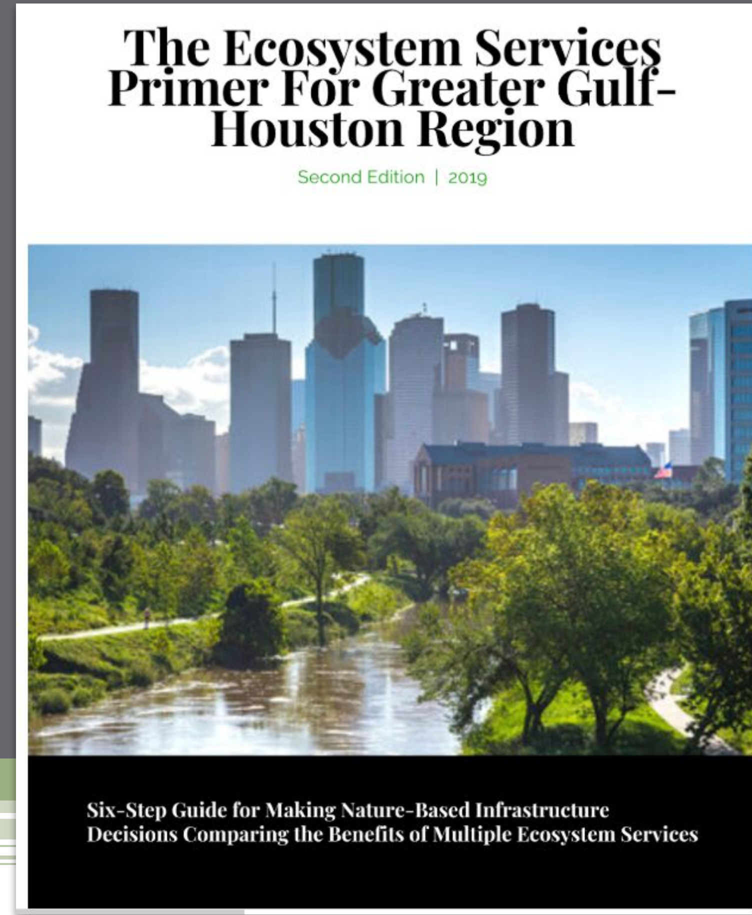
Six-Step Guide for making Nature-Based Infrastructure Decisions Comparing the Benefits of Multiple Ecosystem Services - case examples from Greater Houston TX



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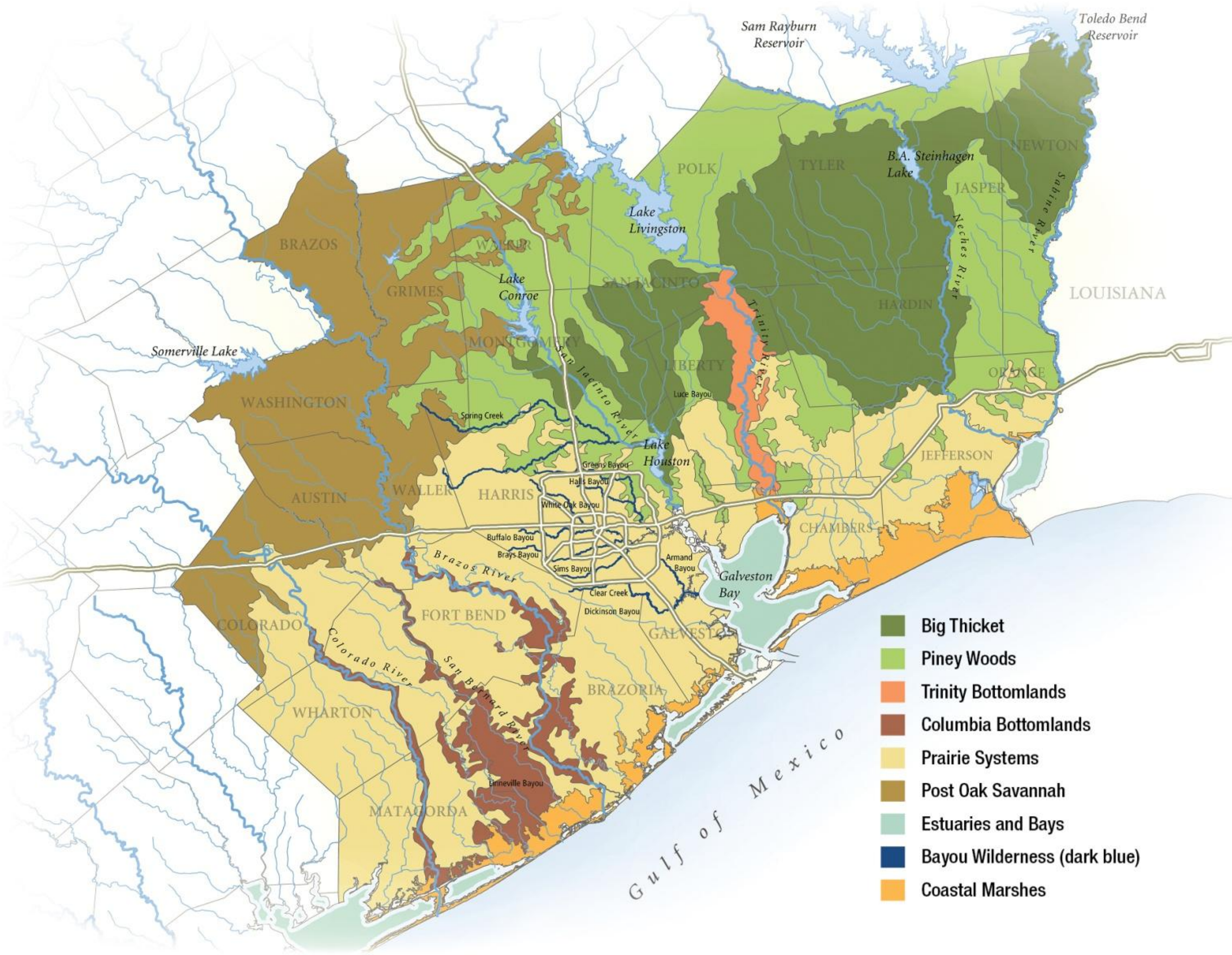
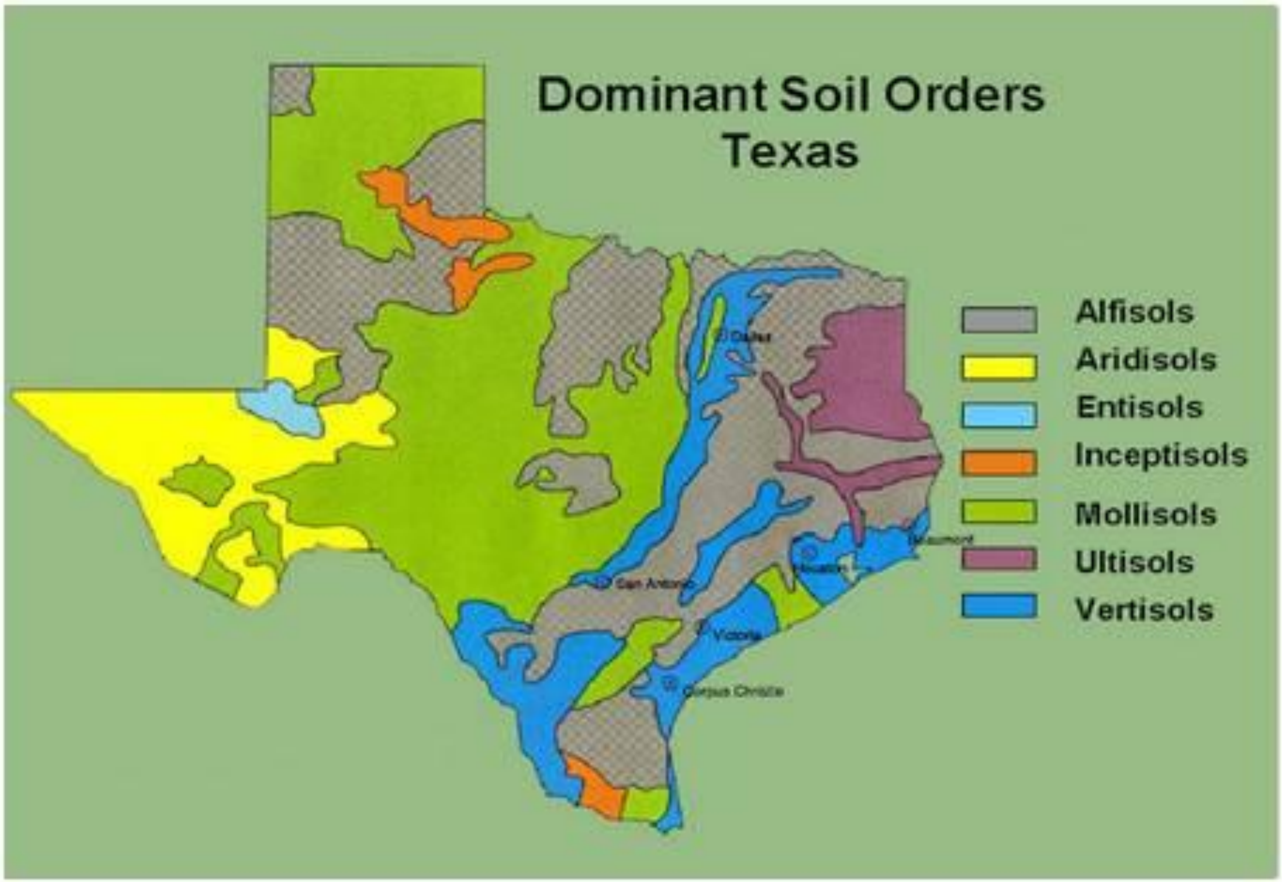
Exploring the 10 Diverse Ecoregions of Greater Houston



