Quantifying Ecosystem Services Benefits of Restoration and Conservation Best Management Practices in the Chesapeake Bay Watershed

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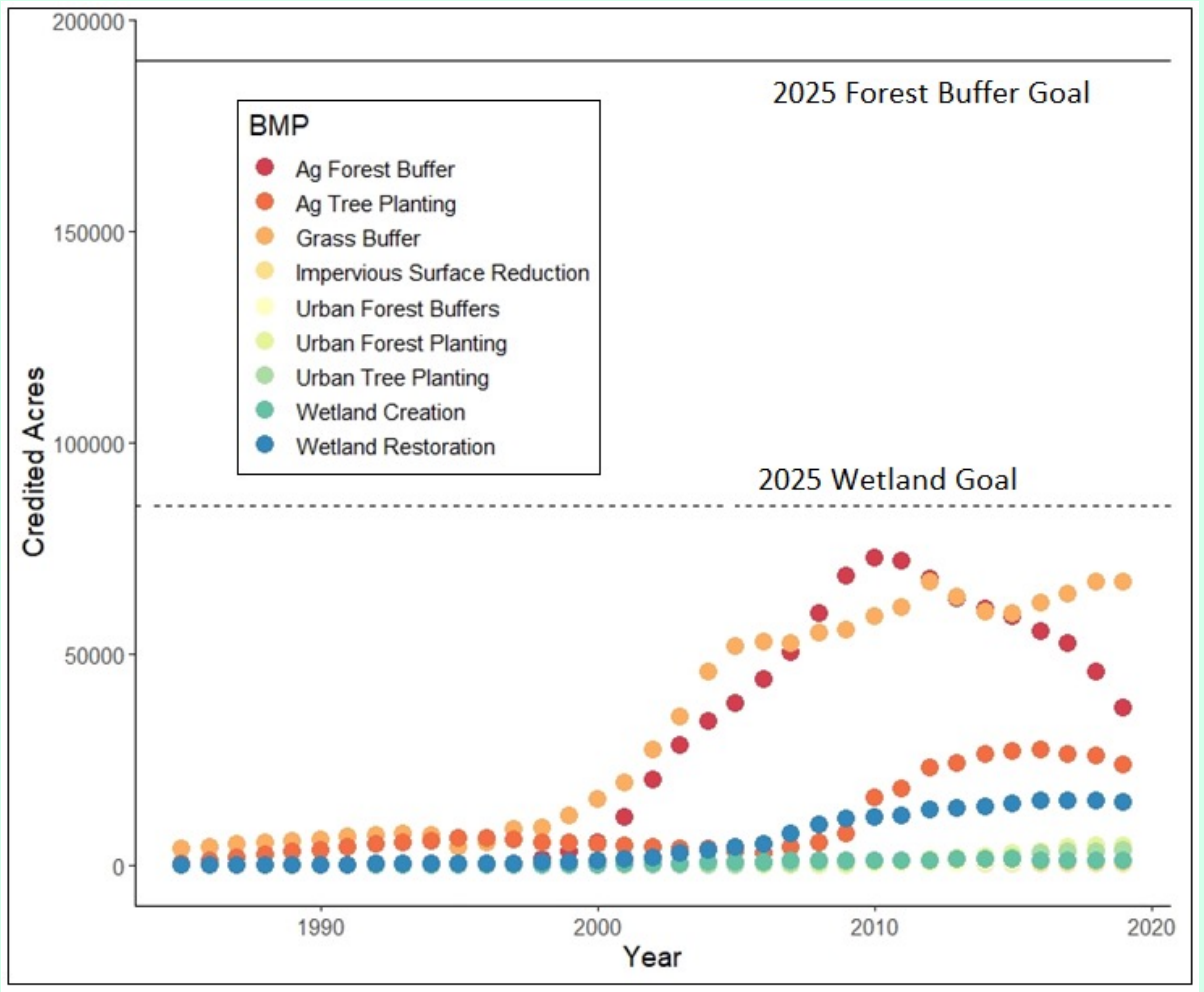
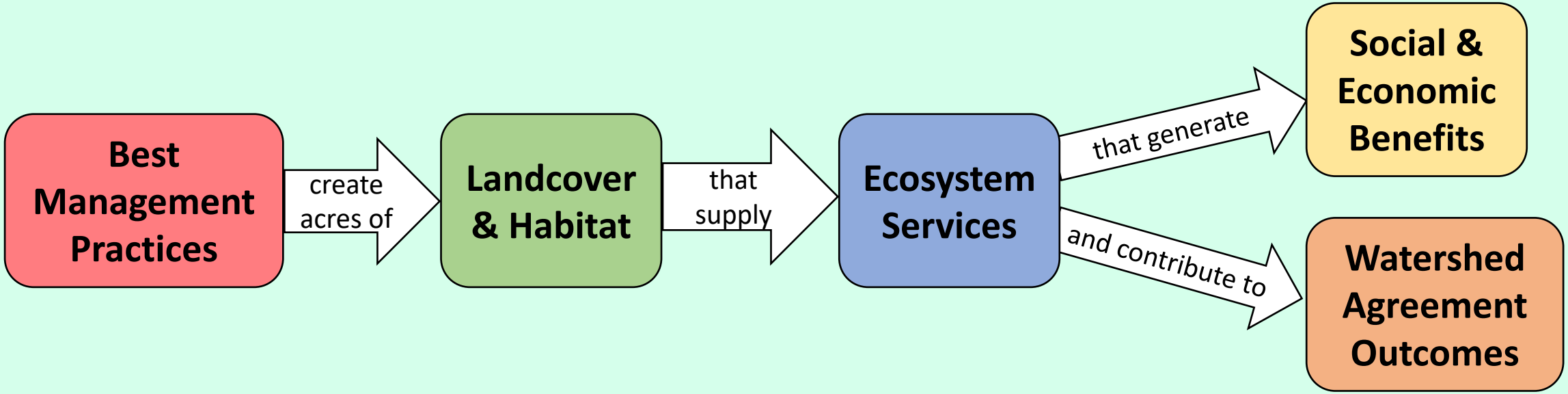
Motivation for Project

- Some BMPs in the Watershed Agreement are behind on implementation – e.g. wetlands and forest buffers
- Need to enhance stakeholder buy-in of implementation of these practices, especially in headwater communities
- Want to be able to better communicate benefits associated with these practices, specifically beyond water quality
- Want to be able to quantitatively describe these benefits



Objectives for Project

- Develop a methodology CBP can use to identify priority ecosystem services associated with the restoration and revitalization of the watershed
- Quantify how management actions or BMPs may affect ecosystem services
- Communicate potential ecosystem services benefits of BMP implementation to stakeholders, including toward indirectly supporting watershed agreement outcomes
- Build off existing information and tools like Co-benefits TetraTech Report and CAST



Project Approach

Step 1. Clarify bounds for the project & determine which BMPs to focus on

Step 2. Identify types of user groups potentially impacted by BMPs and the potential ecosystem services they care about

Step 3. Prioritize to a subset of ecosystem services of highest relevance

Step 4. Identify potential metrics to measure ecosystem services

Step 5. Apply data and models to quantify ecosystem services supply per acre of BMP implementation

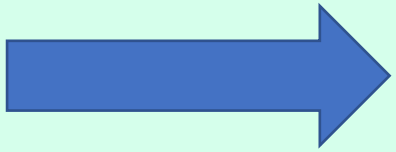
Step 6. Communicate linkages between BMPs, Ecosystem Services, Users, and Watershed Agreement Outcomes

Step 1. Determine which BMPs to focus on

Focus on BMPs that are:

1. Lagging in implementation
2. Relevant to upstream communities
3. Have associated Watershed Agreement goals that have not been met
4. Related to habitat conservation or restoration

Used these 4 "criteria" to scope

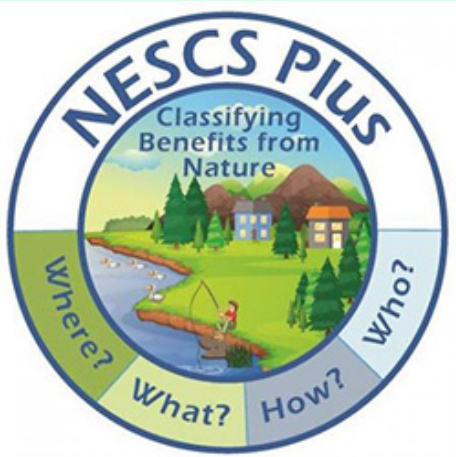


Scoped list of BMPs:

- Agricultural forest buffers
- Agricultural grass buffers
- Agricultural tree planting
- Agricultural cover crops
- Urban forest buffers
- Urban forest planting
- Urban tree planting
- Forest conservation
- Impervious surface reduction
- Wetland creation
- Wetland restoration

Step 2. Identify potential users impacted by BMPs and the ecosystem services they care about

- Use ecosystem services classification systems such as NESCS Plus to identify potential ecosystem services (ES)



<u>"User"-centric stepwise approach</u>
WHO is using these ecosystems and HOW?
WHAT do they care about?
WHERE are they getting benefits?

