ECOSYSTEM SERVICES

Nature Pays Big Dividends

Jewell Cozort – City of San Antonio
Park Biologist

Ecosystem Services Defined

Ecosystem Services: *the goods and services provided by ecosystems that benefit, sustain and support* ***the well-being of people***

Aka "Natural Capital"

- An **ECOSYSTEM** includes all the living things in a particular area — plants, animals and organisms, including people — interacting with each other and with the elements of the nonliving environments

    - Ecosystems vary enormously in size,
        - from a temporary pond in a pothole,
        - to an entire ocean basin.

https://www.nps.gov/blca/learn/nature/potholes.htm

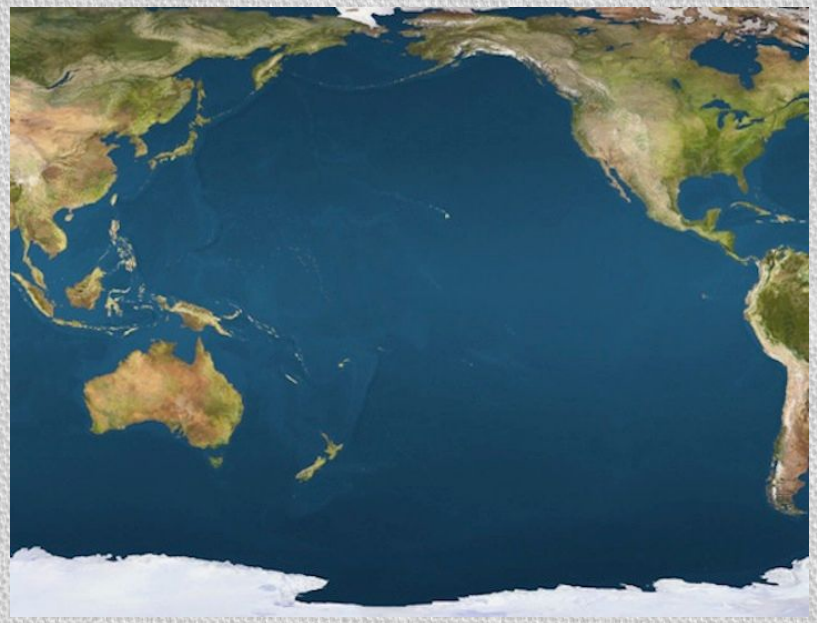

Image from https://www.doi.gov/sites/doi.gov/files/uploads/4_Dr%20Dan%20Aga_Presents%20Final.pdf/

1833
William Forster Lloyd, English Economist

1968
Garrett Hardin, Ecologist
Tragedy of the Commons, Science

TWO LECTURES

ON THE

CHECKS TO POPULATION,

DELIVERED BEFORE

THE UNIVERSITY OF OXFORD,

IN MICHAELMAS TERM 1832.

BY

THE REV. W. F. LLOYD, M. A.

STUDENT OF CHRIST CHURCH,

PROFESSOR OF POLITICAL ECONOMY.

OXFORD,

PRINTED BY S. COLLINGWOOD, PRINTER TO THE UNIVERSITY,

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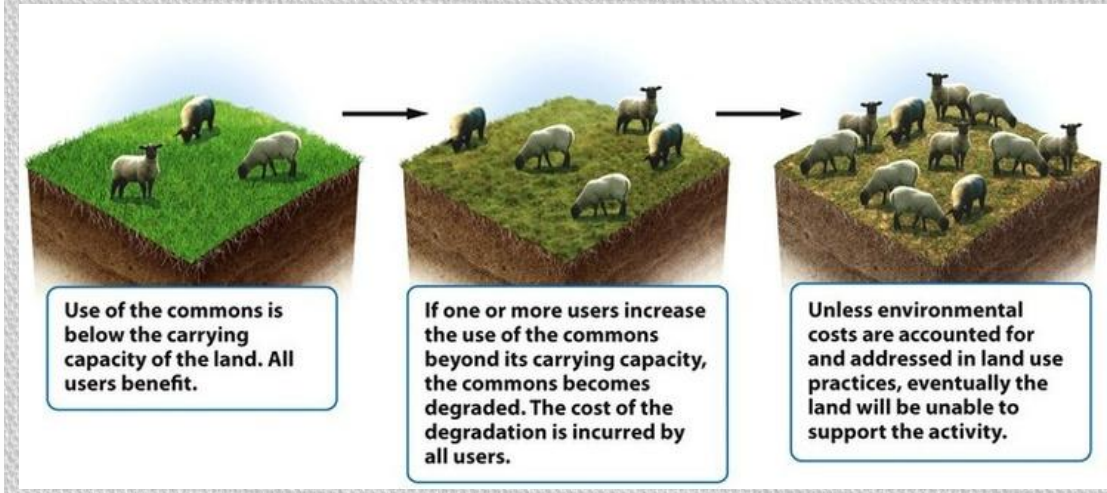

1997
Costanza et. al

2000
United Nations, Kofi Annan

nature
International journal of science

Altmetric: 218 Citations: 7569 More detail »

Article

The value of the world's ecosystem services and natural capital

Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton & Marjan van den Belt

Nature **387**, 253–260 (15 May 1997)
doi:10.1038/387253a0
Download Citation

Received: 23 January 1997
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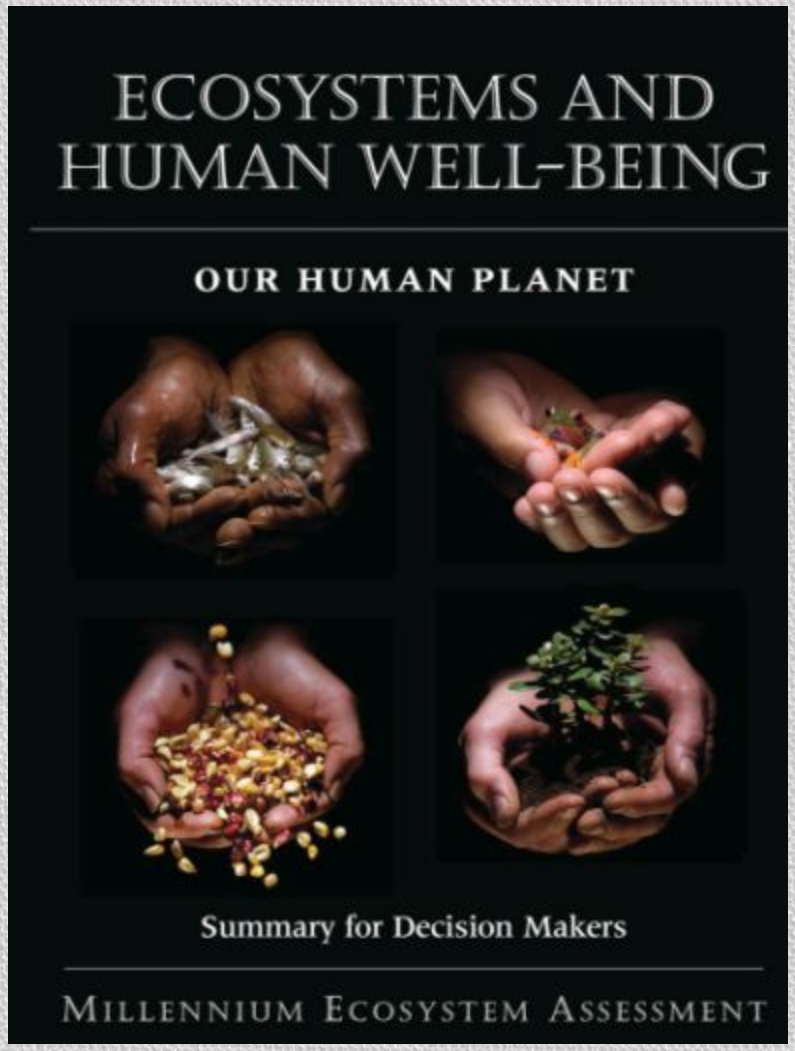
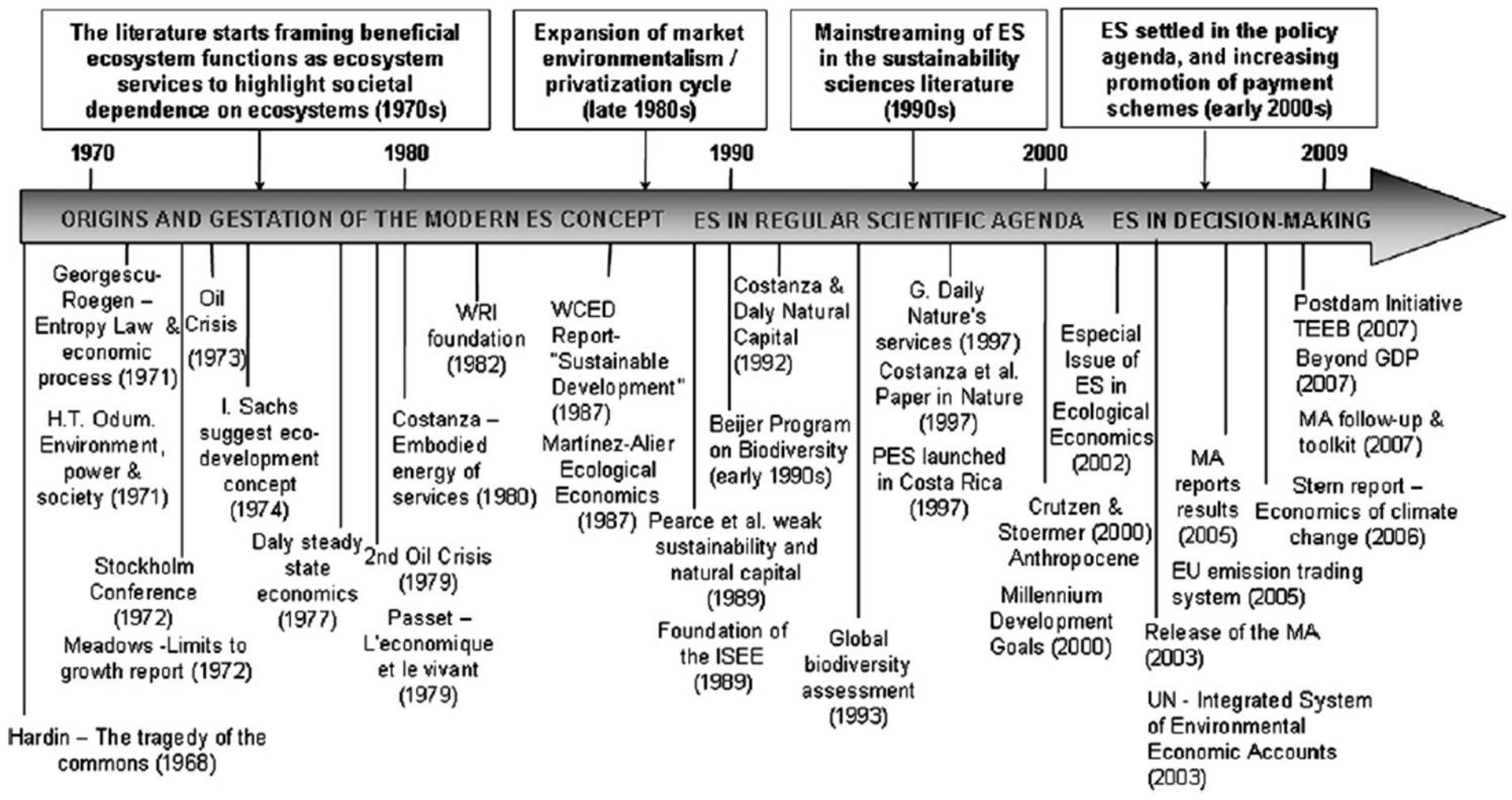
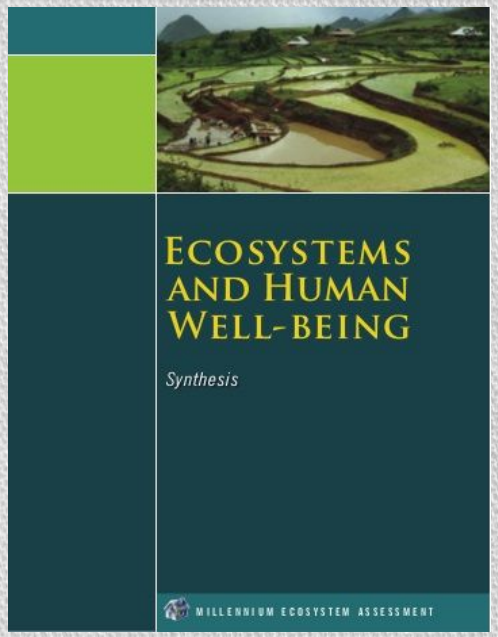
Published online: 15 May 1997