GROWING PRESSURES ON THE 10 ECOREGIONS

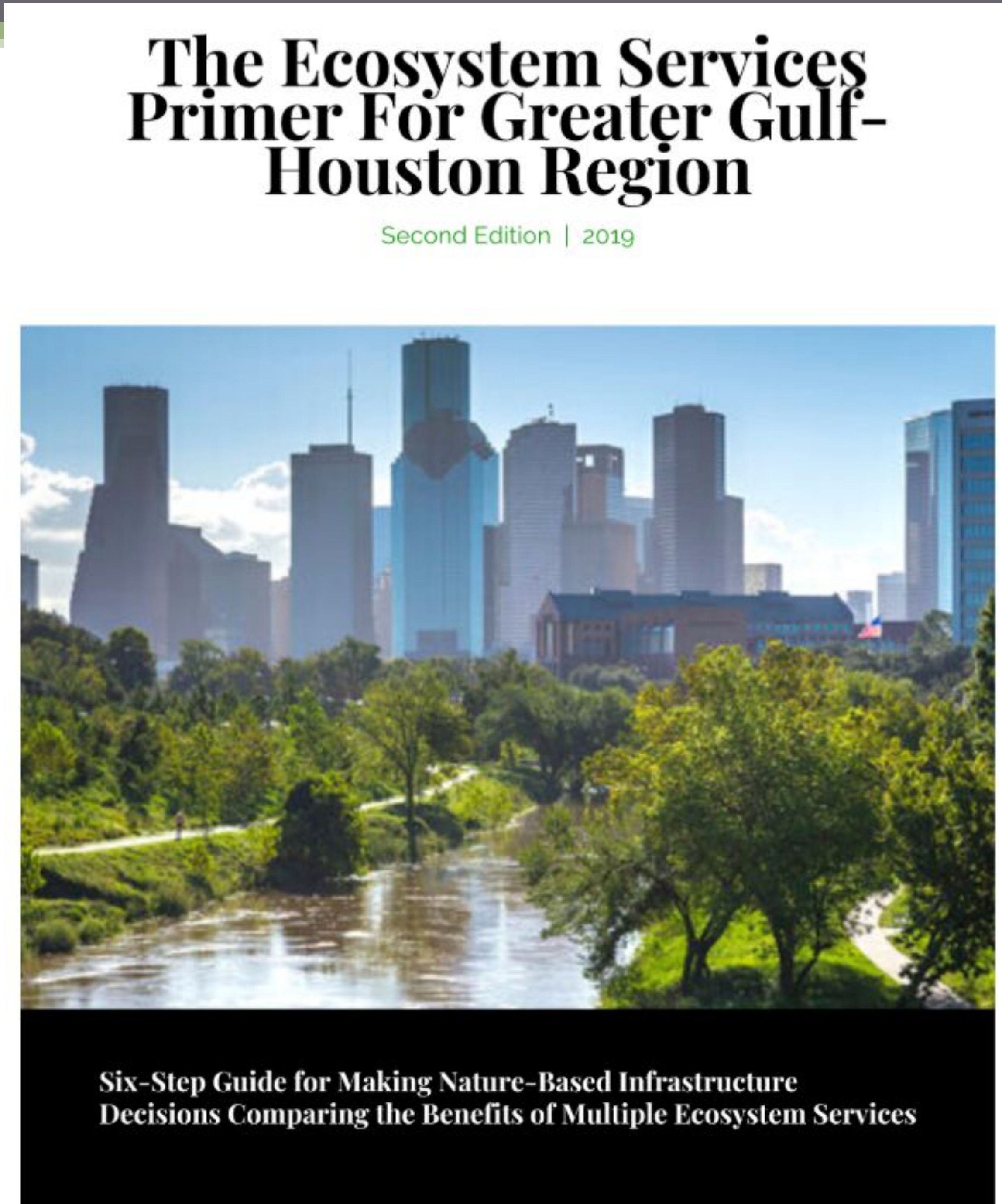
Brays Bayou
31 miles of riparian corridor in Houston experienced 40 inches of rain in 3 days during Hurricane Harvey



Unique Clay-based Soils in the 8-County Gulf-Houston Region

Provide benefits of rich soil nutrients but also require that policy and decision -makers understand clay-based soil characteristics and uses

- **Alfisols**: Coniferous forest soils (clay/sandy loam)
- **Vertisols**: Prairie, Savanna, Riparian forest with Shrink/swell properties (mainly clay)
- **Mollisols**: Grasslands (high organic matter)
- **Ultisols:** Old forest, very weathered (humus/clay)



SIX STEPS IN ECOSYSTEM SERVICES (ES) LAND-USE ANALYSIS:

1) Determine Infrastructure Goals
2) Understanding roles of different ES in decision-making
3) Establish ES baseline
4) Evaluate benefit relevant indicators
5) Consider regional/local challenges
6) Use optimal ES valuation method(s) to make infrastructure decisions

Three key categories of Ecosystem Services in Greater Houston
(1) Coastal Wetland Marshes & Estuaries

1. Water Recreation & Fishing
2. Aquifer Recharge
3. Flood Prevention by slowed storm surge
4. Improved habitat for juvenile fishery species
5. Wildlife habitat and Ecotourism
6. Organic Carbon sequestration – reduction in greenhouse gas/ air pollution
7. Erosion stabilization through soil and root systems
8. Polluted water filtering through wetland grasses improving water quality