Helps to reduce ambiguity and increase direct relevance to people

"[biophysical] components of nature, directly enjoyed, consumed, or used to yield human well-being"
(Boyd & Banzhaf 2007)

Who is impacted?

Beneficiaries or Users

Agricultural	Agricultural Processors	Farmers
	Livestock Grazers	Foresters
	Aquaculturists	
Commercial / Industrial	Private Drinking Water Plant Operators	
	Industrial Processors	Private Energy Generators
	Pharmaceutical and Food Supplement Suppliers	
	Timber, Fiber, and Ornamental Extractors	
	Food Extractors	Fur / Hide Trappers and Hunters
	Property Owner	
Government, Municipal, and Residential	Municipal Drinking Water Plant Operators	
	Public Energy Generators	Military / Coast Guard
	Residential & Nonresidential Property Owners	
Humanity	All Humans	
Inspirational	Artists	
	Spiritual/Ceremonial Participants, Participants of Celebration	
Learning	Researchers	
	Educators and Students	
Non-Use	People Who Care - Option / Bequest	
	People Who Care - Existence	
Recreational	Anglers	Boaters
	Waders/Swimmers/Divers	Hunters
	Food Pickers/Gatherers	Experiencers/Viewers
Subsistence	Water Subsisters	Food/Medicinal Subsisters
	Timber/Fiber/Fur/Hide Subsisters	
	Building Material Subsisters	
Transportation	Transporters of Goods	
	Transporters of People	

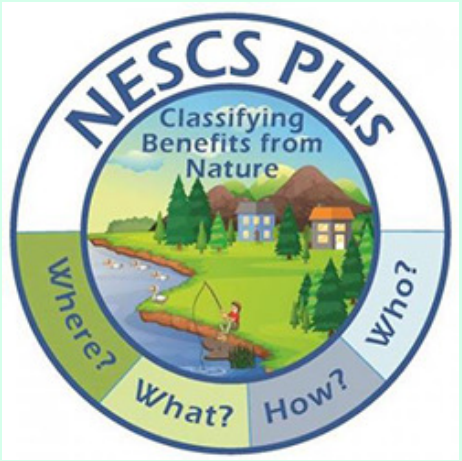
What do they care about?

Ecosystem Service Attributes

Atmosphere	Air quality Wind strength/speed Precipitation Sunlight Temperature	
Soil	Soil quantity Soil quality Substrate quantity Substrate quality	
Water	Water quality Water quantity Water movement	
Fauna	Fauna community Edible fauna Medicinal fauna Keystone fauna Charismatic fauna Rare fauna Pollinating fauna Pest predator/depredator fauna Commercially important fauna Spiritually/culturally important fauna	
Flora	Flora community Edible flora Medicinal flora Keystone flora Charismatic flora Rare flora Commercially important flora Spiritually/culturally important flora	
Fungi	Fungal community Edible fungi Medicinal fungi Rare fungi Commercially important fungi Spiritually/culturally important fungi	
Other Natural Components	Fuel quality Fuel quantity Fiber material quantity Fiber material quality Mineral/chemical quantity Mineral/chemical quality Other natural materials for artistic use or consumption (e.g. shells, acorns, honey)	
Composite (and Extreme Events)	Site Appeal	Sounds Scents Viewscapes Phenomena (e.g. sunsets, northern lights, etc)
	Ecological condition	
	Open space	
	Regulating Services	
	Extreme Events	Flooding Wildfire Extreme weather events Earthquakes

Refined Initial List with Document Review and Partner Feedback

- Use ecosystem services classification systems such as NESCS Plus to identify potential ecosystem services (ES)
- Mine Chesapeake Bay Program (CBP) documents and reports for ecosystem services to add to list
- Feedback from partners on priorities in their regions on anything missing

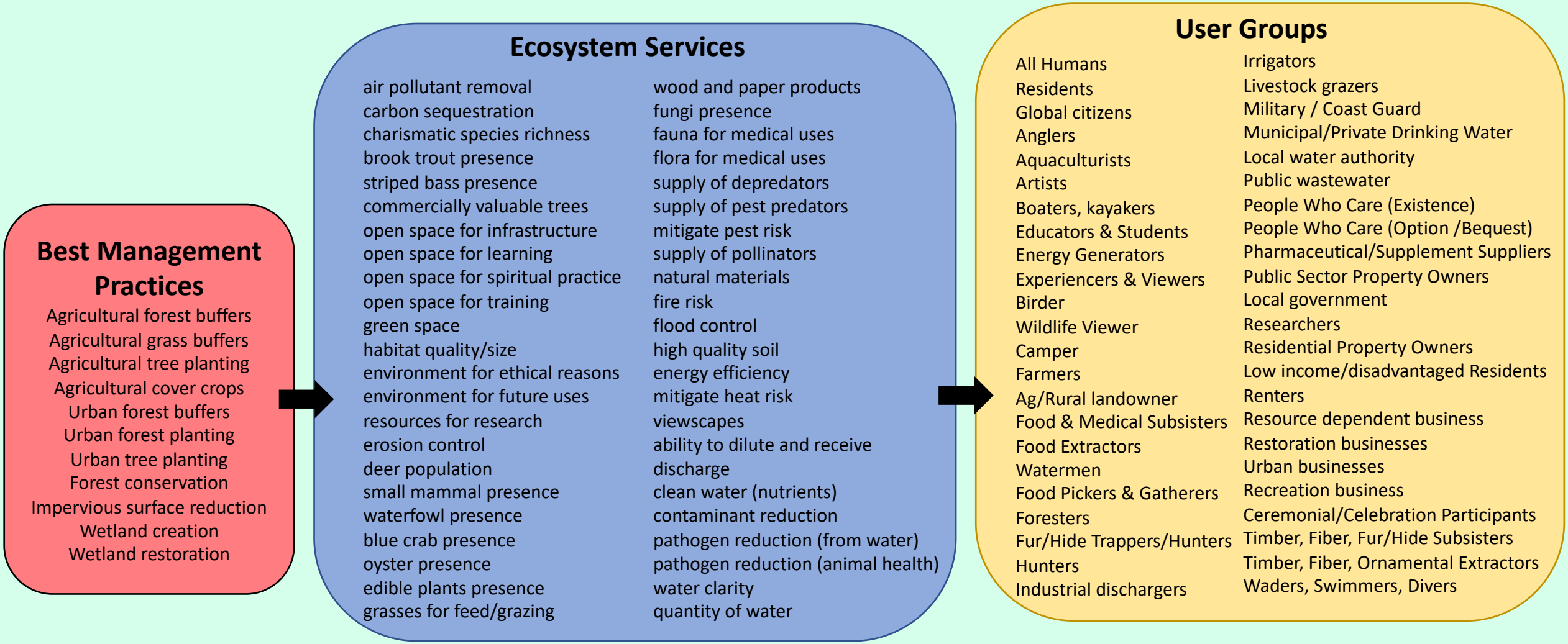


<u>"User"-centric stepwise approach</u>
WHO is using these ecosystems and HOW?
WHAT do they care about?
WHERE are they getting benefits?

Best Management Practice	Forest Buffers	Additional Co-Benefits					
		Habitat Biodiversity	Brook Trout	Stream Health	Fish Habitat	Healthy Watersheds	Tree Canopy
Agricultural Forest Buffer	5	4	4.5	4	4.5	4	4.5
Forest Conservation	3.5	5	4	4	4	5	5
Forest Harvesting Practices	3.5	2	2	4	3	3	2
Narrow Forest Buffer	5	2.5	3.5	2	3.5	2	5
Streamside Forest Buffers	5	4	4.5	3	4.5	3	5
Urban Forest Buffers	5	5	5	4	4	3.5	4.5