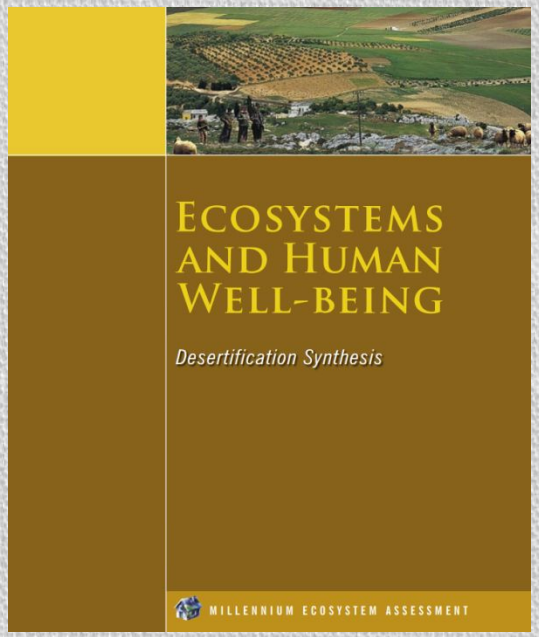


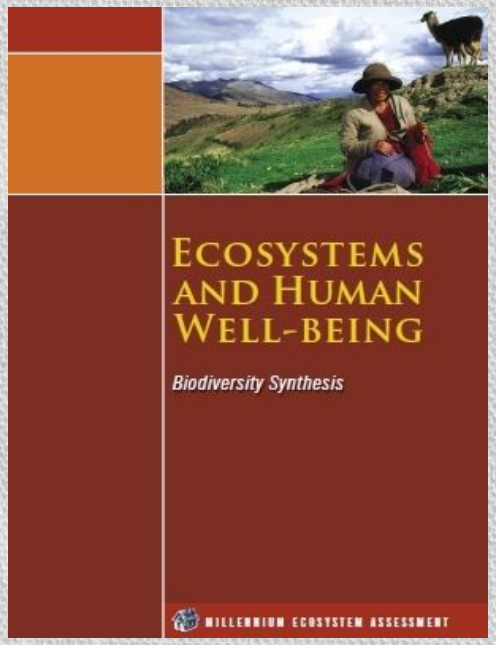

The literature starts framing beneficial ecosystem functions as ecosystem services to highlight societal dependence on ecosystems (1970s)
Expansion of market environmentalism / privatization cycle (late 1980s)
Mainstreaming of ES in the sustainability sciences literature (1990s)
ES settled in the policy agenda, and increasing promotion of payment schemes (early 2000s)
1970
1980
1990
2000
2009
ORIGINS AND GESTATION OF THE MODERN ES CONCEPT
ES IN REGULAR SCIENTIFIC AGENDA
ES IN DECISION-MAKING
Georgescu-Roegen – Entropy Law & economic process (1971)
H.T. Odum. Environment, power & society (1971)
Stockholm Conference (1972)
Meadows -Limits to growth report (1972)
Hardin – The tragedy of the commons (1968)
Oil Crisis (1973)
I. Sachs suggest eco-development concept (1974)
Daly steady state economics (1977)
2nd Oil Crisis (1979)
Passet – L'economique et le vivant (1979)
Costanza – Embodied energy of services (1980)
WRI foundation (1982)
WCED Report- "Sustainable Development" (1987)
Martínez-Alier Ecological Economics (1987)
Pearce et al. weak sustainability and natural capital (1989)
Foundation of the ISEE (1989)
Costanza & Daly Natural Capital (1992)
Beijer Program on Biodiversity (early 1990s)
Global biodiversity assessment (1993)
G. Daily Nature's services (1997)
Costanza et al. Paper in Nature (1997)
PES launched in Costa Rica (1997)
Especial Issue of ES in Ecological Economics (2002)
Crutzen & Stoermer (2000) Anthropocene
Millennium Development Goals (2000)
Release of the MA (2003)
UN - Integrated System of Environmental Economic Accounts (2003)
MA reports results (2005)
EU emission trading system (2005)
Postdam Initiative TEEB (2007)
Beyond GDP (2007)
MA follow-up & toolkit (2007)
Stern report – Economics of climate change (2006)

- **The Millennium Ecosystem Assessment (MEA)**
- Called for by United Nations Secretary-General Kofi Annan in 2000 and published in 2005.
- The main objective of the MEA was:

"…consequences of ecosystem change for human well-being …establish scientific basis for actions to enhance the conservation and sustainable use of ecosystems…"