(2) Ecosystem Services provided by Prairie systems

1. Increased property values

2. Increased wildlife habitat & ecotourism

3. Recharged groundwater

4. Flood control through rainfall absorption and “holding”in clay soils

5. Provided native seed banks for future agriculture and restoration projects

6. Soil erosion prevented

7. Absorption of organic carbon and other green-house gases

8. Replacement of expensive engineered drainage systems and retention ponds

9. Reduced runoff of pollution and nutrients into watersheds

(3) Ecosystem Services provided by a Forests - Conifer and Deciduous species

1. Improved water absorption through root systems and recharged aquifers

2. Erosion Control and improved water quality

3. Habitat for wildlife and birds & ecotourism

4. Increased property values for residents

5. Outdoor recreational opportunities

6. Noise control coming from traveled roads

7. Reduction in greenhouse gases/air pollution

8. Sequestered organic carbon

9. Reduced energy costs by shading buildings

10. Reduced the Urban Heat Island Effect

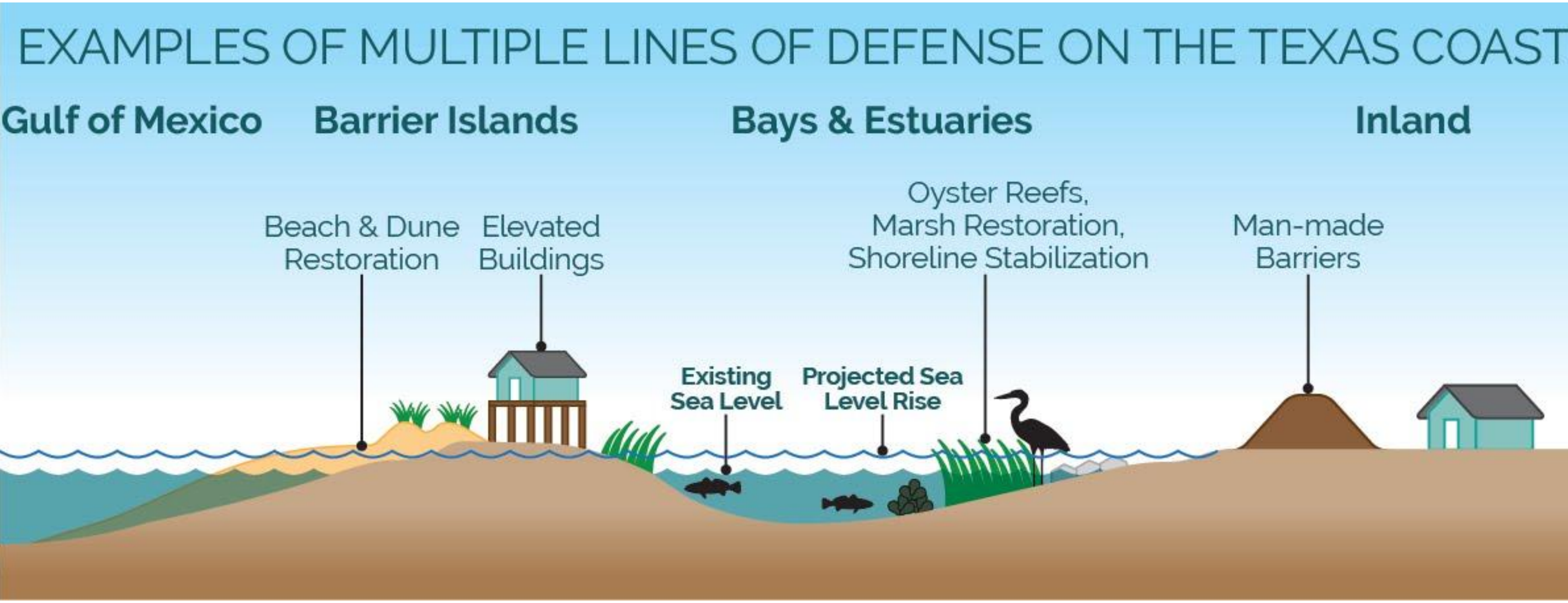
Ecosystem Services (ES) Primer **Step One** - Determining the nature-based infrastructure goals of the decision-maker/entity

Goals

- Function Monitoring - ex: wastewater treatment
- Spatial Impact on Function - ex: water detention basin
- Outright Losses - ex: replacing wetlands w development
- Substitute Equivalency - ex: replacing gray with green
- Building Something New - ex. Low impact Development
- Energy Savings - ex: large-scale native tree planting
- Insurance Savings - ex: wetland mitigation banks
- Property Value - ex. natural areas in development
- Cost of Illness - ex. Improving air quality thru nature

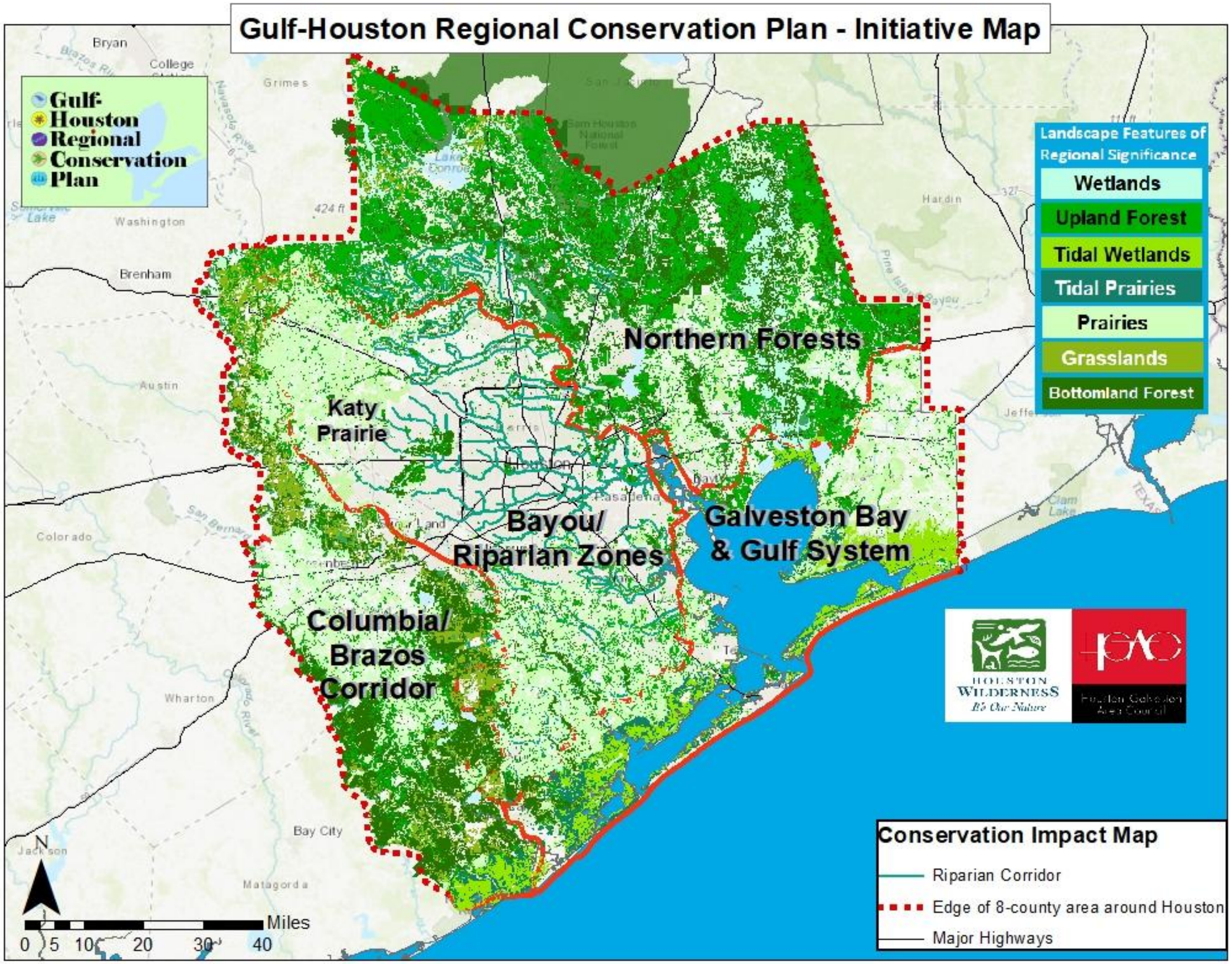
Substitute Equivalency Goal in west Houston

Ecosystem Services (ES) Primer **Step Two** - Understanding the role of various ecosystem services (ES) in decision making



Greater Houston needs multiple lines of defense to provide resilience and sustainability against the growing number of environmental impacts affecting the region – flooding, sea level rise, warming temperatures, large-scale riparian erosion, air and water pollution and loss of coastal wetlands.