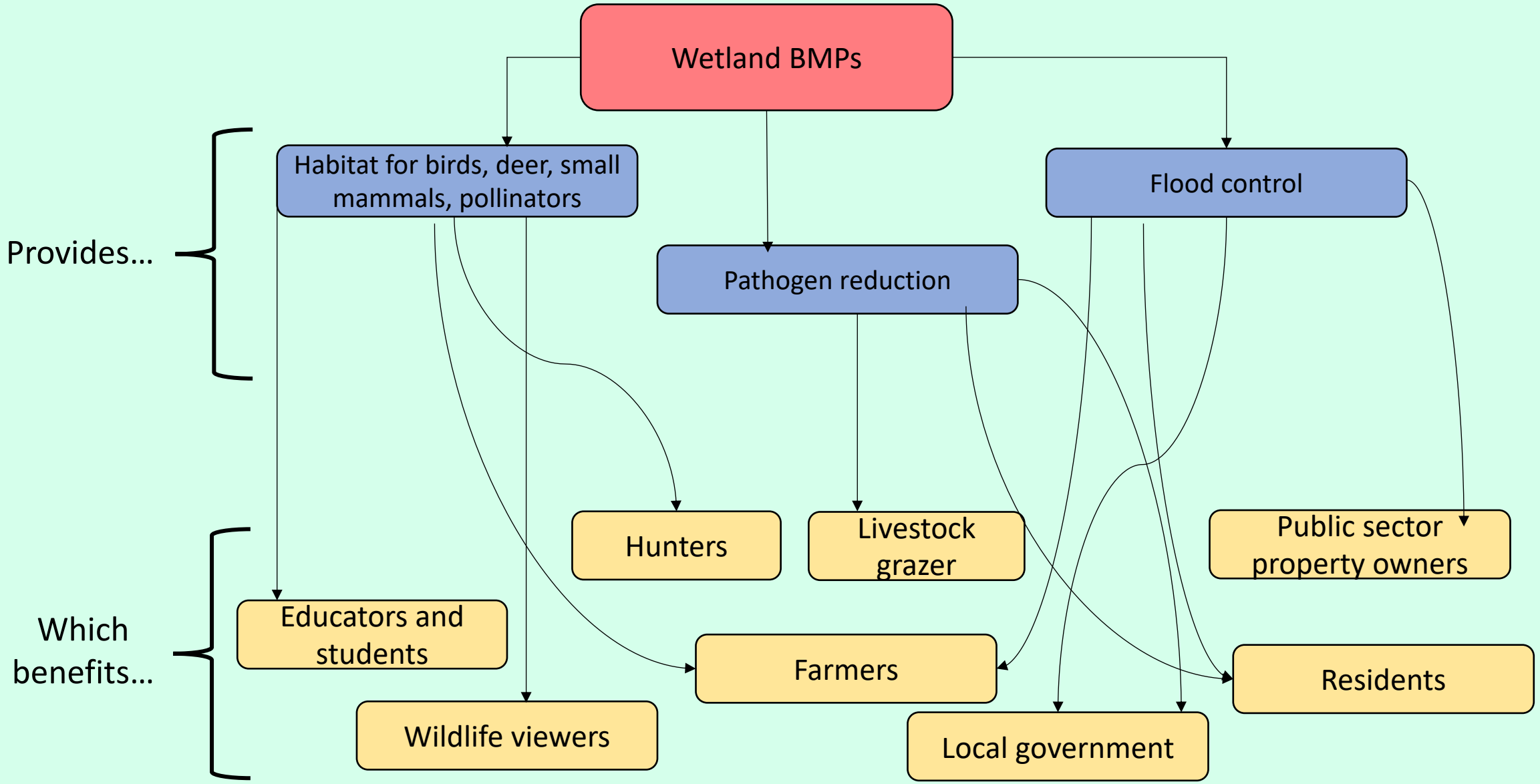
Tetra Tech Co-Benefits Report

In total, review identified focal BMPs could provide 45 potential types of ecosystem services benefitting 46 different types of users



Rossi et al. 2022

Example: Wetland BMPs provide many ecosystem services & benefit many types of natural resource users



Step 3. Prioritize Most Relevant Ecosystem Services

- Chesapeake Bay Scientific Technical and Reporting Team (STAR) and Local Government Advisory Committee (LGAC) partners asked to identify **top 5** ecosystem services and users most relevant to their region or expertise

- Used the FEGS Scoping Tool to assign importance weights based on:
  I. Stakeholder groups most likely to be impacted or of high priority
  II. The different roles those stakeholders play as users of natural resources
  III. The ecosystem services those users care about

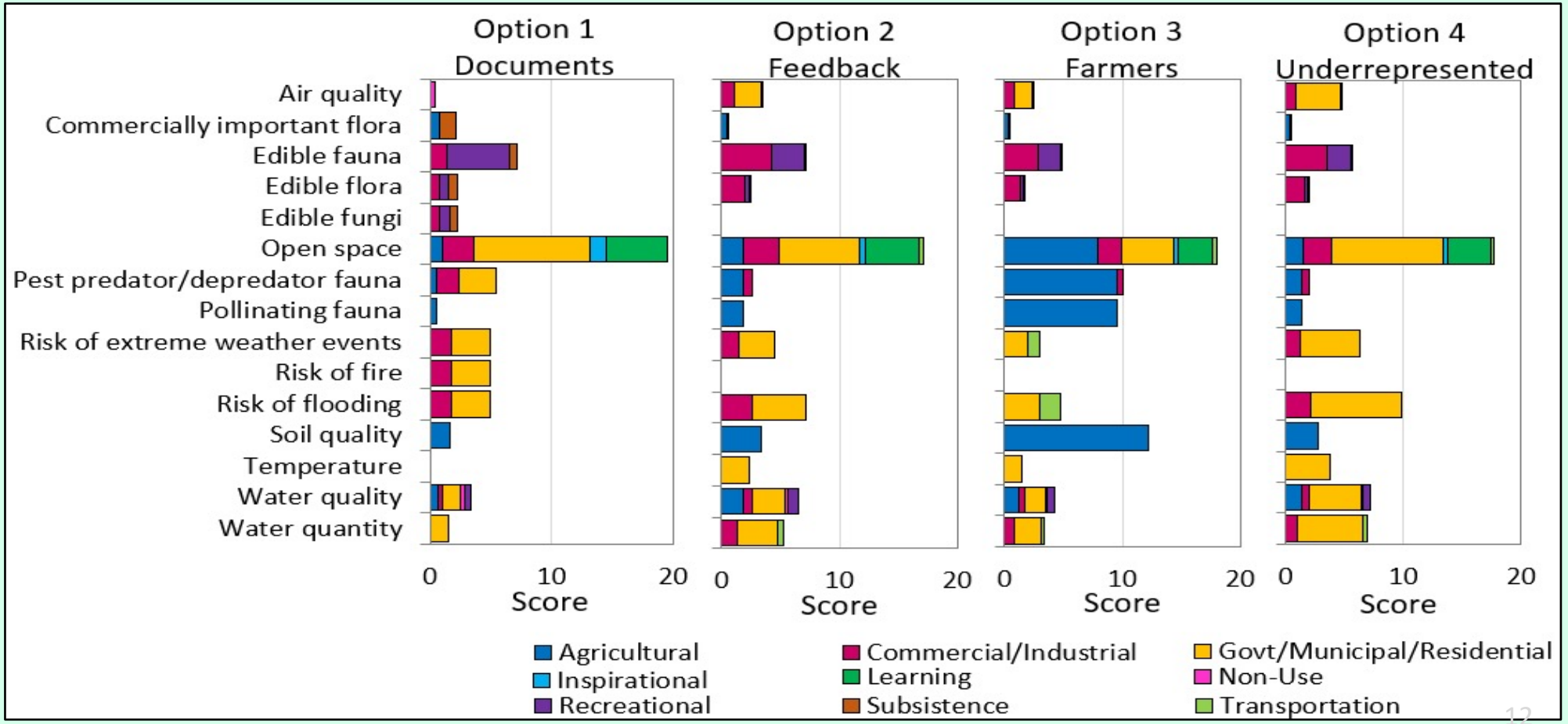
FEGS Scoping Tool

Based on Multi-criteria Decision Analysis (MCDA) approaches

Top Ecosystem Services under Alternative Prioritization

- Explored different weighting options based on 1) documents, 2) partner rankings, 3) farmers as most likely to be impacted by BMPs, and 4) underrepresented/low-income communities to address inclusivity and EJ goals

Top ES have moderate relevance to many different types of users or have high relevance to a few users



Step 4. Identify potential ecosystem services metrics

- "User-centric" perspective to identify metrics that would resonate with stakeholders by asking "What directly matters to each beneficiary?"
  - E.g., Water quality for drinking vs. recreation
  - E.g., Edible flora for Recreational food gatherers vs. livestock grazers
- Reviewed existing tools, literature, and libraries for example metrics

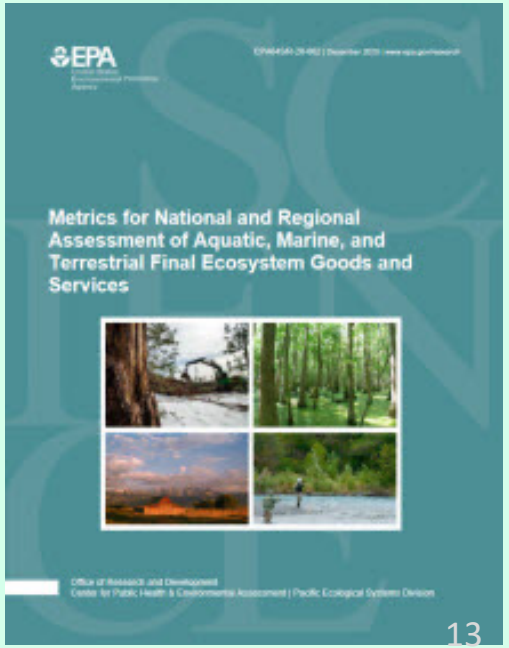
EnviroAtlas
people health nature economy

USEPA H2O HYDRO-ECOLOGY GIS

InVEST

EcoService Models Library (ESML)
A searchable database of ecological models for estimating the production of ecosystem goods and services.