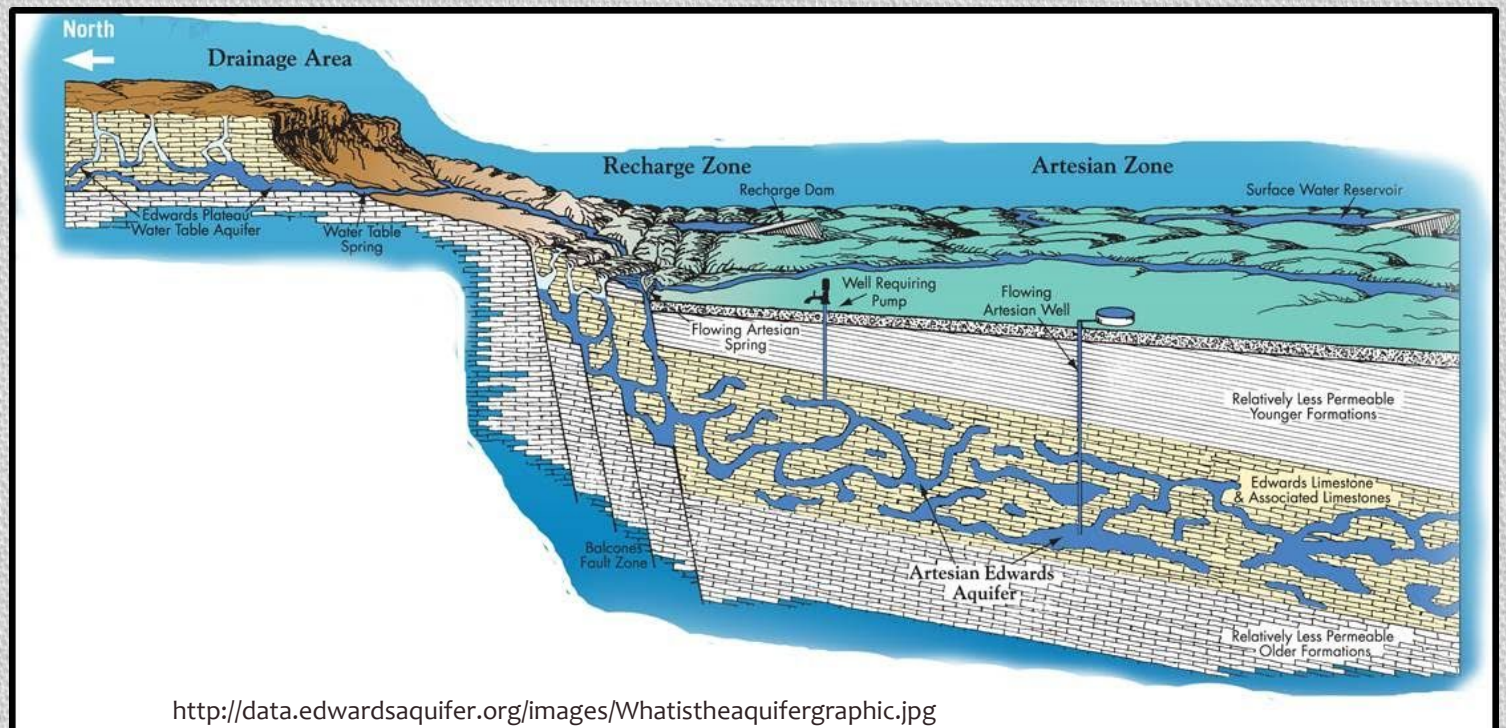


The MEA groups ecosystem services into four broad categories:

1. **<u>Provisioning Services</u>**: food and water, wood, fuel, fiber, pharmaceuticals and material for industrial products.

2. Regulating Services:

- Local climate and air quality
- Carbon Sequestration and storage
- Moderation of extreme events
- Waste-water treatment
- Decompose waste
- Erosion prevention and maintenance of soil fertility
- Pollination
- Biological Control and regulating pests



http://data.edwardsaquifer.org/images/Whatistheaquifergraphic.jpg

3. Cultural Services:

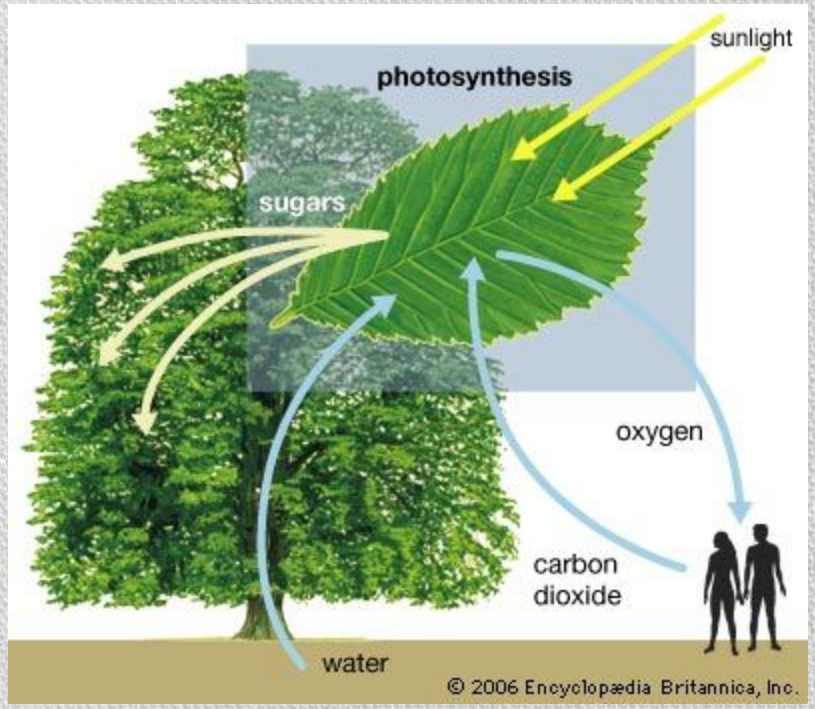
- Recreation
- Mental and physical health
- Tourism
- Aesthetic appreciation and inspiration for culture, art, and design
- Spiritual experience and sense of place
- Sites for education

https://www.lonelyplanet.com/travel-tips-and-articles/the-worlds-best-places-to-get-a-yes/40625c8c-8a11-5710-a052-1479d2767118

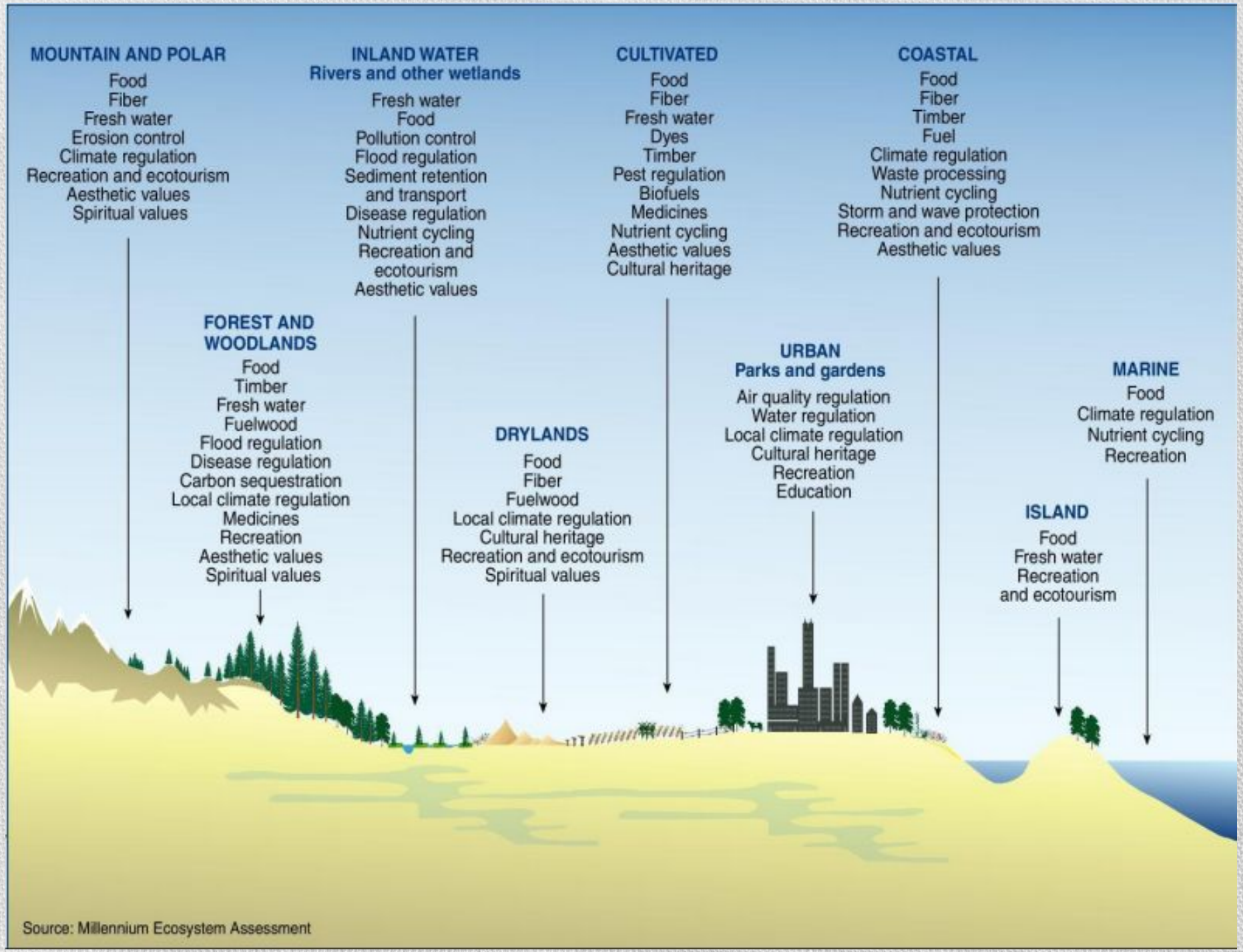
Bagan, Myanmar (Burma)

http://thehabitualhiker.com/best-hiking-trails/

4. **Supporting Services**: Nutrient cycling, soil formation, primary production, habitats, and genetic diversity



https://www.technologyreview.com/s/531131/sharing-flood-mitigation-strategies-with-at-risk-countries/


MOUNTAIN AND POLAR
Food
Fiber
Fresh water
Erosion control
Climate regulation
Recreation and ecotourism
Aesthetic values
Spiritual values
INLAND WATER
Rivers and other wetlands
Fresh water
Food
Pollution control
Flood regulation
Sediment retention and transport
Disease regulation
Nutrient cycling
Recreation and ecotourism
Aesthetic values
CULTIVATED
Food
Fiber
Fresh water
Dyes
Timber
Pest regulation
Biofuels
Medicines
Nutrient cycling
Aesthetic values
Cultural heritage
COASTAL
Food
Fiber
Timber
Fuel
Climate regulation
Waste processing
Nutrient cycling
Storm and wave protection
Recreation and ecotourism
Aesthetic values
FOREST AND WOODLANDS
Food
Timber
Fresh water
Fuelwood
Flood regulation
Disease regulation
Carbon sequestration
Local climate regulation
Medicines
Recreation
Aesthetic values
Spiritual values
DRYLANDS
Food
Fiber
Fuelwood
Local climate regulation
Cultural heritage
Recreation and ecotourism
Spiritual values
URBAN
Parks and gardens
Air quality regulation
Water regulation
Local climate regulation
Cultural heritage
Recreation
Education
MARINE
Food
Climate regulation
Nutrient cycling
Recreation
ISLAND
Food
Fresh water
Recreation and ecotourism
Source: Millennium Ecosystem Assessment

Direct Benefit

Provisioning

(Products from ecosystems)

Food
Fresh water
Fuel wood
Biochemicals
Genetic Resources

Cultural

(Nonmaterial benefits from ecosystems)

Spiritual and Religious
Recreation and ecotourism
Aesthetic
Inspirational
Educational
Sense of place
Cultural heritage

Indirect Benefit

Regulating

(Benefits from regulation of ecosystem processes)

Climate Regulation
Disease regulation
Water regulation
Water purification

Supporting

(Services necessary for production of all other services)

Soil formation
Nutrient cycling
Primary Production

Direct Ecosystem Services

Provisioning

Service	Cost
apple (food)	$ 1.29
2 x 4 lumber (1) (wood)	$ 2.79
Amoxicillin (pharma)	$ 8.00
Saws water Bill / month (water)	$ 40.00

Cultural

Service	Cost
Entrance Fee Government Canyon (recreation)	$ 6.00
Camera for nature photography (Inspiration)	$ 300
Trip to Grand Canyon (recreation)	$ 500 – 1000
Aesthetic Beauty	Priceless?
Sense of Place	Priceless ?