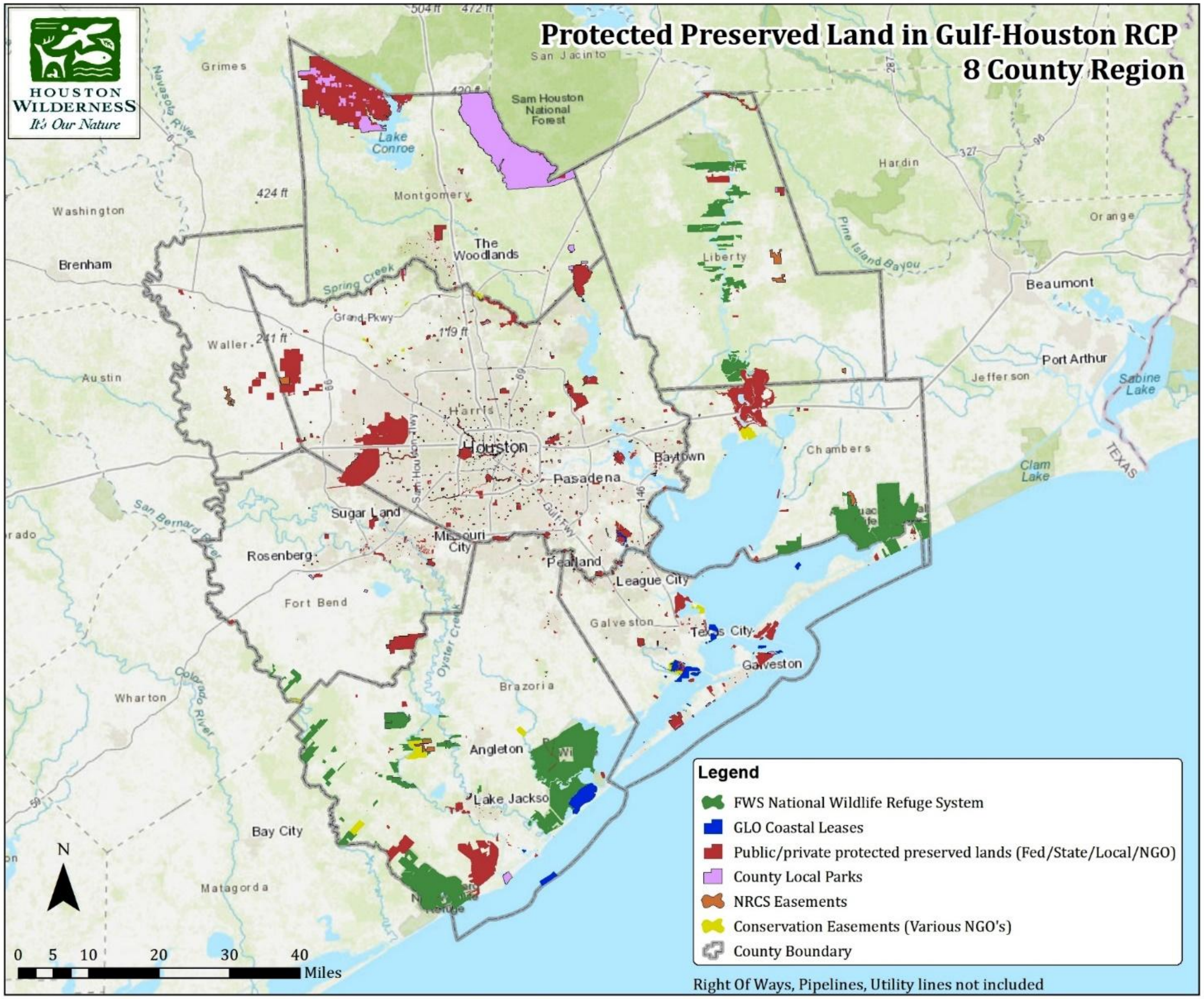
Hybrid design approaches are often chosen that allow for nature-based infrastructure (NBI) coupled with gray infrastructure composed of synthetic/concrete materials and processes.



Gulf-Houston Regional Conservation Plan (GulfHoustonRCP.org) was established as a long-term collaborative of environmental, business, and governmental entities working together to implement an ecosystem continuity and connectivity plan for the region, encouraging improved ecosystem services

Key Goals:

1)Increase Protected/Preserved Land to 24% by 2040
2)Increase Nature-based Infrastructure to 50% by 2040
3)Annually increase organic carbon sequestration by .04%



Under the 1st Key Goal of the Gulf-Houston Regional Conservation Plan decision-makers can use the GIS maps provided by Houston Wilderness and other collaborative partners to assist in understanding the role of various ecosystem services (ES) in infrastructure decisions

Ecosystem Services (ES) Primer **Step 3** – Establishing an ES baseline for the targeted area(s)

Case Example:
Berm along Port Houston Container Terminal

Infrastructure Goals:

- Building Something New
- Property values
- Noise Reduction

Nature-Based Solution:

- 30-foot Natural Berm
- Large-Scale Native Trees
- Native grasses

- **Cost to Construct: $1.5 Million**

Case Example: Exploration Green flowing into Clear Creek

Infrastructure Goals:

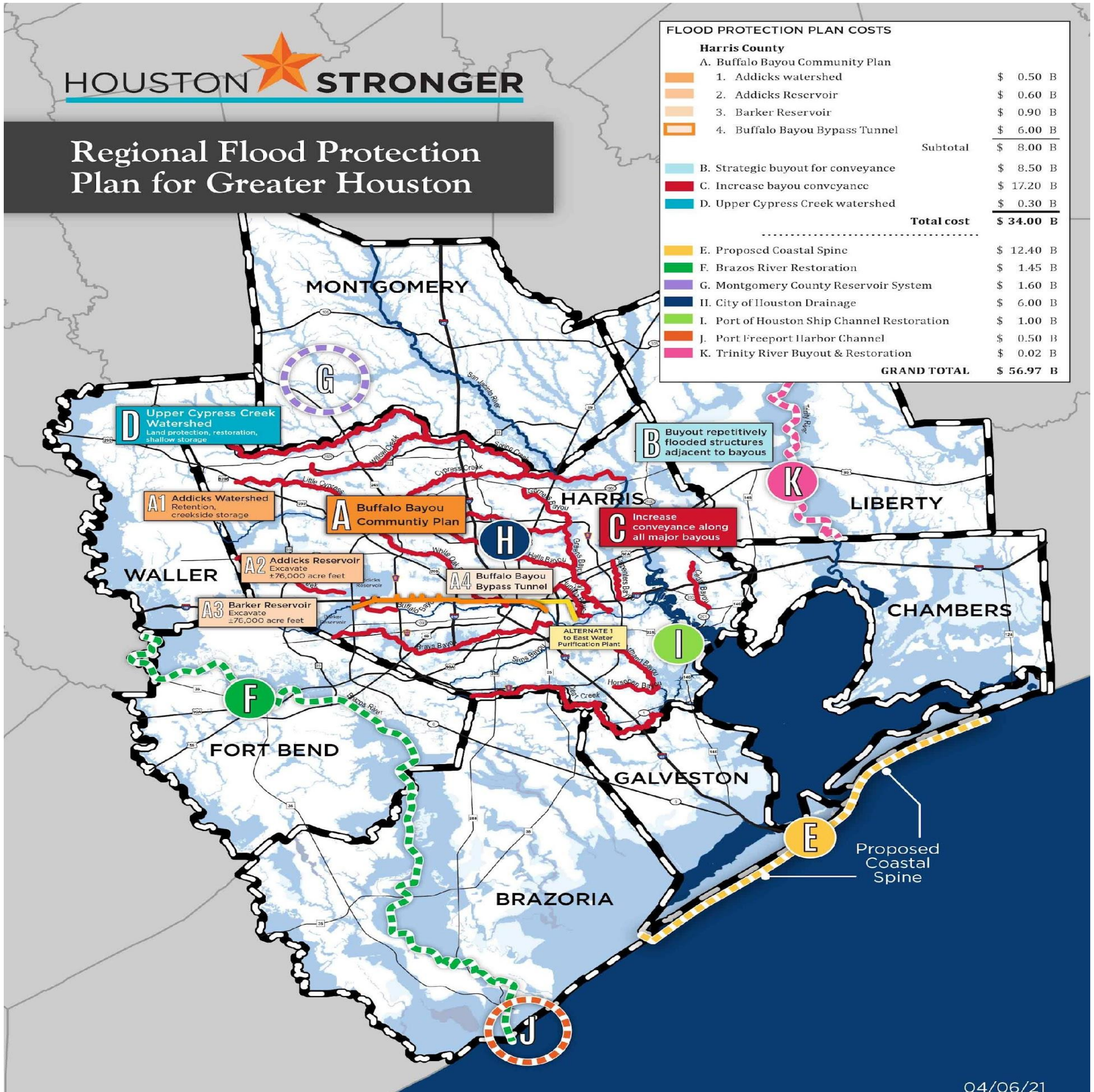
- Spatial Impact on Function
- Outright Losses
- Outdoor Recreation
- Improved habitat