i-Tree

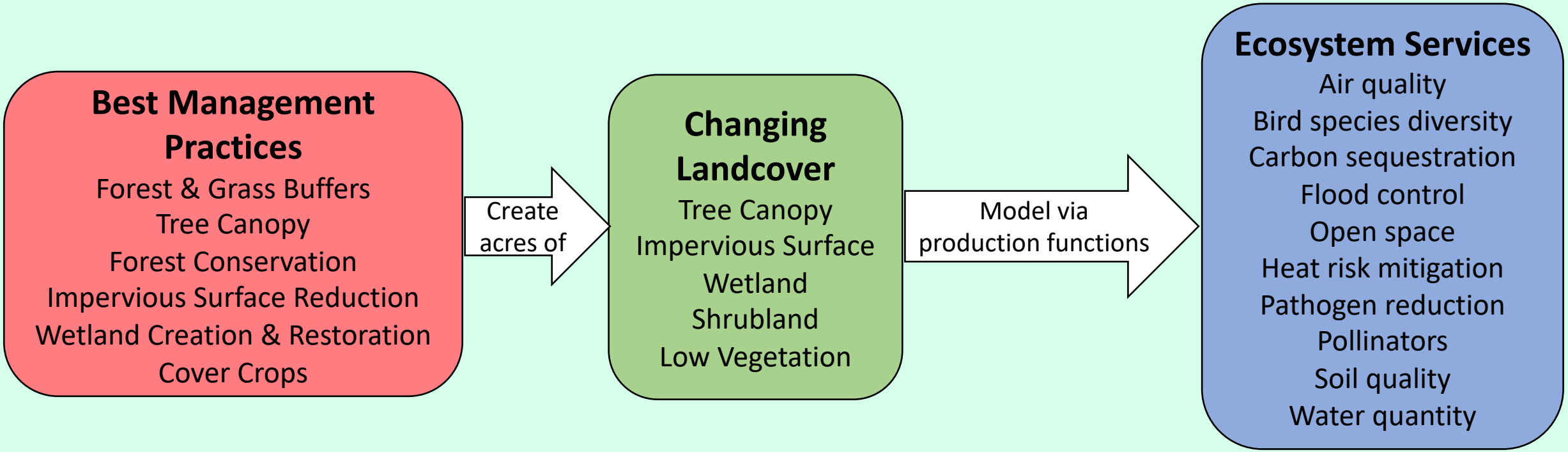


Example ecosystem services metrics

FEGS	Short list of metrics	Source
Air quality	concentration of CO, NO2, O3, PM 10, PM 2.5, SO2	iTree (Nowak 2020)
Edible flora	plant diversity, cover of edible species	EnviroAtlas (Pickard et al. 2015)
Habitat quality	habitat suitability for species of interest, species richness	inVEST; Smith et al 2017 (Smith et al. 2017, Sharp et al. 2020)
Heat risk	daytime and nighttime temperature reduction	EnviroAtlas (Pickard et al. 2015)
High quality soil	soil C content, N fixation, pH, salinity, type, percent sand, bulk density, organic matter	NESP; Smith et al, 2017 (Russell et al. 2013, Olander et al. 2017, Smith et al. 2017)
Open space	open space access index; distance to open space	EnviroAtlas; NESP (Russell et al. 2013, Pickard et al. 2015, Olander et al. 2017)
Pest predator fauna	density of certain pest predators (e.g., ladybugs)	ESML (US EPA 2020)
Pollinator fauna	area of wild pollinator habitat; ratio of pollinator habitat to pollinator dependent crops	EnviroAtlas; inVEST (Pickard et al. 2015, Sharp et al. 2020, Warnell et al. 2020)
Risk of flooding	flood depth, duration, extent and frequency; maximum retained rainwater; soil precipitation retention; surface water runoff; wave attenuation	EnviroAtlas; inVEST; EPA H2O; ESML (Russell et al. 2013, Pickard et al. 2015, Sharp et al. 2020)
Water clarity	mean sediment retention; secchi depth; turbidity	Angradi et al. (2018)
Water quality- nutrients	concentration of nitrates in groundwater	Terziotti et al. (2018)
Water quality- pathogens	concentration of harmful bacteria (e.g., fecal coliform)	Wainger et al. (2015)
Water quantity	water availability	inVEST (Sharp et al. 2020)

Step 5. Apply data and models to quantify ES supply per acre of BMP implementation

- Each BMP associated with a CAST land cover class
- Identified or generated statistical models of ES supply per acre of landcover



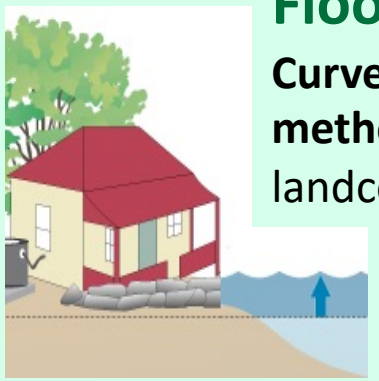
Ecosystem Services Quantification Methods

Air Quality

Air pollutant removal rates in urban and rural areas obtained from **i-Tree** and multiplied by acres of tree cover

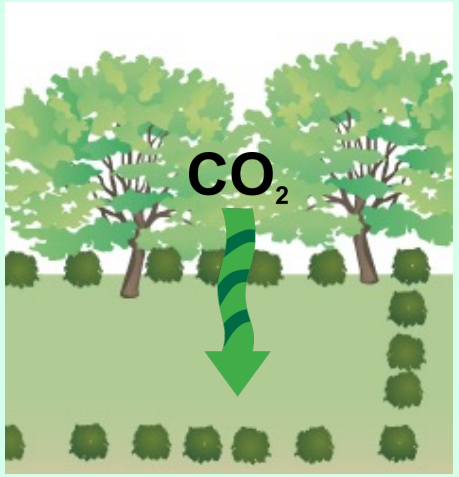
Bird Diversity

Species area curves relate increasing acres of land cover type to potential bird species richness, obtained from USGS GAP



Flood Control

Curve number method based on landcover, soil type



Carbon Sequestration

Average rates of burial of atmospheric carbon into soil (i.e., in support of mitigating climate change) by landcover type, obtained from **COMET-Planner** and literature review, multiplied by acres of landcover

Pollination

InVEST pollinator model to assign index of habitat suitability based on land cover, and characteristics of pollinators such as nesting and foraging distance

https://ian.umces.edu/media-library

Ecosystem Services Quantification Methods

Water Quantity (Stream Flow)

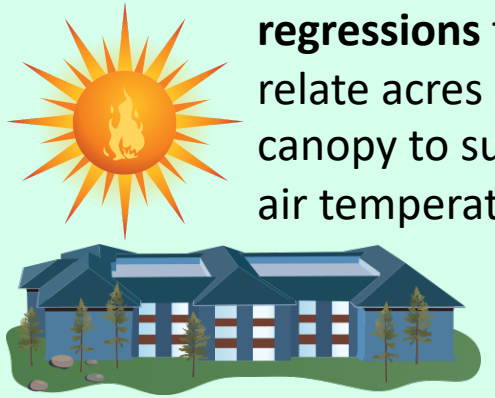
CAST Hydrological Model

Open Space

Acres of **landcover per capita** identified as wetland, tree canopy, shrubland, and low vegetation

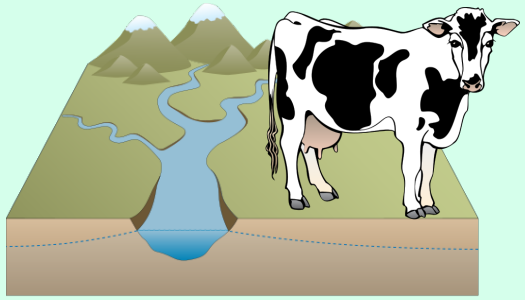
Heat Risk Reduction

Statistical **regressions** to relate acres of tree canopy to summer air temperatures



Soil Quality

Average **carbon content of soil** by landcover type, obtained from and literature review, multiplied by acres of landcover