Indirect Ecosystem Services

Regulating

Service	Cost
Edwards Aquifer (Water Regulation/ purification)	?
Dragonfly nymph feeding on Mosquitos (Disease Regulation)	?
Climate	?

Supporting

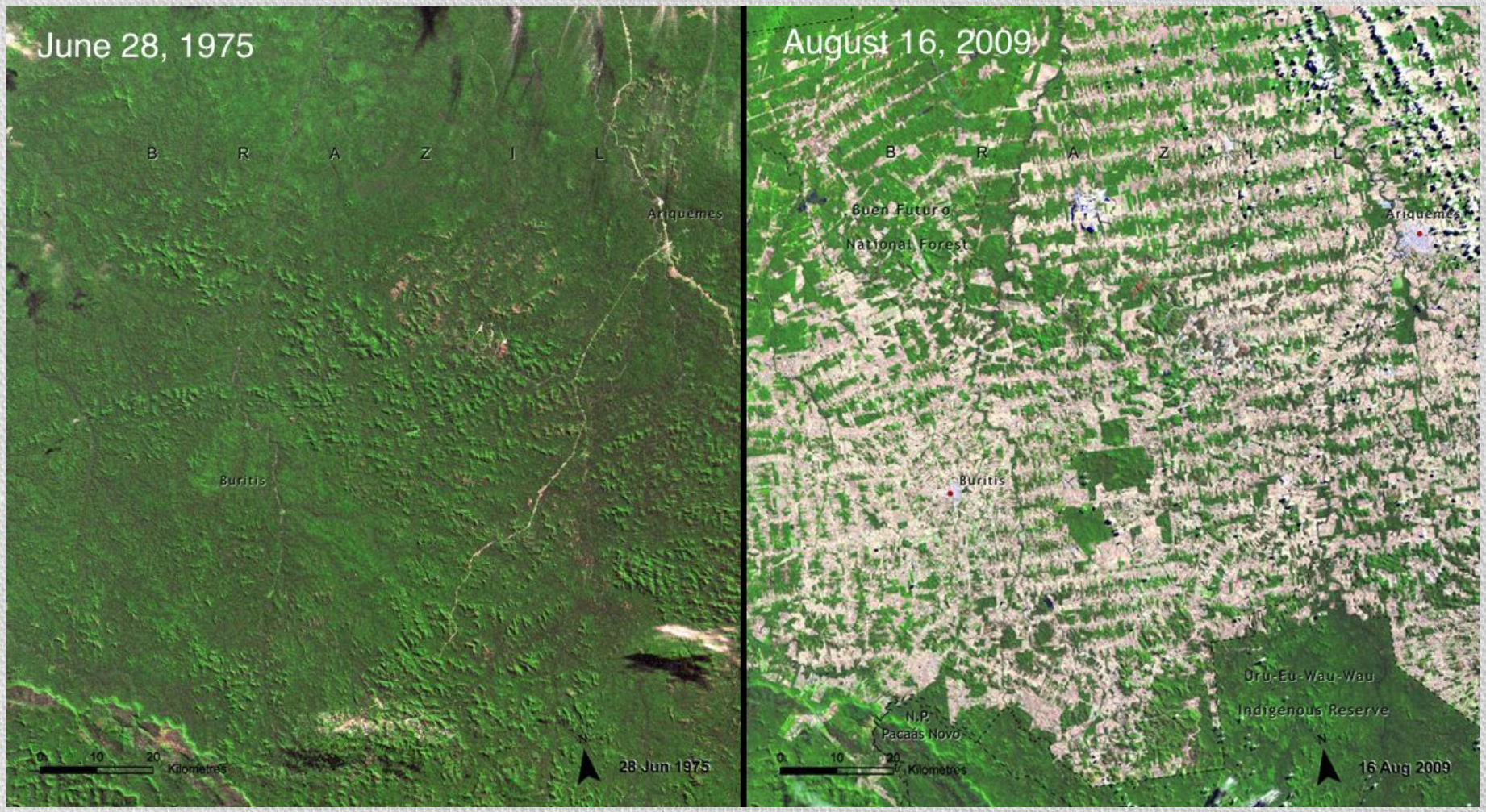
Service	Cost
Nutrient Cycling	?
Soil Formation (100 years/ cm of soil)	?
Primary Production (basis of food chain)	?

Indirect Ecosystem Services

- Undervalued
- Not traded in formal markets
- When supply or condition changes it may not be reflected in the market
- Few people are conscious of the role natural ecosystems play in generating goods

Hard to quantitate

Rainforests get swallowed by farms in Brazil



Water regulation, oxygen, carbon sequestration… etc.

Erosion, habitat loss

Furthermore, ecosystem services…

- existed long before humanity
- basic fundamentals of life
- easily taken for granted
- so large in scale it's hard to imagine humans could disrupt them
- but when we do the damage it's not easily reversed on a timescale relevant to society

Putting a price on nature is not easy

Several methods exist to estimate monetary value

- Market Price - ***Estimates value for ecosystem products or services that are bought and sold in commercial markets.***
- Travel Cost - ***How much are people willing to pay to travel to a destination for recreational purposes?***
- Contingent Valuation – ***How much are you willing to pay for an environmental service?***
- Damage Cost Avoided, Replacement Cost, and Substitute Cost - ***How much would it cost to replicate manually what the ecosystem service does for us?***

Criticism

Monetary values make conservation reliant on markets that fluctuate

It assumes all ecosystem services are financially beneficial to people

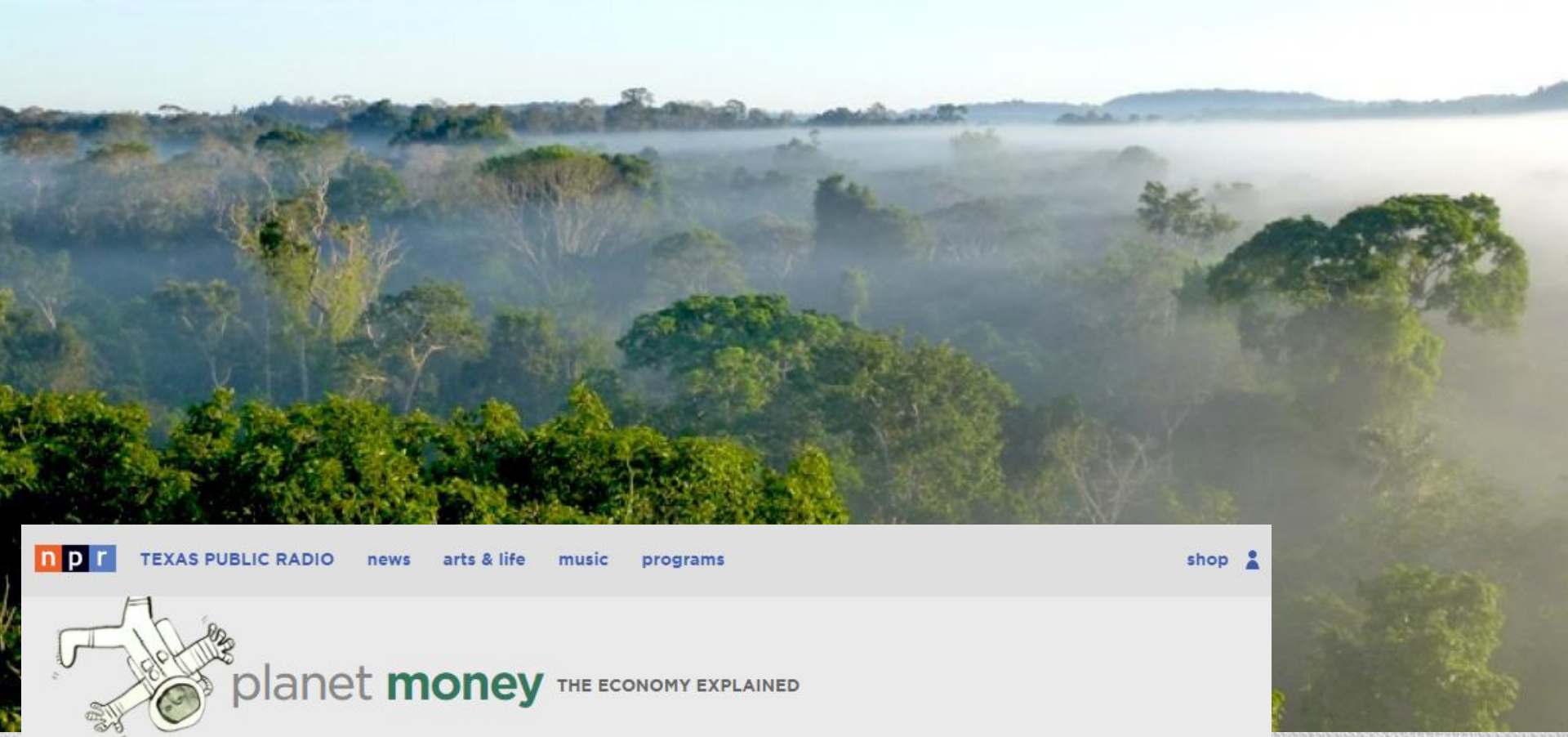
Wolves taking cattle, wolves critical in regulating prey populations