Nature-Based Solution:

- 178 acres of Stormwater Filtering Features
- Large-Scale Native Trees
- Native grasses

- **Cost to Construct:** **$2.5 Million**

Ecosystem Service (ES) Primer **Step Four** – Considering regional/local challenges



FLOOD PROTECTION PLAN COSTS

Harris County		
A. Buffalo Bayou Community Plan		
1. Addicks watershed		$ 0.50 B
2. Addicks Reservoir		$ 0.60 B
3. Barker Reservoir		$ 0.90 B
4. Buffalo Bayou Bypass Tunnel		$ 6.00 B
	Subtotal	$ 8.00 B
B. Strategic buyout for conveyance		$ 8.50 B
C. Increase bayou conveyance		$ 17.20 B
D. Upper Cypress Creek watershed		$ 0.30 B
	Total cost	**$ 34.00 B**
E. Proposed Coastal Spine		$ 12.40 B
F. Brazos River Restoration		$ 1.45 B
G. Montgomery County Reservoir System		$ 1.60 B
H. City of Houston Drainage		$ 6.00 B
I. Port of Houston Ship Channel Restoration		$ 1.00 B
J. Port Freeport Harbor Channel		$ 0.50 B
K. Trinity River Buyout & Restoration		$ 0.02 B
	GRAND TOTAL	**$ 56.97 B**

<u>Case Example</u>: <u>Houston Stronger Flood Prevention Plan</u>

<u>Infrastructure Goals:</u>

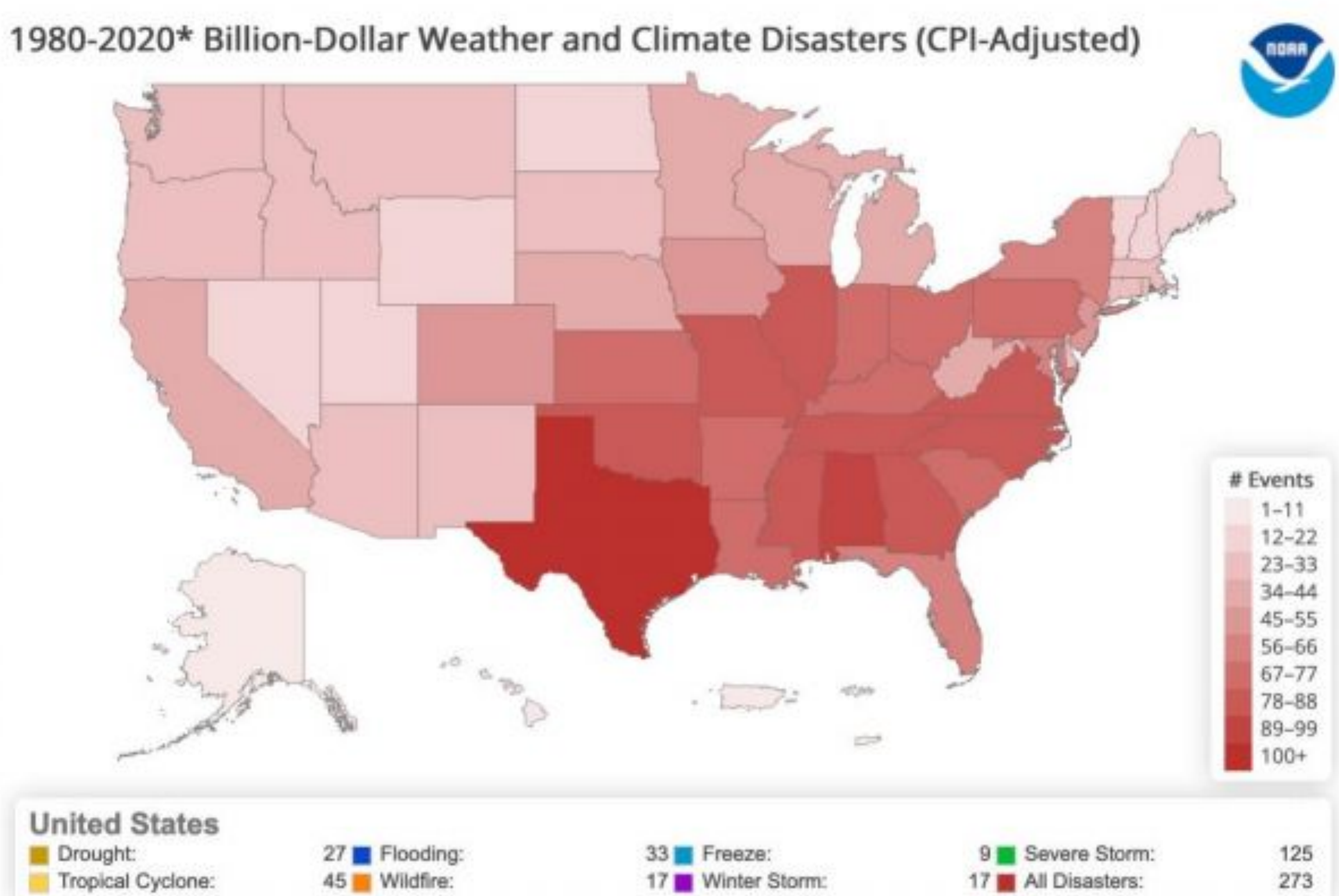
- Outright Losses
- Building Something New
- Insurance Savings

<u>Nature-Based Solutions:</u>

- Removing sediment/silt from large reservoirs
- Strategic property buyouts
- Restoration along Ship Channel, 3 major rivers and multiple bayous/
- creeks

