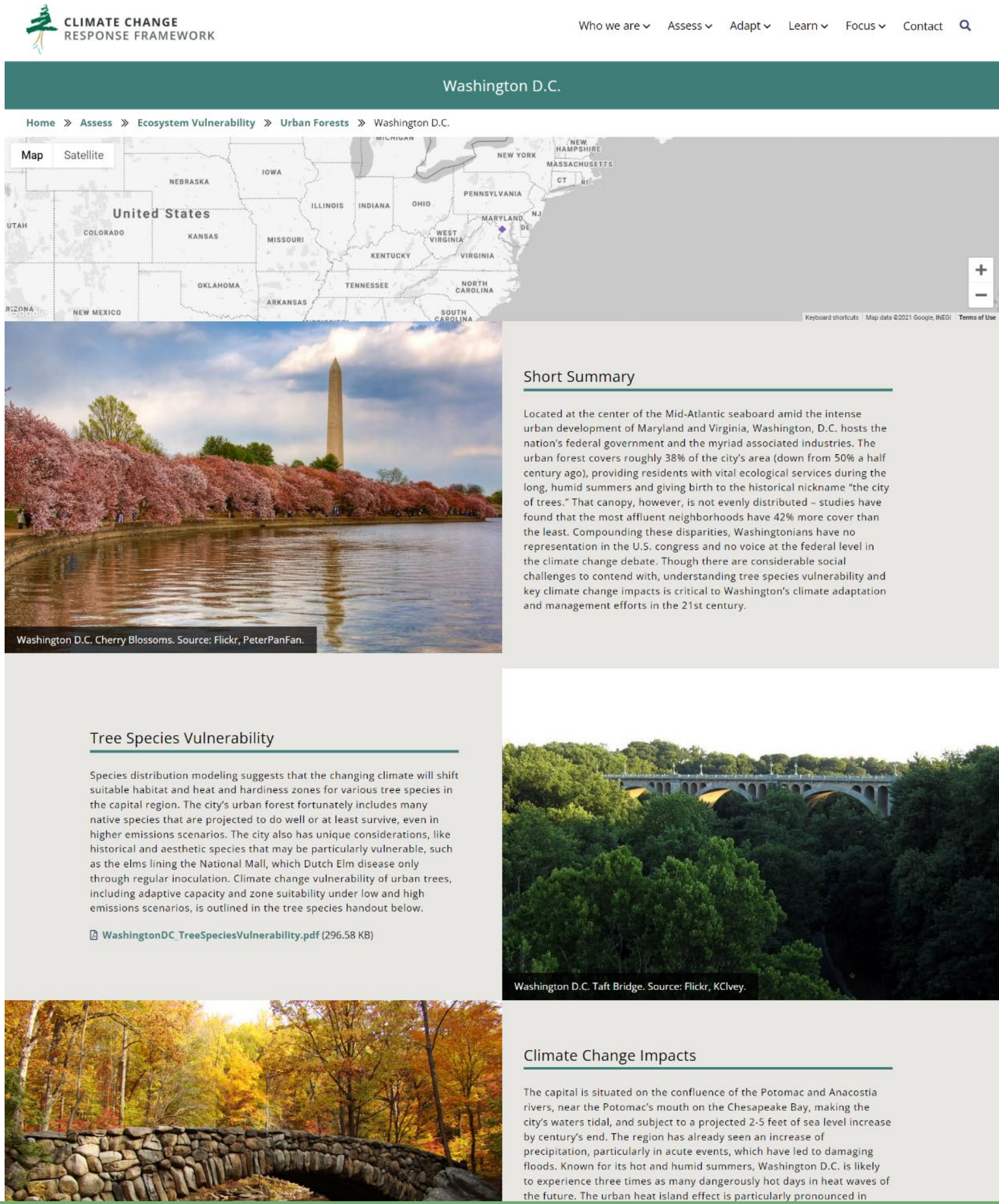
		LOW EMISSIONS		HIGH EMISSIONS	
		ZONE		ZONE	
COMMON NAME	ADAPT	SUIT	VULN	SUIT	VULN
Honeylocust*	·	✓	●	✗	○
Ironwood	+	✓	▼	✓	▼
Japanese flowering cherry	–	✗	△	✗	△
Japanese pagoda tree	·	✓	●	✗	○
Japanese tree lilac	+	✗	⊖	✗	⊖
Japanese zelkova	+	✓	▼	✗	⊖
Jefferson elm	+	✓	▼	✓	▼
Katsura tree	–	✓	⊖	✗	△
Kentucky coffeetree	+	✓	▼	✗	⊖
Kousa dogwood	+	✓	▼	✗	⊖
Lacebark elm	+	✓	▼	✓	▼
Littleleaf linden	+	✗	⊖	✗	⊖
London planetree	·	✓	●	✗	○
Musclewood	+	✓	▼	✓	▼
New Harmony elm	+	✓	▼	✓	▼
Northern red oak	+	✓	▼	✗	⊖
Northern white cedar, Arborvitae	·	✗	○	✗	○
Norway maple*	+	✗	⊖	✗	⊖