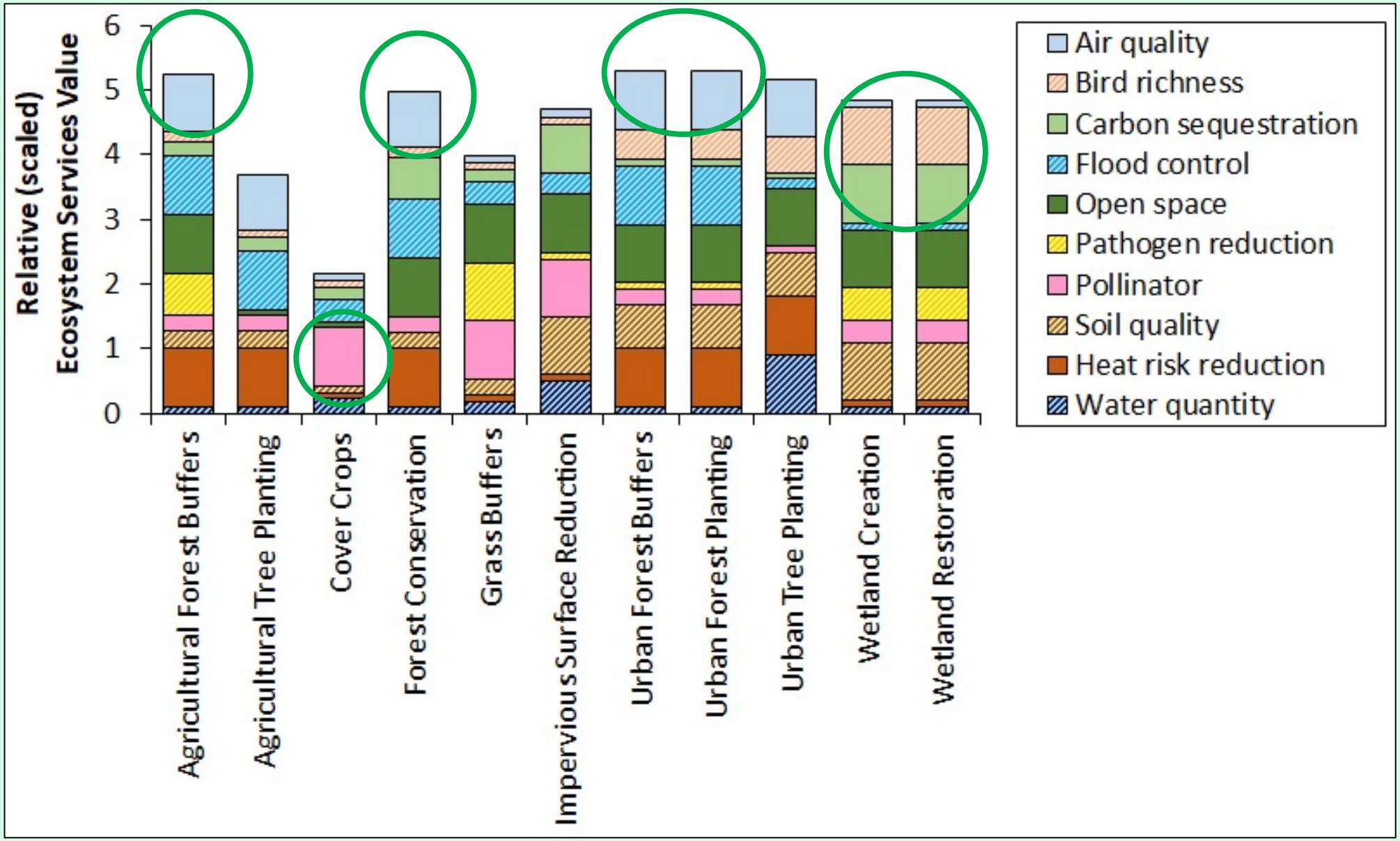


Pathogen Reduction

Fecal indicator bacteria removal efficiencies obtained from literature review, multiplied by acres of landcover type

https://ian.umces.edu/media-library

Estimated ES Values (Scaled) Vary by BMP



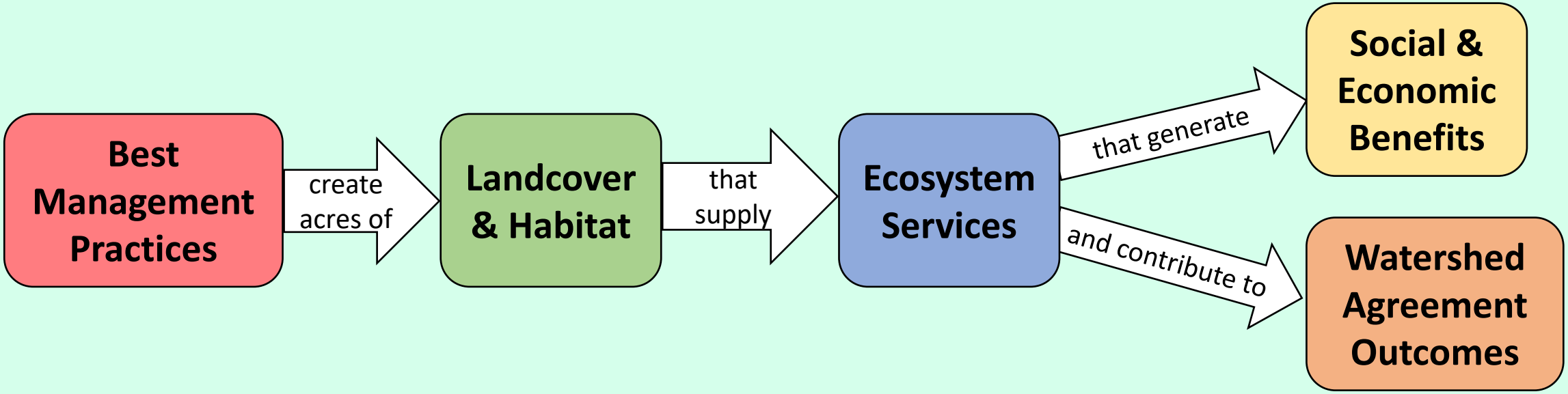
Forests overall highest values

Cover crops good for pollinators

Wetlands good for bird richness and carbon sequestration

Step 6. Communicate Benefits of Restoration & Conservation Related BMPs

- Communicate linkages between BMPs, Ecosystem Services, Users, and Watershed Agreement Outcomes
- Integrate ecosystem services information into existing CB tools to compare and communicate multiple benefits of BMP implementation



Lookup Tables of Quantified ES Values per Acre of BMP Implementation

- Designed to work with CAST landcovers
- Does not account for ‘change in ES’ which would depend on the ‘replaced’ landcover

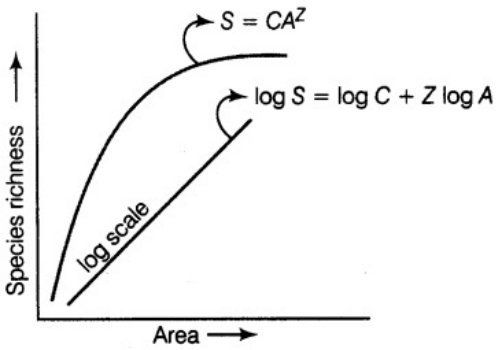
Pollinator Index

LULC CATEGORY	BUMBLEBEE	BICOLOR SWEAT BEE	BLUE SWEAT BEE	ORCHARD BEE
WATER	0.009	0.003	0.002	0.002
EMERGENT WETLAND	0.024	0.008	0.008	0.008
TREE CANOPY	0.020	0.009	0.009	0.008
SHRUBLAND	0.033	0.015	0.015	0.014
LOW VEG	0.044	0.020	0.015	0.013
BARREN	0.000	0.000	0.000	0.000
STRUCTURE	0.010	0.005	0.004	0.003
IMP SURFACES	0.010	0.005	0.004	0.003
IMP ROADS	0.011	0.005	0.004	0.004
TC OVER STRUCTURE	0.016	0.007	0.006	0.006
TC OVER IMP SURF	0.015	0.007	0.006	0.006
TC OVER IMP ROADS	0.011	0.005	0.005	0.004