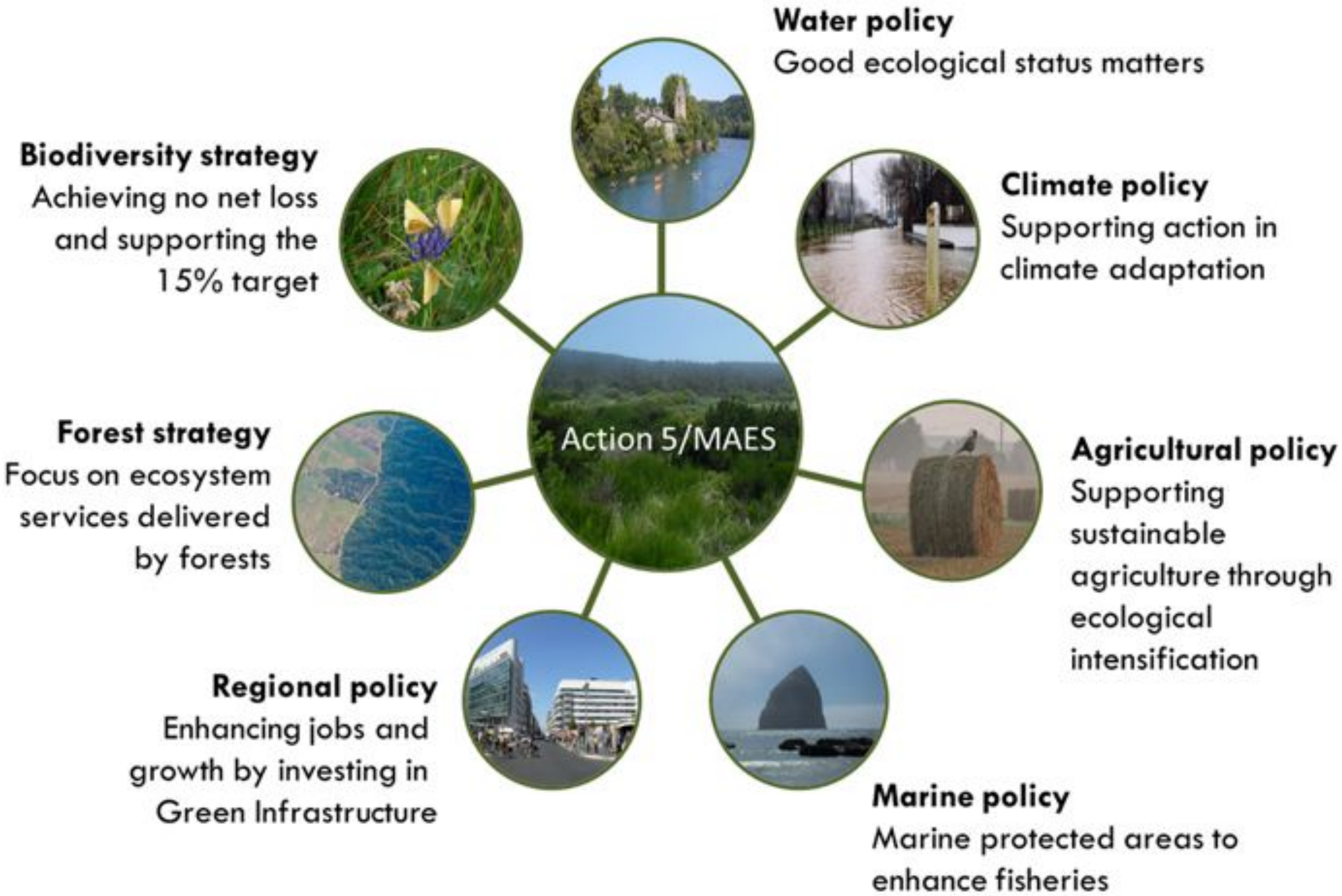
•<u>**Cost to Construct:**</u> **$15.37 Billion**

Ecosystem Service (ES) Primer **Step Four (continued)** – Considering regional/local challenges

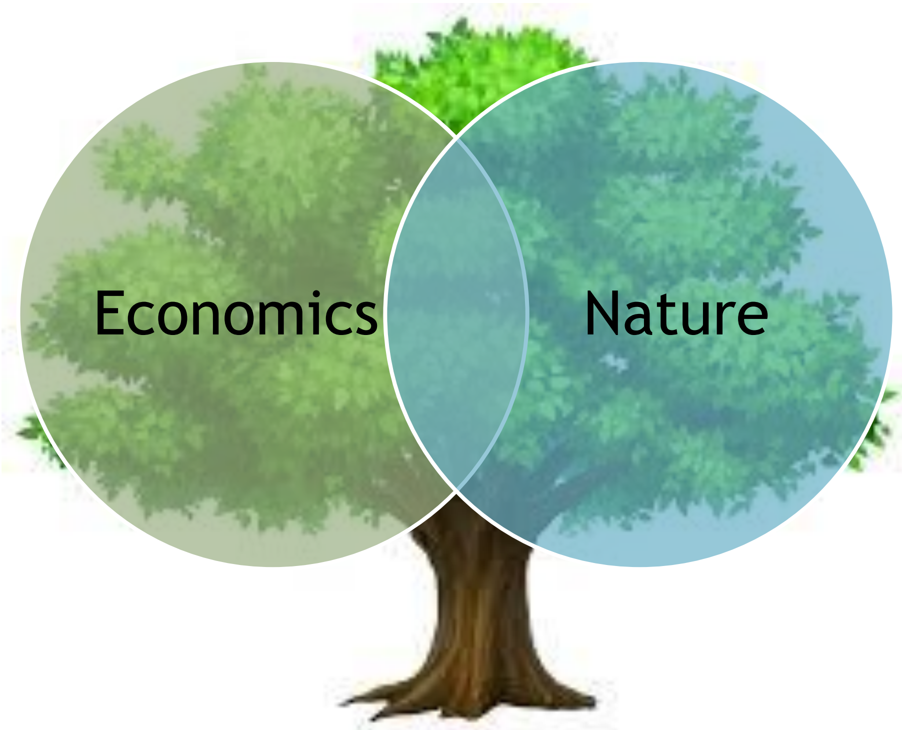


The Greater Houston Region experiences a wide array of extreme weather and climate events, including heatwaves, prolonged droughts, intense rainfall events, hurricanes, and floods.

Ecosystem Services (ES) Primer **Step 5** - Create flow chart of ES benefits and economic valuations, including evaluating benefit relevant indicators



Ecosystem Services (ES) Primer **Step Six** – Using optimal ES valuation methods to determine infrastructure solution(s)