If we always put things into the context of economic welfare, officials and the public will opt for policy that promises economic growth and more jobs

Morality and ethics should be driving force behind conservation and environmentalism

Assumptions: the process of valuation

- When asking Willingness To Pay we assume that people:
  - Hold values in advance or can easily generate them
  - Have sufficient information and understanding of what they are valuing
  - Can decide (alone) on the values they attribute to ecosystems
  - Value consistently
  - Value according to individual rationality



planet money THE ECONOMY EXPLAINED

RADIO

Ecuador To World: Pay Up To Save The Rainforest. World To Ecuador: Meh.

4:13

+ Queue

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September 2, 2013 · 3:21 AM ET

Heard on Morning Edition

DAVID KESTENBAUM

Stored carbon value for Coalition for Rainforest Nations

All figures come from the latest Food and Agriculture Organization of the United Nations data.

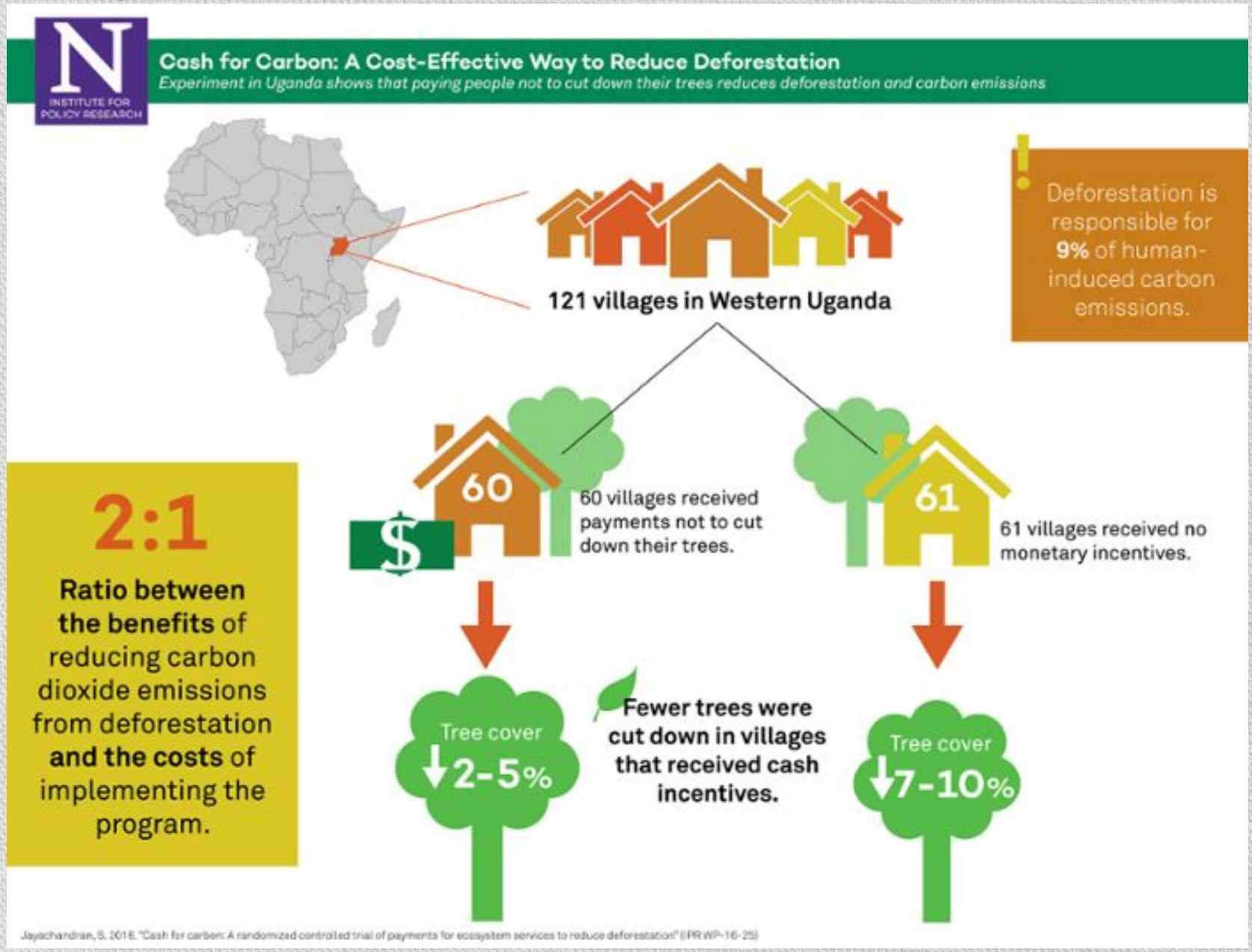
Country	Total forest area 2005		Change in forest 00-05*	Primary forest cover 2005	Change in primary forest 00-05	Total forest carbon 2005*	Value of carbon*
	1000 ha	land area	percent	1000 ha	percent	M tons	$million
Bolivia	58,740	54.2%	-2.2%	29,360	-2.3%	5,877	$117,540
Central African Rep.	22,755	36.5%	-0.6%	–	N/A	3,008	$60,160
Chile	16,121	21.5%	-0.4%	4,142	-0.1%	3,232	$64,640
Congo	22,471	65.8%	0.6%	7,464	-0.4%	5,181	$103,620
Costa Rica	2,391	46.8%	1.8%	180	0.0%	214	$4,280
D.R. Congo	133,610	58.9%	-1.2%	–	N/A	32,152	$643,040
Dominican Rep.	1,376	28.4%	0.0%	–	N/A	94	$1,880
Guatemala	3,938	36.3%	-6.4%	1,957	-6.4%	572	$11,440
Nicaragua	5,189	42.7%	-6.3%	1,849	N/A	795	$15,900
Papua New Guinea	29,437	65.0%	-2.3%	25,211	-4.7%	4,710	$94,200
Total	296,028		-1.4%			55,835	$1,116,700

* Total change in forest, 00-05 — negative numbers represent deforestation, positive numbers reflect the growth of plantations and secondary forests.

* Total forest carbon, 2005 — Includes carbon stored in above-ground biomass, below-ground biomass, dead wood, leaf litter, and soils of forests.

* Value of carbon — Figures assume a rate of $20 per ton

Money Talks



http://www.ipr.northwestern.edu/about/news/2017/infographic-jayachandran-deforestation.html

If you add it all up…

1997 Study

The entire biosphere

- a minimum of
  $33 trillion/yr

- Global Gross National Product is
  $18 trillion/yr

ELSEVIER

Ecological Economics 25 (1998) 3–15

ECOLOGICAL ECONOMICS

The value of the world's ecosystem services and natural capital[1]

Robert Costanza [a,b,*], Ralph d'Arge [c], Rudolf de Groot [d], Stephen Farber [e], Monica Grasso [b], Bruce Hannon [f], Karin Limburg [g], Shahid Naeem [h], Robert V. O'Neill [i], Jose Paruelo [j], Robert G. Raskin [k], Paul Sutton [l], Marjan van den Belt [m]

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Abstract

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Ecological systems; Capital stocks; Ecosystem services

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PII S0921-8009(98)00020-2

2011 Study

The entire biosphere

- a minimum of
  $125 trillion/yr

Global Environmental Change 26 (2014) 152–158

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journal homepage: www.elsevier.com/locate/gloenvcha

Changes in the global value of ecosystem services

Robert Costanza [a,*], Rudolf de Groot [b], Paul Sutton [c,d], Sander van der Ploeg [b], Sharolyn J. Anderson [d], Ida Kubiszewski [a], Stephen Farber [e], R. Kerry Turner [f]

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ABSTRACT

In 1997, the global value of ecosystem services was estimated to average $33 trillion/yr in 1995 $US ($46 trillion/yr in 2007 $US). In this paper, we provide an updated estimate based on updated unit ecosystem service values and land use change estimates between 1997 and 2011. We also address some of the critiques of the 1997 paper. Using the same methods as in the 1997 paper but with updated data, the estimate for the total global ecosystem services in 2011 is $125 trillion/yr (assuming updated unit values and changes to biome areas) and $145 trillion/yr (assuming only unit values changed), both in 2007 $US. From this we estimated the loss of eco-services from 1997 to 2011 due to land use change at $4.3–20.2 trillion/yr, depending on which unit values are used. Global estimates expressed in monetary accounting units, such as this, are useful to highlight the magnitude of eco-services, but have no specific decision-making context. However, the underlying data and models can be applied at multiple scales to assess changes resulting from various scenarios and policies. We emphasize that valuation of eco-services (in whatever units) is not the same as commodification or privatization. Many eco-services are best considered public goods or common pool resources, so conventional markets are often not the best institutional frameworks to manage them. However, these services must be (and are being) valued, and we need new, common asset institutions to better take these values into account.