InVEST

Bird Species Richness

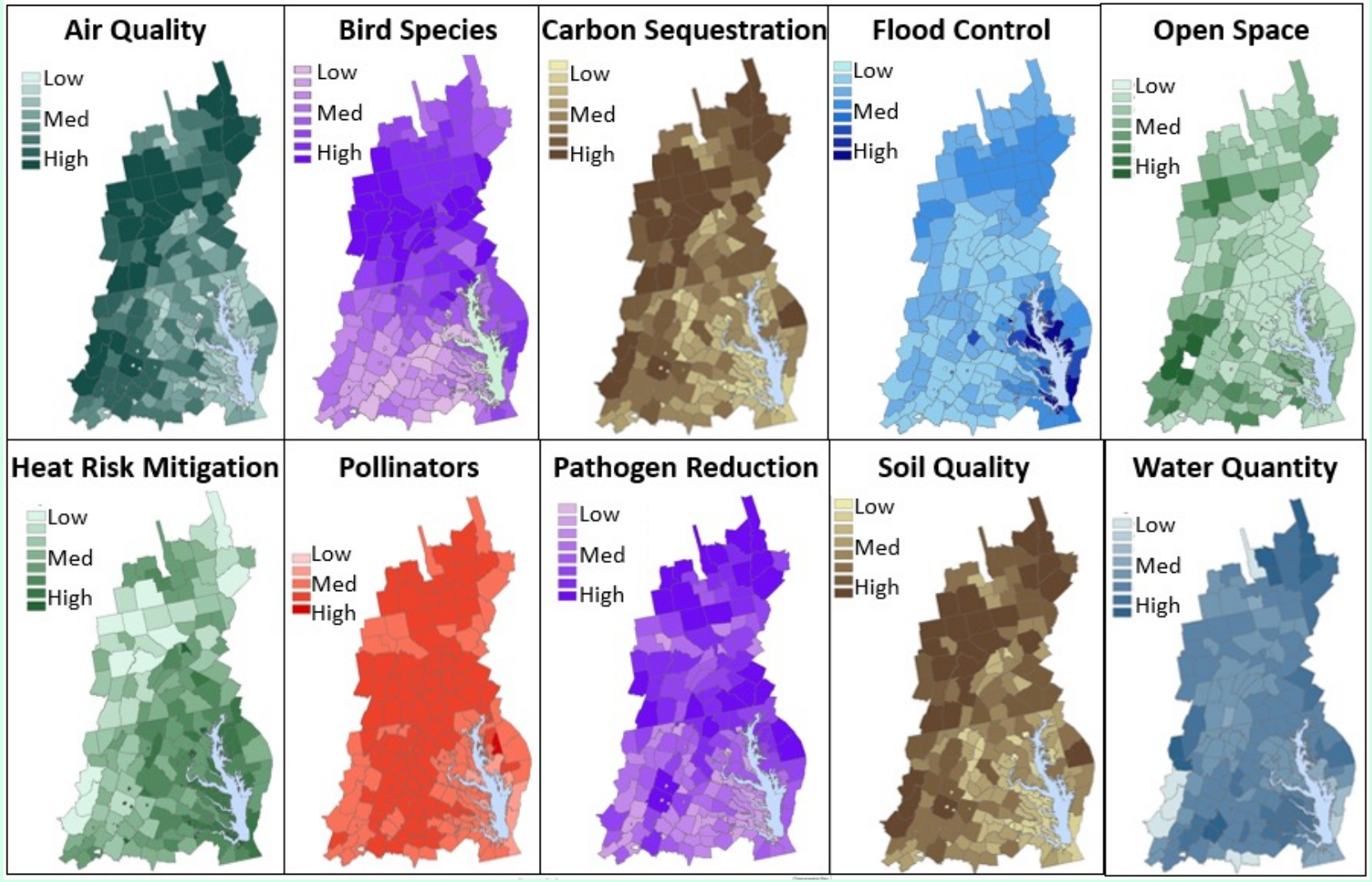
LAND USE	SPECIES AREA EQUATION:
NATURAL TREE CANOPY	S=68.97*A^0.038
LOW VEGETATION	S=67.09*A^0.042
WETLAND	S=84.59*A^0.029
SHRUBLAND	S=62.57*A^0.043
STRUCTURES	S=64.33*A^0.062
IMPERVIOUS SURFACES	S=63.97*A^0.066
IMPERVIOUS ROADS	S=69.25*A^0.057
TREE CANOPY OVER STRUCUTURE	S=74.04*A^0.055
TREE CANOPY OVER IMPERVIOUS SURFACES	S=71.36*A^0.053
TREE CANOPY OVER IMPERVIOUS ROADS	S=73.32*A^0.050
WATER	S=44.46*A^0.051



https://cast.chesapeakebay.net/

Maps of Current ES Value by County

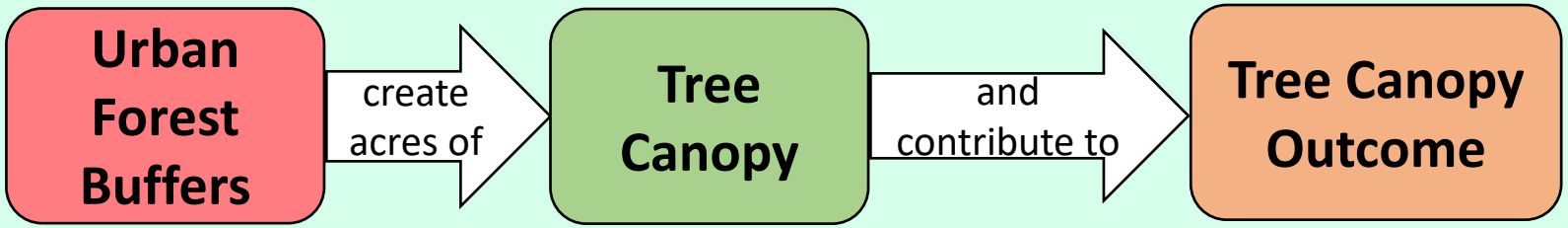
- Designed to work with Geographic Targeting Portal: Benefits to People
- Could be used to identify areas where BMP implementation could help improve current values



https://gis.chesapeakebay.net/targeting/

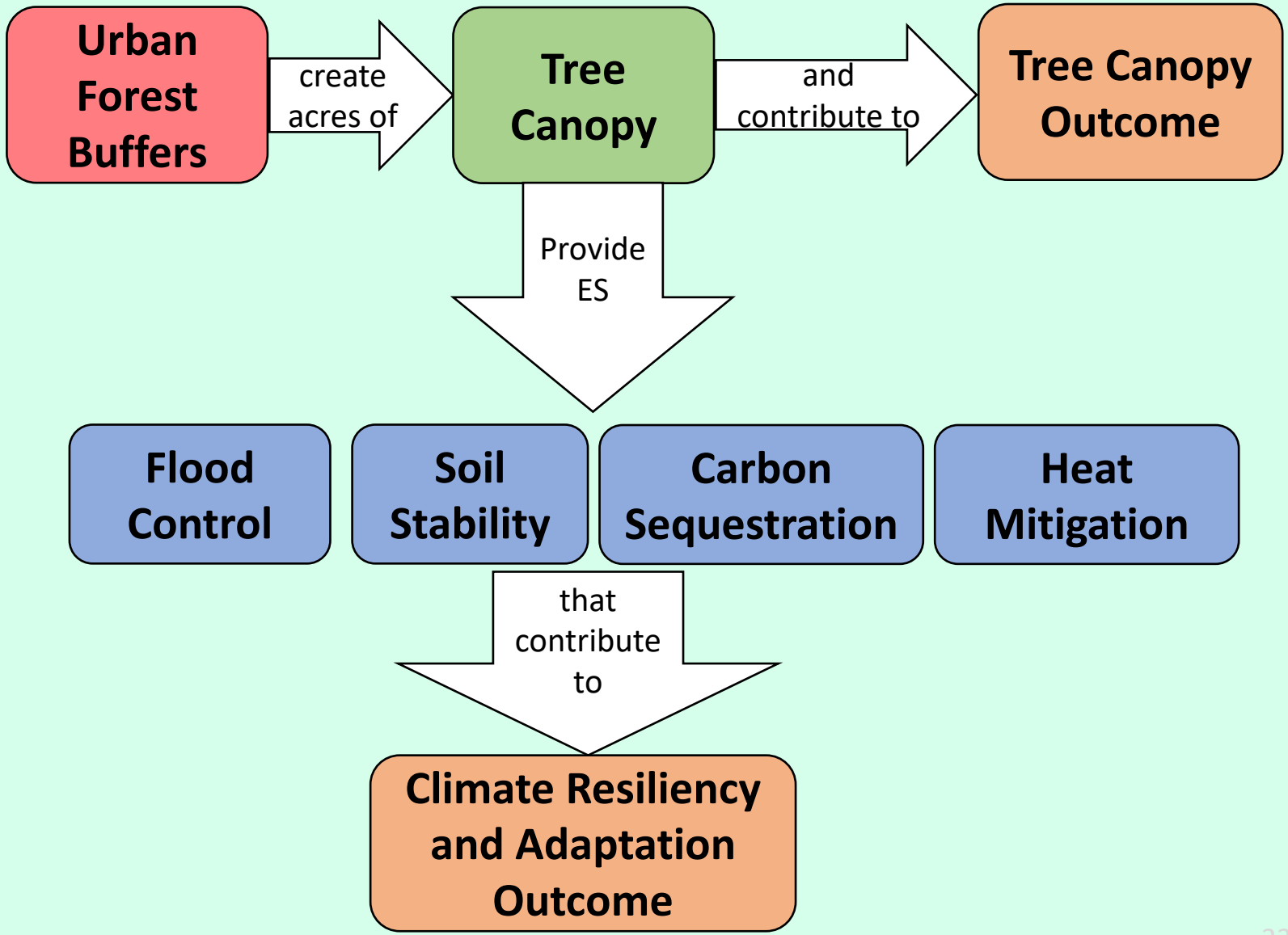
Relationships between BMPs and Watershed Agreement Outcomes

- Project also recognized where BMP implementation contributes to Watershed Agreement Outcomes