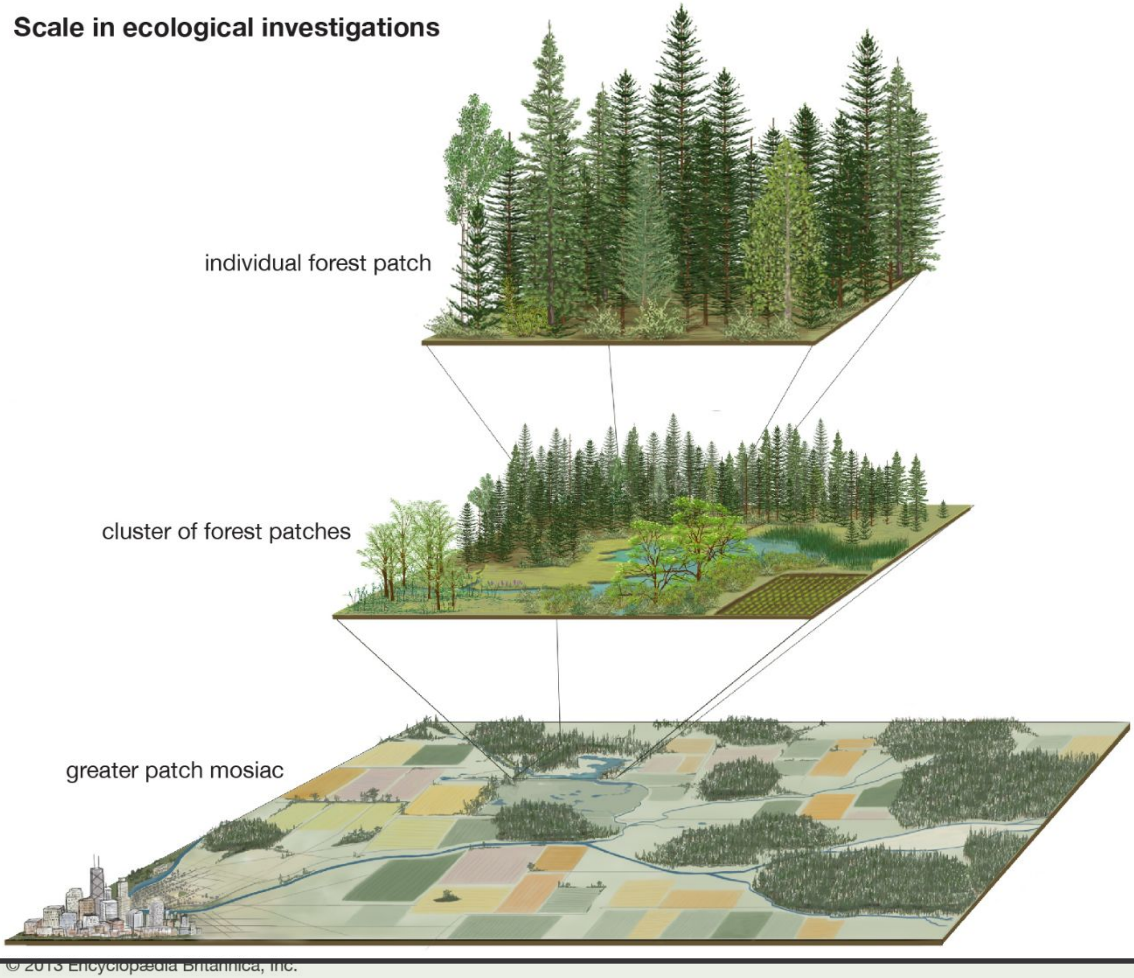


Economic Methods

- On-site Ecological Function Analysis
- Avoided Cost
- Replacement Cost
- Mitigation/Restoration Cost
- Direct Market Price
- Hedonic Pricing

METHOD 1

Ecological Function Analysis



- *On-Site Ecological Function Analysis measures a specific ecosystem's productive output and how adding more nature-based infrastructure increases the ES.*
- *This analysis can also provide a baseline inventory for use in conjunction with a cost-based or market price method.*

Infrastructure Goals: Use for Ecological Function Monitoring, Spatial Scale Impact on Function, and Building Something New

Specific ES values of Native Tree Species

One type of ecological function analysis measures a specific species' ecosystem functions and compares them against each other to consider the effectiveness of increased ES in a nature-based infrastructure context.

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Total CO_2 stored and Annual CO_2 sequestration of Regional Native Tree Species

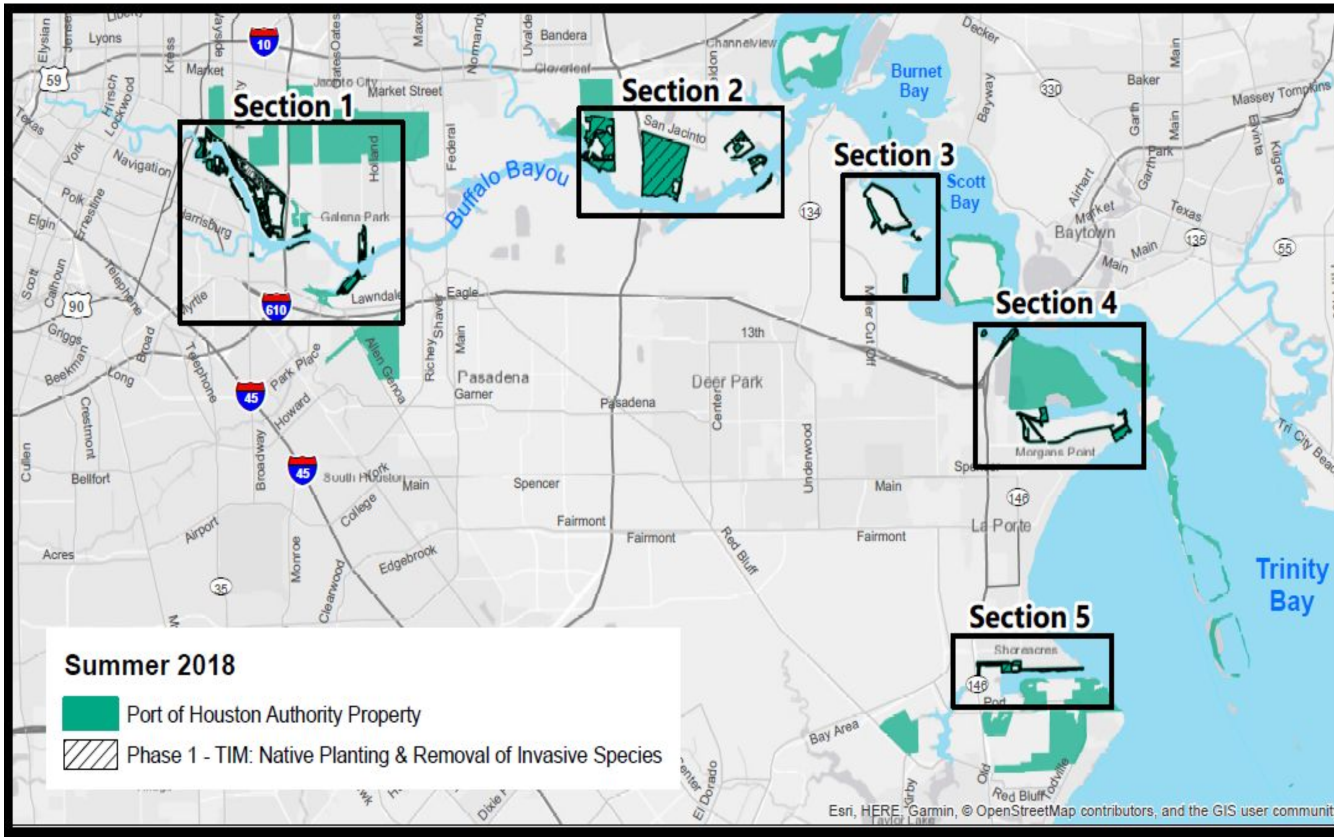
Tree species	Total CO_2 Stored (lbs.) DBH ≈ 10 years
Live Oak	1023
Black Cherry	971
River Birch	925
Boxelder	898
Laurel Oak	875
Water Oak	869
Red Maple	859
Willow Oak	739
Sweetgum	719
Slippery Elm	669
American Elm	667
Tulip Tree	659
American Sycamore	652
Green Ash	624
Eastern Cottonwood	591
Black Willow	590
Loblolly Pine	479

Tree species	CO_2 sequestrated (lbs./tree/year) DBH ≈ 10 years
Live Oak	268
River Birch	215
Green Ash	200
Slippery Elm	197
Laurel Oak	194
Winged Elm	179
Eastern Cottonwood	176
Water Oak	173
Black Willow	169
Boxelder	159
Elm	151
Sweetgum	150
Baldcypress	146
Willow Oak	142
Red Maple	139
Plum	139
Southern red Oak	121

If 2,000 Live Oak trees are planted in 2020, by 2030 the Live Oak trees will be absorbing 268 pounds of carbon each year, for a total of 536,000 lbs each year. And, adding mulch and/or organic compost increases soil organic carbon.