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1. Introduction

Ecosystems provide a range of services that are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et al., 1997; Millennium Ecosystem Assessment (MEA), 2005; TEEB Foundations, 2010; TEEB Synthesis, 2010). Interest in ecosystem services in both the research and policy communities has grown rapidly (Braat and de Groot, 2012; Costanza and Kubiszewski, 2012). In 1997, the value of global ecosystem services was estimated to be around US$ 33 trillion per year (in 1995 $US), a figure significantly larger than global gross domestic product (GDP) at the time. This admittedly crude underestimate of the welfare benefits of natural capital, and a few other early studies (Daily, 1997; de Groot, 1987; Ehrlich and Ehrlich, 1981; Ehrlich and Mooney, 1983; Odum, 1971; Westman, 1977) stimulated a huge surge in interest in this topic.

In 2005, the concept of ecosystem services gained broader attention when the United Nations published its Millennium Ecosystem Assessment (MEA). The MEA was a four-year, 1300-scientist study for policymakers. Between 2007 and 2010, a second international initiative was undertaken by the UN Environment Programme, called the Economics of Ecosystems and Biodiversity (TEEB) (TEEB Foundations, 2010). The TEEB report was picked up extensively by the mass media, bringing ecosystem services to a broader audience. Ecosystem services have now also entered the consciousness of mainstream media and business. The World Business Council for Sustainable Development has actively supported and developed the concept (WBCSD, 2011, 2012). Hundreds of projects and groups are currently working toward

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Biome	Unit values 2007$/ha/yr		Change
	1997	2011	2011-1997
Marine	796	1,368	572
Open Ocean	348	660	312
Coastal	5,592	8,944	3,352
* Estuaries	31,509	28,916	-2,593
* Seagrass/Algae Beds	26,226	28,916	2,690
* Coral Reefs	8,384	352,249	343,865
Shelf	2,222	2,222	0
Terrestrial	1,109	4,901	3,792
Forest	1,338	3,800	2,462
Tropical	2,769	5,382	2,613
Temperate/Boreal	417	3,137	2,720
Grass/Rangelands	321	4,166	3,845
* **Wetlands**	20,404	140,174	119,770
* Tidal Marsh/Mangroves	13,786	193,843	180,057
Swamps/Floodplains	27,021	25,681	-1,340
Lakes/Rivers	11,727	12,512	785
Desert	-	-	0
Tundra	-	-	0
Ice/Rock	-	-	0
Cropland	126	5,567	5,441
Urban	-	6,661	6,661

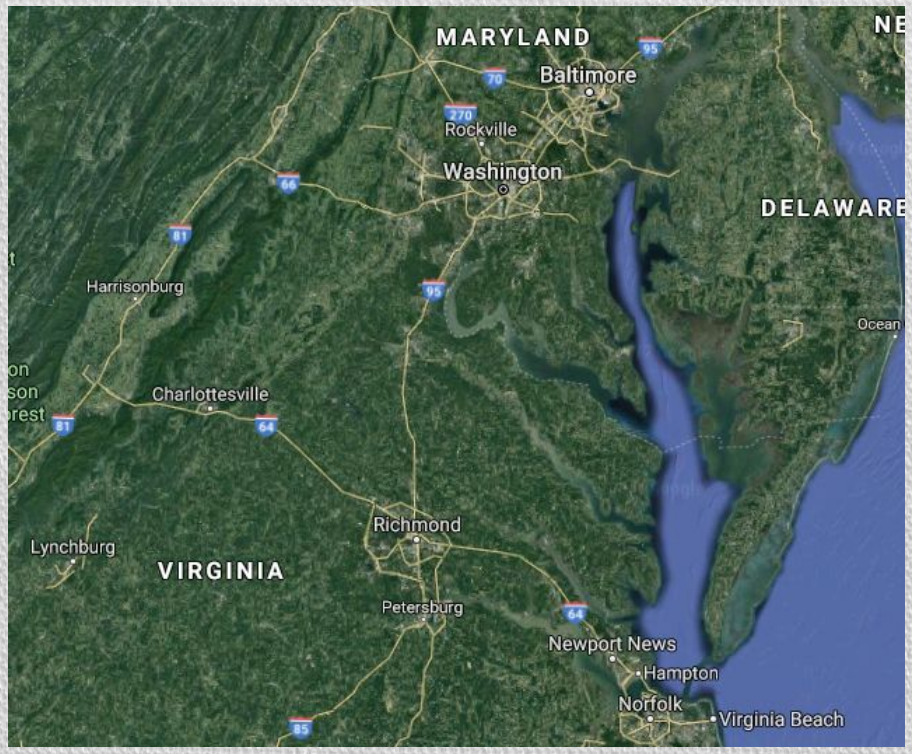
CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

About CBF • About the Bay • The Issues

Home > Issues > What We Have to Lose

What We Have to Lose

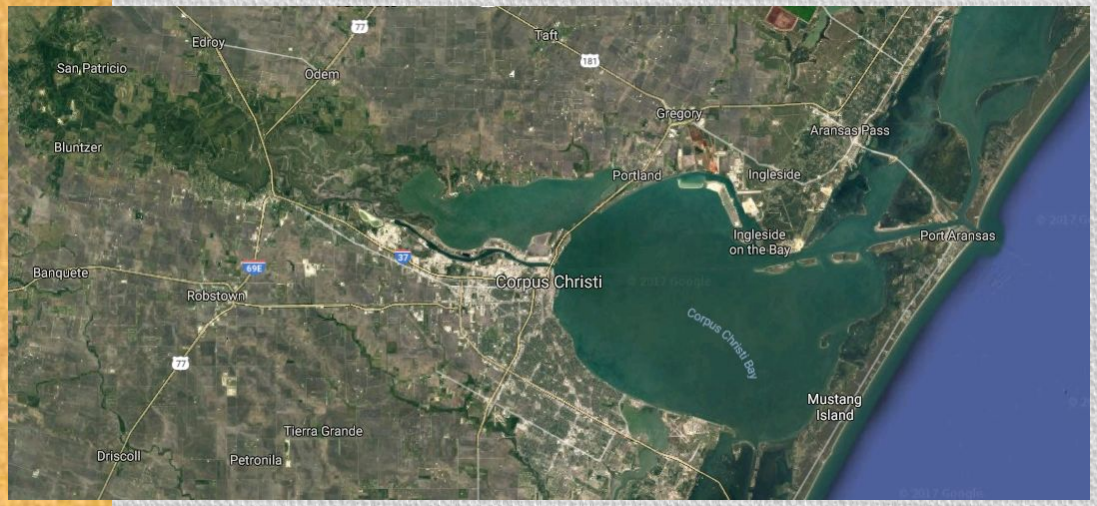
Saving the Bay is Worth the Investment



Commercial Seafood industry in MD, VA

- $3.9 billion in sales
- $890 million in income
- 34,000 jobs

Clean Water Act (1972) is estimated to have benefited the Chesapeake Bay by $357.9 million to $1.8 billion for recreational boating, fishing, and swimming alone.



Nature and wildlife tourist activities

- $674 million annually – over 50% of overall visitor spending

12,914 jobs

stedc.tamucc.edu/files/Tourism_2014.pdf

VULTURES CLEAN UP CARCASSES

WITH VULTURES › ONE HOUR
They clean carcasses bare
before disease spores can form

WITHOUT VULTURES › A FEW DAYS
They reduce the spread of diseases like Anthrax,
Rabies, Tuberculosis, Botulism, Brucellosis

Diclofenac caused renal failure and death (up to 99.9% decline in vulture species)

Feral dogs filled niche = rabies ↑

VULTURES ARE WORTH MILLIONS

A single vulture is worth over US **$ 11,000** dollars just for its cleaning services.
By halting the spread of disease, they are worth much, much more to governments in saved health service costs, not to mention tourism, etc.

CMS

BirdLife INTERNATIONAL

VULTURE Specialist Group

We don’t see the Value of an Ecosystem Service until it stops

CORNELL CHRONICLE

Insect pollinators contribute $29 billion to U.S. farm income

By Krishna Ramanujan | May 22, 2012

66% from honeybee ($19.14 million)

Begins to become a national security issue!

2013 government shut down (16 days)

cost $ 500 million in lost revenue from tourism alone ($31.25 million/day)

Assuming the same rate lost/day this 3 day shut lost $93.75 million

Not to mention disruption to scientific research!