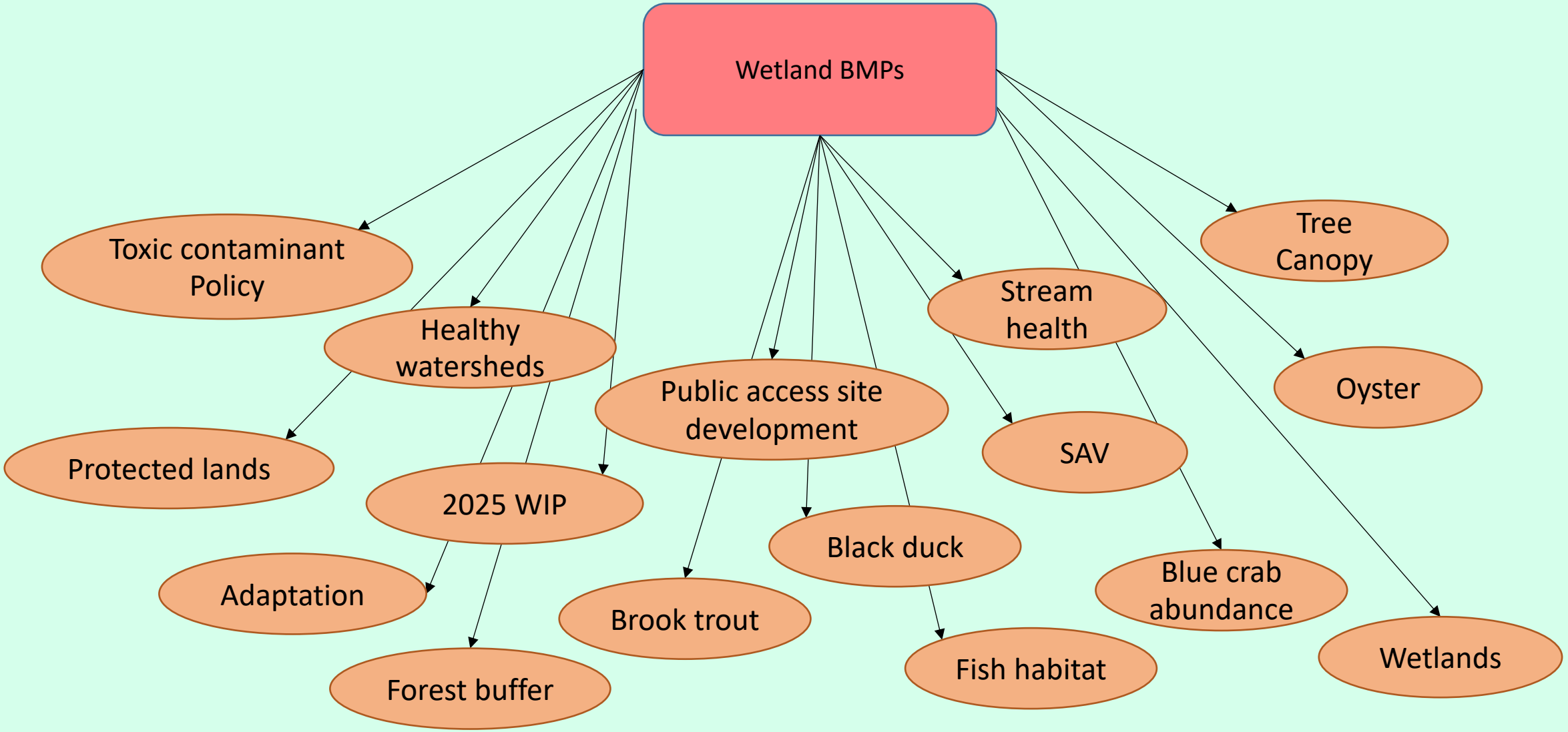


Relationships between BMPs and Watershed Agreement Outcomes

- Project also recognized where BMP implementation contributes to Watershed Agreement Outcomes
- And that ecosystem services gained from BMPs could contribute (indirectly or directly) to Outcomes



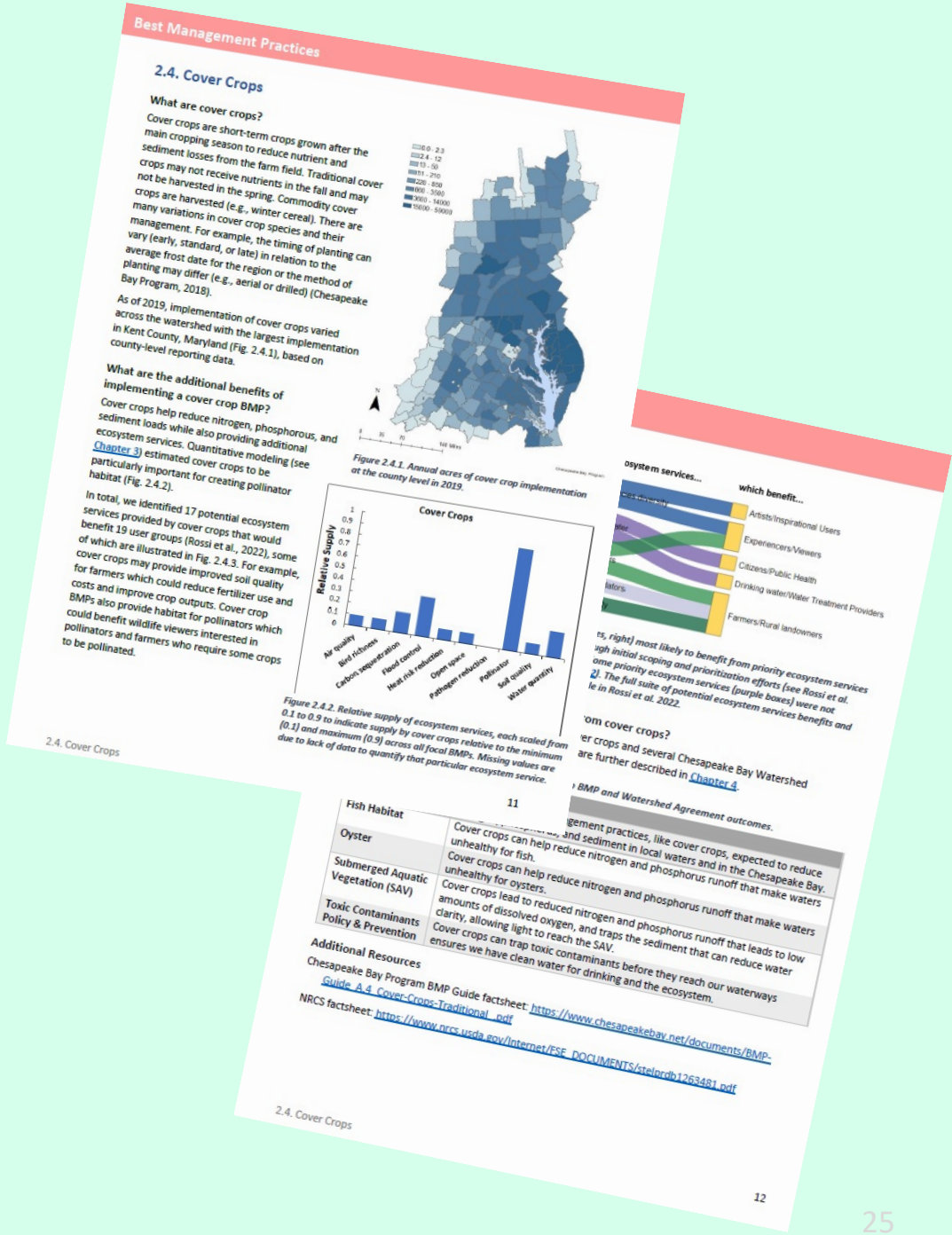
Example: Wetland BMPs are Connected to Many Outcomes