***Port Houston Tree & Riparian Enhancement of Ecological Services** (PoH TREES program), a collaborative nature-based solution that* targets large-scale tree plantings using native tree species with higher ranked ES values on lands along the 25 miles of the Houston Ship Channel

PORT OF HOUSTON TREES PROGRAM



Infrastructure Goals:

- Function Monitoring to impact air pollution, water absorption & carbon sequestration
- Spatial Impact on Function

Nature-Based Solution:

- Targeted Large-Scale Native Tree Plantings

- **Cost to Construct:** **$250,000**

METHOD

2

Direct Market Price - looks at the actual price of a commodity derived from an ecosystem in an existing market

<u>Shrimp Harvested in Galveston Bay</u>

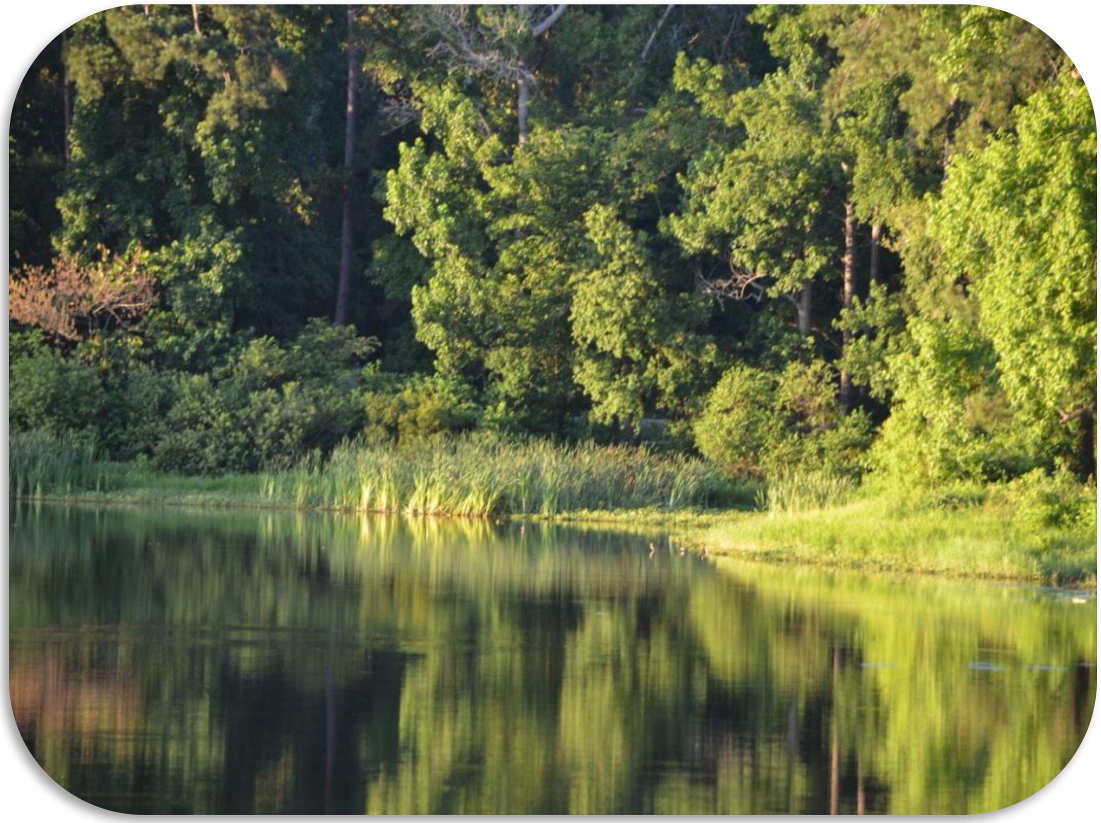
<u>ES Value Derived from Direct Market Price:</u>

Pounds of shrimp per year harvested from Galveston Bay could be multiplied by the price per pound consumers pay for them at different seasoned times

Infrastructure Goal: Use for Provisioning Ecosystem Services (goods harvested from ecosystem)

METHOD 3

Avoided Cost Method - Determines the cost that would have been incurred in the absence of the ecosystem service provided.



For example, looking at the cost to repair damages that would have occurred if stormwater had not been retained by a wetland in a flood event will give a ES value for the stormwater retention that is provided by the wetland.

Infrastructure Goals: Use for Outright Losses, Energy Savings, Insurance Savings, and Cost of Illness

METHOD

4

Replacement Cost Method – determines (or compares) the costs that would be incurred in the replacement of an ecosystem service with gray infrastructure to accomplish the same goal(s)

DOW CHEMICAL PLANT IN FREEPORT, TX

Value Derived from Replacement Cost Method:

Constructing a wetland in the current tertiary pond vs building a sequencing batch reactor

- **Cost to Construct:** **$1.4 Million vs $40 Million**

Infrastructure Goals: Use for Outright Losses and Substitute Equivalency

METHOD 5

Mitigation and Restoration Cost Method – looks at the cost of getting ecosystem services (ES) restored in damaged ecosystems

BRAYS BAYOU TIDAL BASINS ES VALUE DERIVED FROM MITIGATION & RESTORATION COST METHOD:

- *Provide retention area for heavy rain events*
- *Develop natural marshlands and green spaces along Brays Bayou*
- *Improve water quality and reduce the need for treatment*
- *Provide recreation and tourism opportunities for the community*

Cost to Construct: **$3.2 Million each (along 5 Brays Bayou locations)**

Infrastructure Goals: Use for Ecological Function Monitoring, Spatial-Scale Function on Impact, Outright Losses and Building Something New

METHOD 6

Hedonic Pricing – considers the value of the demand for an ecosystem service (ES) by looking at how the ES affects values in a related market, usually real estate or recreational use, using regression analysis

CROSS CREEK RANCH MASTER PLANNED COMMUNITY
ES VALUE DERIVED FROM HEDONIC PRICING:

Value of homes range from $300,000 - $1 million depending on proximity to the large nature-based infrastructure built in the center of the development

Infrastructure Goals: Use for Property & Recreational Use

The Ecosystem Services Primer For Greater Gulf-Houston Region

Second Edition | 2019

Six-Step Guide for Making Nature-Based Infrastructure Decisions Comparing the Benefits of Multiple Ecosystem Services

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CONCLUDING COMMENT:

Using the six-step approach, practical ecosystem services (ES) appraisals can compare the relative magnitude of changes in the provisions of, based on targeted goals and across different evaluation methods, and can be possible even with limited availability and precision of scientific and economic valuation information.

www.HoustonWilderness.org

Thank You!

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Additional Resources

MPC E3 - Cross Creek Ranch - virtual video on RCP, MPC and 1% recreational bonds for MUDs

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RESEARCH ARTICLE

Plants People Planet PPP

A simple tree planting framework to improve climate, air pollution, health, and urban heat in vulnerable locations using non-traditional partners

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Societal Impact Statement
Planting trees is considered an effective method for climate change adaptation and mitigation. This framework provides a replicable blueprint to improve health, urban heat, flooding, and air pollution via a multisectoral, collaborative, environmental data-driven approach. Native tree species with targeted ecosystem services are selected, and sites are strategically identified based on environmental and health benefits, with the intent of engaging community involvement through education and large-scale tree plantings. Including non-traditional partners in the framework provides heightened awareness of the relationship between climate change and health, thus catalyzing decision-making regarding sustainable actions that reduce effects of climate change. This native tree planting framework is highly adaptable in other cities.

Summary

- A multidisciplinary framework is presented for a data-driven, climate change adaptation and climate change and air pollution mitigation project. This framework leverages heightened awareness of the connections between climate change, air pollution, and health to expand the cadre and societal impacts of those working to intervene in resilience planning and implementation.
- The framework, implemented in Houston, Texas, USA, beginning in 2019, consists of three parts: (1) identification of optimal native tree species for climate change adaptations and air pollution mitigation around variables important locally; (2) selection of large-scale native tree planting locations where populations are already disproportionately experiencing flooding, increased heat, and air pollution-related health effects that could be further exacerbated from climate change; and (3) engagement of multisectoral leadership broadened beyond those traditionally working on climate change resilience through heightening awareness of the link to human health.
- Native tree species were identified that had the highest combination of absorption of carbon dioxide, other air pollutants, and water absorption (aiding in flood adaptation and air pollution/heat mitigation). Thousands of the top tree species were planted in locations that experience substantial flooding during large rain events,

Plants People Planet. 2022;4:243–257. wileyonlinelibrary.com/journal/ppp3 | 243