Bracken Bat Cave
San Antonio, Tx

Saves south Texan cotton farmers $740,000 per year

Worth $3.7 billion in U.S. in reduced crop damage and pesticide use

- Bat Conservation International

Alamo Forest Partnership

Animation showing tree canopy loss in Bexar County, 1985-2001. City limits are outlined in red

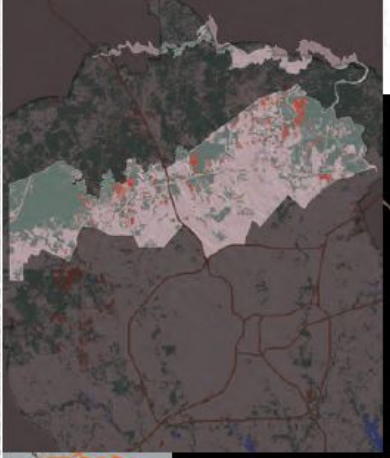
Animation showing tree canopy loss in Bexar County, 1985-2001. City limits are outlined in red

ALAMO FOREST PARTNERSHIP

1985 – 2001 (16 year period)

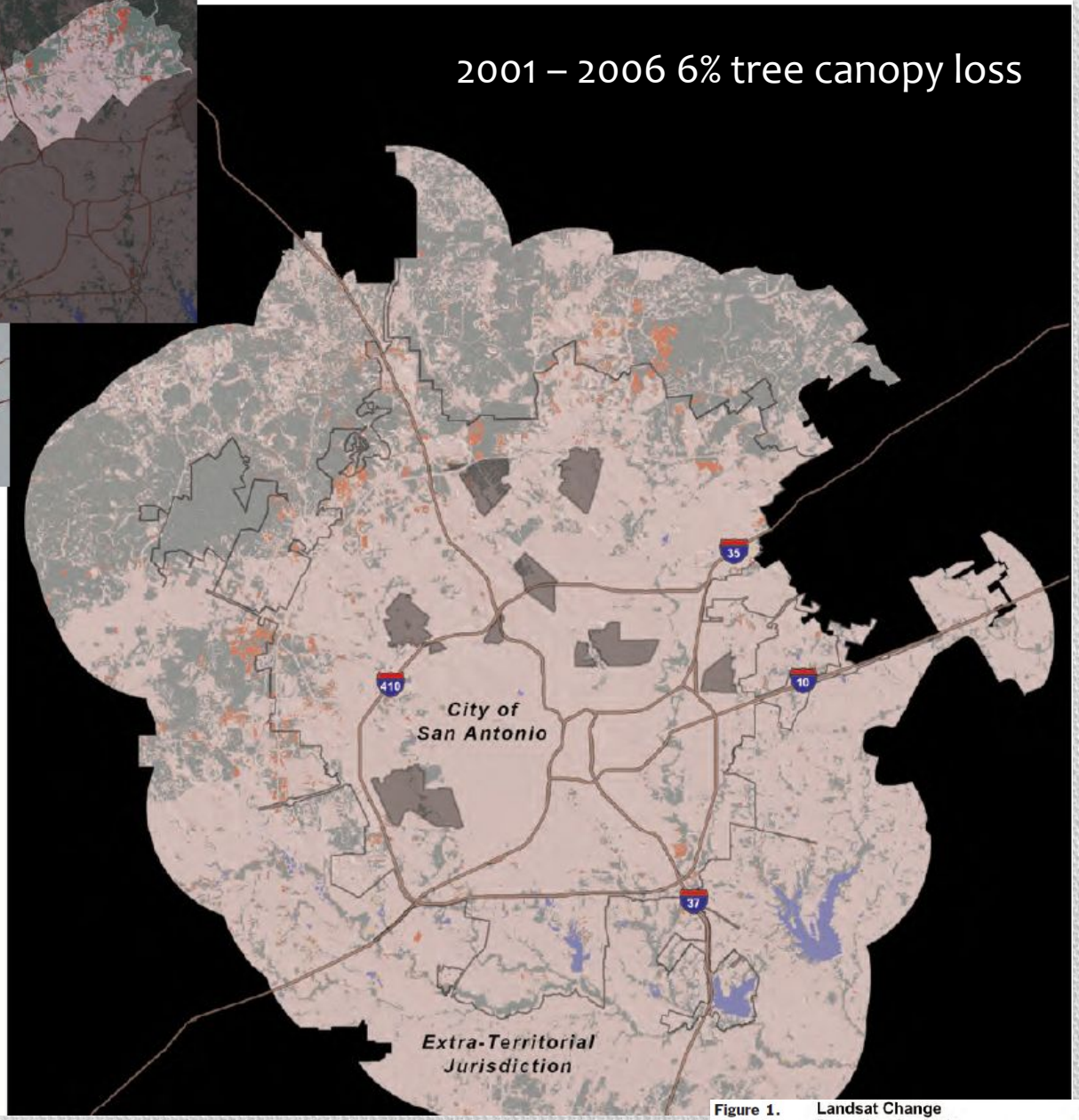
Lost 45,000 acres of heavy tree canopy (22% of dense forest)
potential for 3.7 million pounds of pollutants (value of $8.9 million/yr)

storm water flow increased by an estimated 73 million cubic feet
est $2/cubic foot to build a storm water system to mitigate that's a cost of $146 million



Edwards Aquifer Recharge and Transition Zone

2001 – 2006 6% tree canopy loss



Forest Loss (2001-2006)
Forest Gain (2001-2006)
Forest (No Change)
Water

Figure 1. **Landsat Change Detection Analysis**
Tree Canopy Loss/Gain 2001-2006
City of San Antonio and Extra-Territorial Jurisdiction

0 3 6 Miles

Change detection performed using 30-meter pixel resolution Landsat imagery from 2001 and 2006.

Sources: American Forests, U.S. Geological Survey, City of San Antonio

Forest Loss (2001-2006)
Forest Gain (2001-2006)
Forest (No Change)
Water

American Forests

ALAMO FOREST PARTNERSHIP

Table 2. San Antonio Change in Ecosystem Services as Measured with Landsat Data*

2001-2006	Tree Canopy Change	Loss of Air Pollution Removal	Loss of Air Pollution Removal Value	Loss in Stormwater Value	Loss in Stormwater Value @ $.64/cu ft.
	acres	lbs./yr	dollar value	cu. ft.	dollar value
ETJ	-2,632	-295,714	-$704,327	-93,036,121	-$59,543,117
COSA	-1,833	-205,968	-$490,572	-57,957,865	-$37,093,034
EARZ	-3,207	-360,132	-$857,757	-40,652,214	-$26,017,417

Modified table and text excerpts from http://www.alamoforestpartnership.org/urban-ecosystem-analyses/

Incentives

Choose from 2 options to get your 50-gallon

SAWS Rain Barrel

Distribution Event
Limit 1 Rain Barrel

Retail Store
Limit 2 Rain Barrels

MAXIMUM 2 RAIN BARREL COUPONS PER SAWS RESIDENTIAL ACCOUNT

* SUBJECT TO CHANGE BY RETAILER.

Notable Policies in San Antonio that protect ecosystem services

Edwards Aquifer Protection Program – City of San Antonio

Voter approved

1/8th of a cent addition to local sales tax to purchase sensitive properties over EA

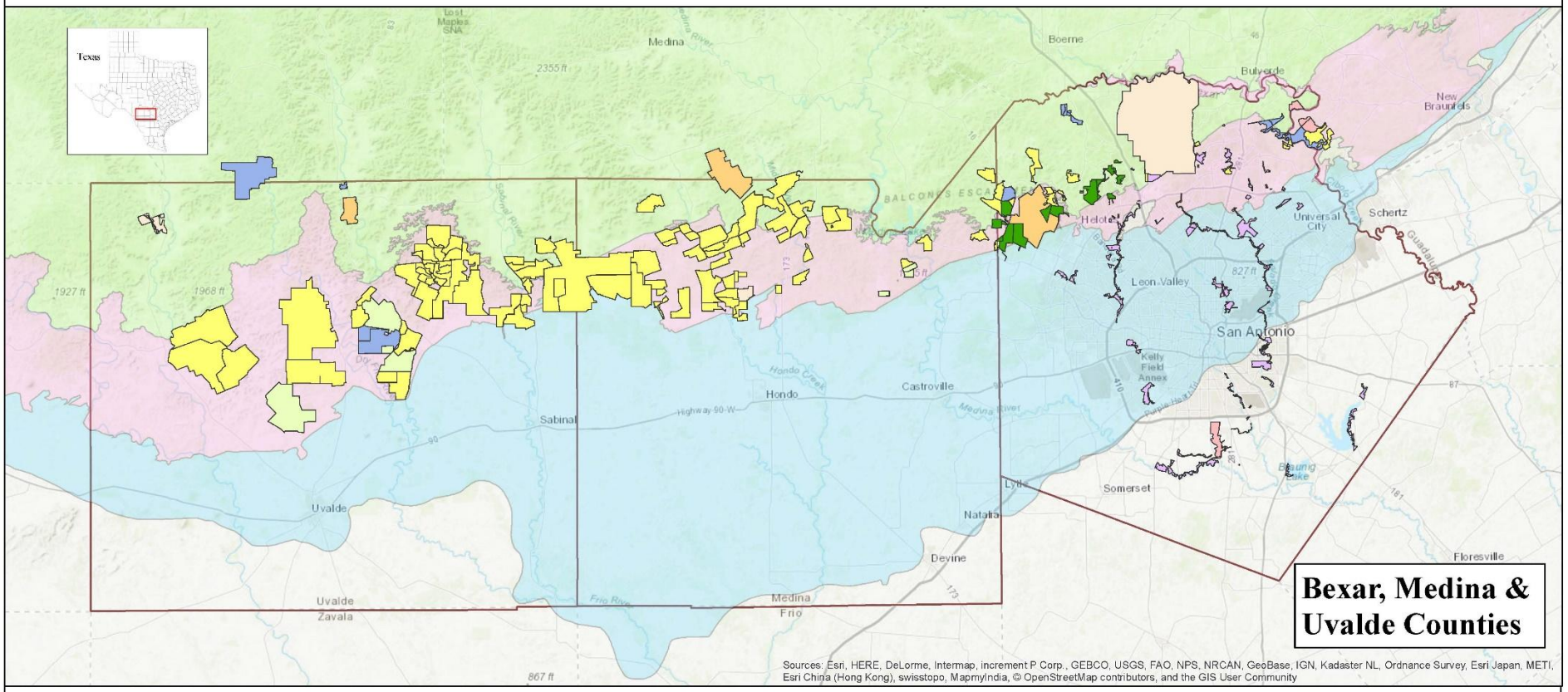
- Proposition 3 (2000) $45 million
- Proposition 1 (2005, 2010, 2015) $280 million