More information: forestadaptation.org/washington-dc

NIACS Washington DC climate change resources

Tree species projections can be used to:

- Understand the overall **vulnerability** of the region's urban forest (developed using tree inventories)
- Used as a tool to help inform **decision-making**
- Integrate into **adaptation** projects to support approaches & tactics



forestadaptation.org/washington-dc/

Tools to inform Baltimore tree planting

Summary:

- NIACS combined multiple datasets into one list for GBWC
- Each dataset (Tree Atlas, DC results) uses different methodologies to establish predictions
- Approaches have differing levels of uncertainty
- **Requires local expertise and judgement when interpreting results!**

GBWC's Climate-informed tree species list: Key terms.

~200 trees and cultivars organized by botanical name and common name

Washington DC urban tree results

- Adapt
- Zone suitability
- Vulnerability

USFS Tree Atlas results for the Greater Baltimore Urban region

- Adapt score
- Abundance
- Habitat change
- Capability

Results describe habitat suitability under a future with

- Less warming RCP 4.5
- High, more warming RCP 8.5

GBWC Combined dataset

			Vulnerabilty of Washington DC Urban Trees					USFS Tree Atlas Results for the Greater Baltimore Urban Region					
				Climate change projection by end of century (2070-2099)						*Climate change projection by end of century (2070-2099)*			
				Less warming (RCP4.5 scenario)		High emissions, more warming (RCP8.5 scenario)				Less warming (RCP4.5 scenario)		High emissions, more warming (RCP8.5 scenario)	
Does this species have a climate projection?	**BOTANICAL NAME**	**COMMON NAME**	**Planted Adapt**	**Zone Suitability**	**Vulnerability**	**Zone Suitability**	**Vulnerability**	**Adapt score**	**Abundance**	**Habitat Change**	**Capability**	**Habitat Change**	**Capability**
DC Heat/Hardiness	Acer buergerianum	Trident Maple	High	Suitable	Low	Suitable	Low						
DC Heat/Hardiness	Acer campestre	Hedge Maple	High	Suitable	Low	Unsuitable	Moderate						
DC Heat/Hardiness	Acer campestre	Hedge Maple - 'Queen Elizabeth'											
DC Heat/Hardiness	Acer floridanum	Florida Maple											
N	Acer ginnale	Amur Maple	Medium	Unsuitable	Moderate-High	Unsuitable	Moderate-High						
N	Acer griseum	Paperbark Maple	Low	Suitable	Moderate	Unsuitable	High						
Baltimore Tree Atlas	Acer negundo	Boxelder	Medium	Suitable	Low-Moderate	Unsuitable	Moderate-High	High	Common	No change	Good	No change	Good
DC Heat/Hardiness	Acer palmatum	Japanese Maple											
Baltimore Tree Atlas	Acer Rubrum	Red Maple	Medium	Suitable	Low-Moderate	Suitable	Low-Moderate	High	Abundant	Sm. dec.	Good	Sm. dec.	Good
N	Acer rubrum 'Armstrong'	Armstrong Maple											
N	Acer Rubrum 'Autumn Blaze'	Red Maple 'Autumn Blaze'											
Baltimore Tree Atlas	Acer saccharinum	Silver Maple	Medium	Suitable	Low-Moderate	Unsuitable	Moderate-High	High	Rare	Sm. dec.	Poor	No change	Fair
N	Acer saccharum	Sugar Maple	Medium	Suitable	Low-Moderate	Unsuitable	Moderate-High	High	Rare	Lg. inc.	Good	Lg. inc.	Good
N	Acer saccharum 'Green Mountain'	Sugar Maple - 'Green Mountain'											
N	Acer saccharum 'Legacy'	Sugar Maple - 'Legacy'											
Baltimore Tree Atlas	Acer spicatum	Mountain Maple						High	Absent	Unknown	Unknown	Unknown	Unknown
N	Acer Tataricum	Tatarian Maple											
N	Acer triflorum	Three Flower Maple											

What this data <u>can</u> and <u>can't</u> do

Can do -

- Describe regional habitat suitability for certain trees given climate change (from less warming to greater warming)
- Links to peer-reviewed, unbiased and scientific data on the topic
- Create connections to broader climate-informed thinking across the region through the NIACS urban effort.

Can't do -

- Tell you what to do.
  - These are model results and require additional **expertise** and **judgement** to determine site-level suitability

Additional reading: Urban tree species assessment

Read a technical description:

Brandt, Leslie A., Gary R. Johnson, Eric A. North, Jack Faje, and Annamarie Rutledge, “Vulnerability of Street Trees in Upper Midwest Cities to Climate Change” Frontiers in Ecology and Evolution (2021): 623. https://doi.org/10.3389/fevo.2021.721831

Thank you!

Contact us with any questions!

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