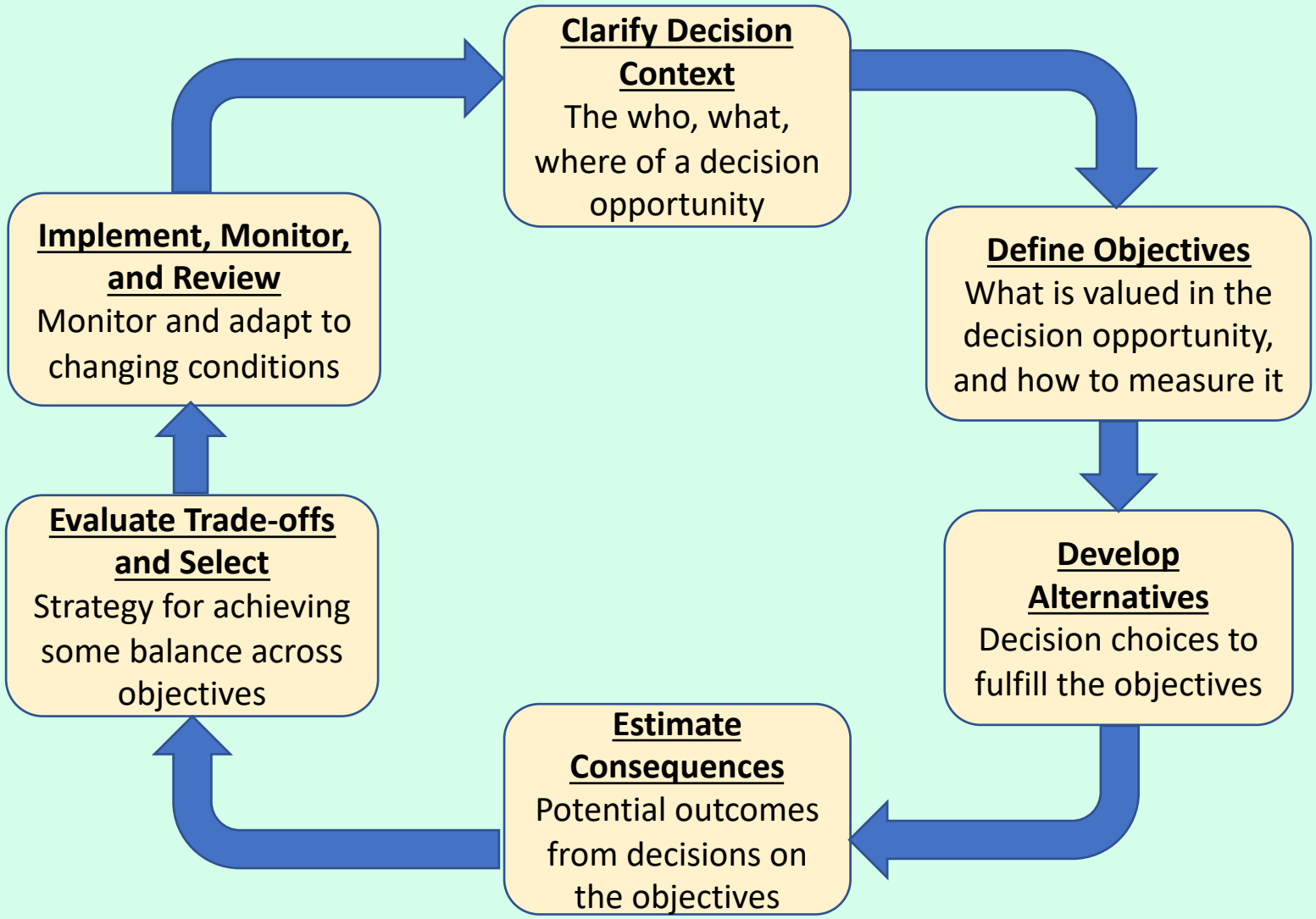
https://cast.chesapeakebay.net/ecohealth/index

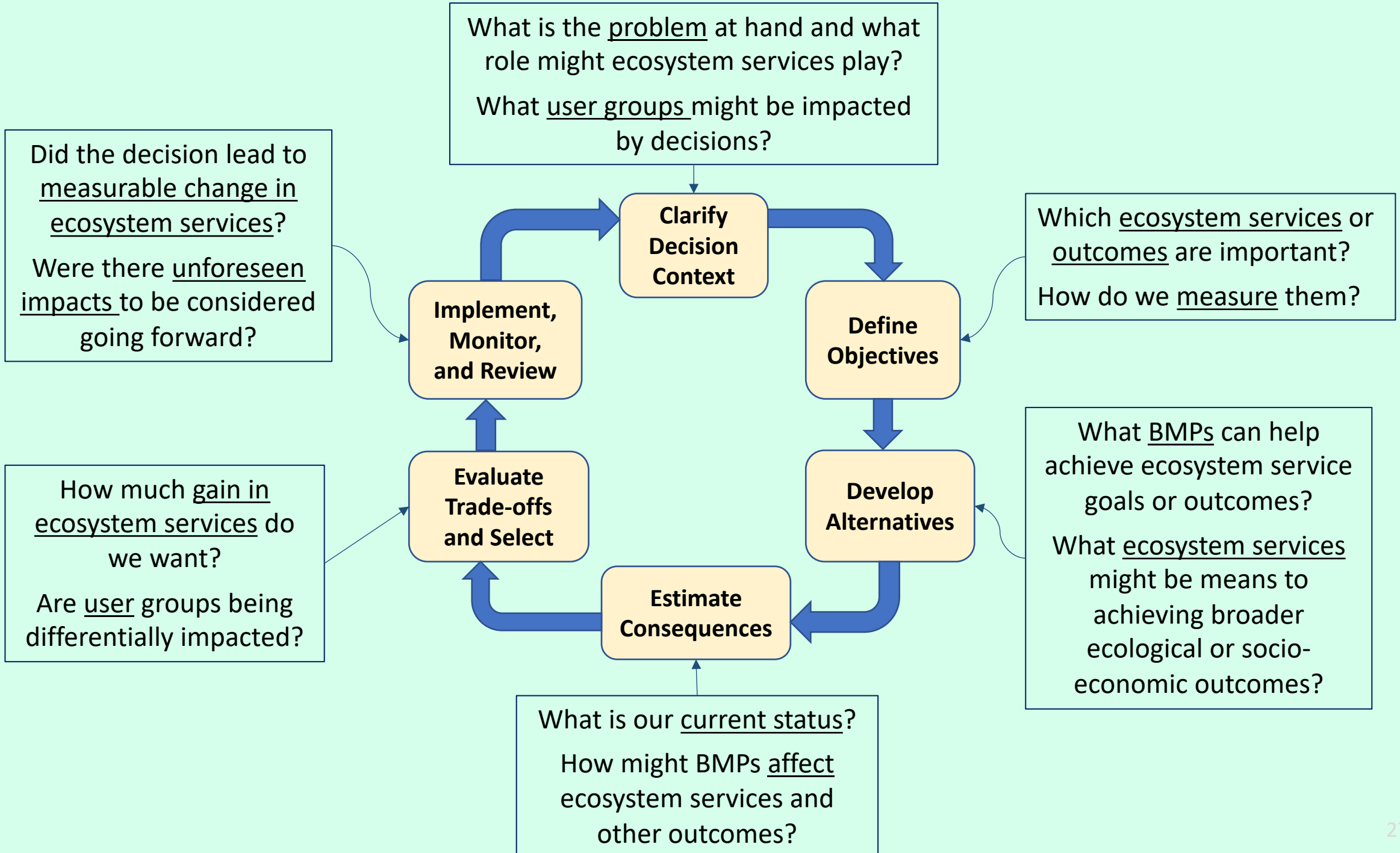
Additional Information

- Journal article and Report
- Scoping & Prioritization Methods
- Relationship Tables
  - What Ecosystem Services could BMPs provide?
  - What User Groups could benefit from BMPs?
  - How do BMPs and the ES they provide contribute to Watershed Agreement Outcomes?
- Example Metrics
- Fact Sheets of ES Quantified for each Focal BMP
- Descriptions of Quantification Methods



Ecosystem Services Information Can Be Useful Whatever Stage you are at in a Decision Process




What is the problem at hand and what role might ecosystem services play?
What user groups might be impacted by decisions?
Clarify Decision Context
Which ecosystem services or outcomes are important?
How do we measure them?
Define Objectives
What BMPs can help achieve ecosystem service goals or outcomes?
What ecosystem services might be means to achieving broader ecological or socio-economic outcomes?
Develop Alternatives
What is our current status?
How might BMPs affect ecosystem services and other outcomes?
Estimate Consequences
How much gain in ecosystem services do we want?
Are user groups being differentially impacted?
Evaluate Trade-offs and Select
Did the decision lead to measurable change in ecosystem services?
Were there unforeseen impacts to be considered going forward?
Implement, Monitor, and Review

For More Information

- Rossi, R., C. Bisland, L. Sharpe, E. Trentacoste, B. Williams, and S. Yee. 2022. Identifying and Aligning Ecosystem Services and Beneficiaries Associated with Best Management Practices in Chesapeake Bay Watershed. Environmental Management 69:384-409. https://doi.org/10.1007/s00267-021-01561-z
- Rossi, R.E., C. Bisland, B. Jenkins, V. Van Note, B. Williams, E. Trentacoste, Susan Yee. 2023. Quantifying Ecosystem Services Benefits of Restoration and Conservation Best Management Practices in the Chesapeake Bay Watershed. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. EPA/600/R-22/170
- Chesapeake Assessment Scenario Tool: https://cast.chesapeakebay.net/
- Watershed Data Dashboard: https://gis.chesapeakebay.net/wip/dashboard/
- Geographic Targeting Portal: https://gis.chesapeakebay.net/targeting/
- Chesapeake Bay Environmental Justice and Equity Dashboard: https://gis.chesapeakebay.net/diversity/dashboard/
- The Eco-Health Relationship Browser: https://cast.chesapeakebay.net/ecohealth/index
- National Ecosystem Goods and Services Classification System: www.epa.gov/eco-research/nescs-plus
- Final Ecosystem Goods and Services Scoping Tool: https://www.epa.gov/eco-research/final-ecosystem-goods-and-services-fegs-scoping-tool
- FEGS Metrics Report: https://www.epa.gov/eco-research/final-ecosystem-goods-and-services-fegs-metrics-report
- Ecosystem Services Models Library: https://esml.epa.gov
- EPA H2O: https://www.epa.gov/water-research/ecosystem-services-scenario-assessment-using-epa-h2o
- EnviroAtlas: https://www.epa.gov/enviroatlas
- InVEST: https://naturalcapitalproject.stanford.edu/software/invest
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