GRAND TOTAL: 160,330 acres

City of San Antonio
Edwards Aquifer Protection Program

CITY OF SAN ANTONIO
EDWARDS AQUIFER
PROTECTION PROGRAM

PARKS & RECREATION
SAN ANTONIO



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

- Proposition 3 Properties
- Proposition 1 Properties
- City Parks
- Federal Managed Land
- San Antonio Water System
- Texas Parks and Wildlife
- The Nature Conservancy
- Conservation Land
- Edwards Aquifer Drainage Zone
- Edwards Aquifer Recharge Zone
- Edwards Aquifer Artesian Zone

0 5 10 20 30 40 Miles

N W E S

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Notable Policies and initiatives in San Antonio that protect ecosystem services

- City of San Antonio - Tree Preservation Ordinance
- Edwards Aquifer Authority Act (1993) passed in Texas Legislature
- San Antonio River Improvements Project

Ecosystem Services
Urban Parks and City Trees

- Carbon Removal
- Soil Conservation
- Wildlife habitat
- Water control
- Air quality

- Health benefits
- Community enrichment
- Real estate values
- Business benefits
- Noise reduction

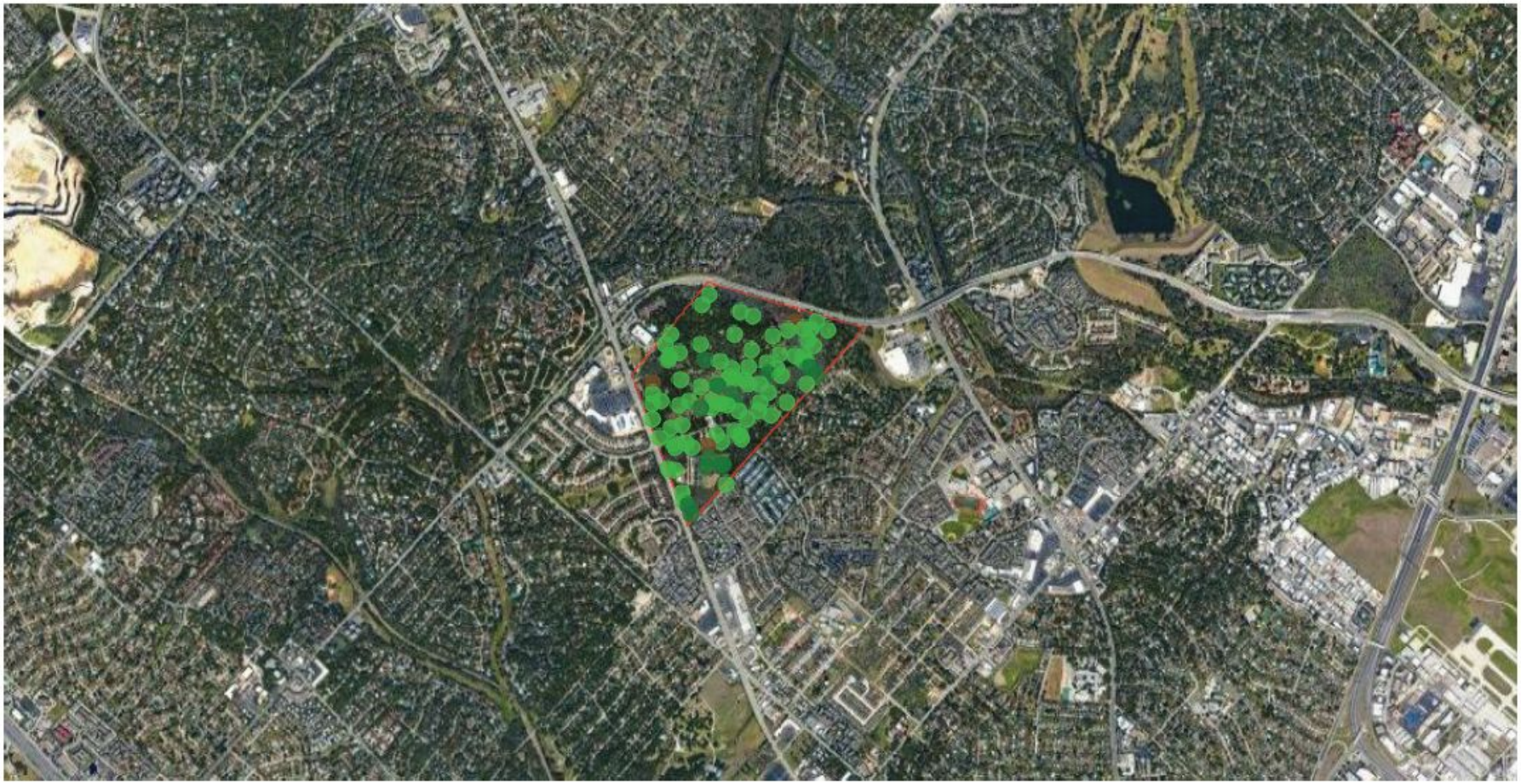
HOWARD W. PEAK GREENWAY TRAILS SYSTEM PLAN

CITY OF SAN ANTONIO

i-Tree Canopy v7.0

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 8/11/2020



Tree Benefit Estimates: Carbon (English units)

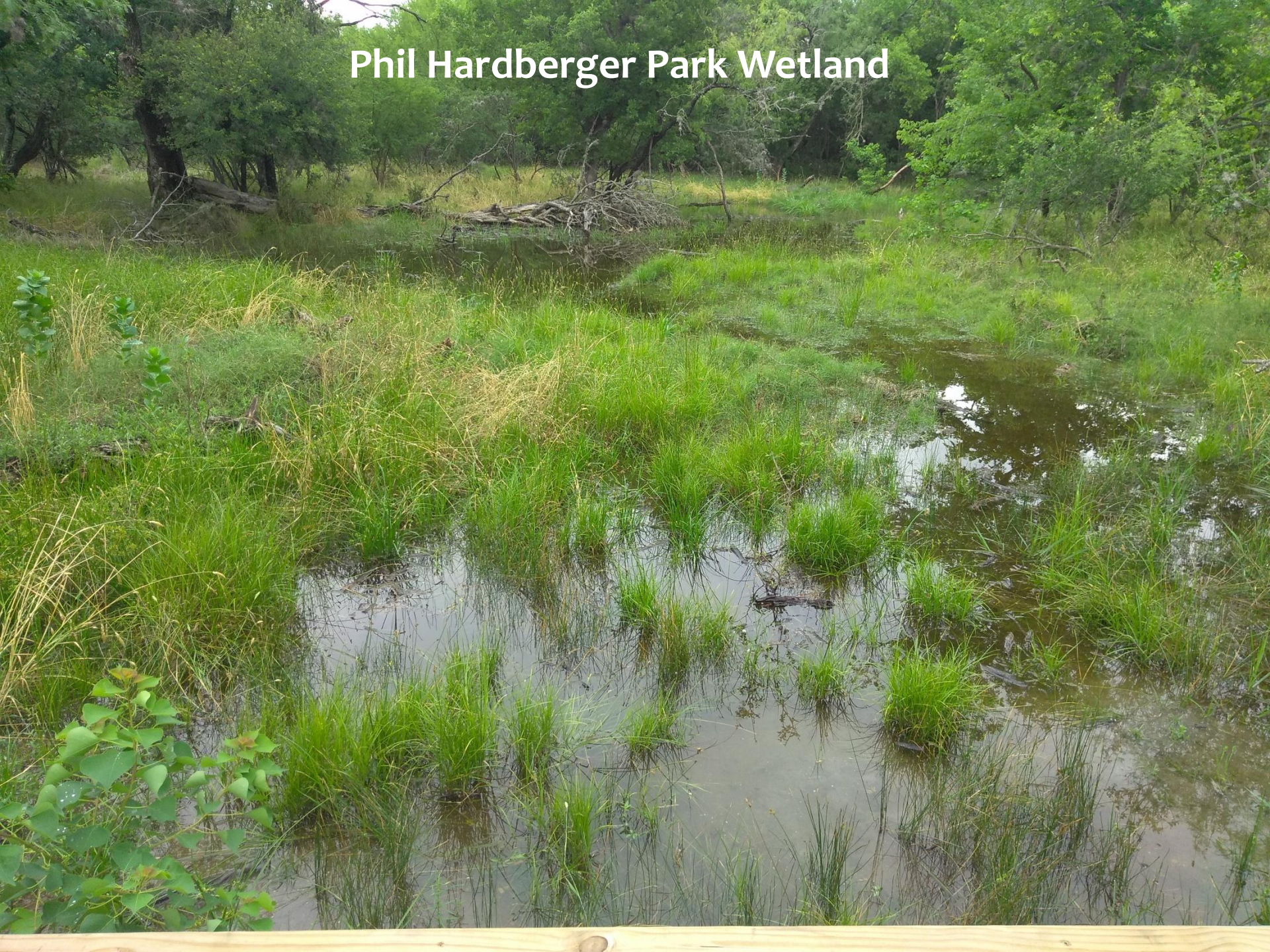
Description	Carbon (T)	±SE	CO_2 Equiv. (T)	±SE	Value (USD)	±SE
Sequestered annually in trees	227.38	±11.42	833.74	±41.89	$38,781	±1,949
Stored in trees (Note: this benefit is not an annual rate)	5,710.47	±286.92	20,938.38	±1,052.04	$973,924	±48,934

Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Amount sequestered is based on 1.365 T of Carbon, or 5.005 T of CO_2, per ac/yr and rounded. Amount stored is based on 34.281 T of Carbon, or 125.697 T of CO_2, per ac and rounded. Value (USD) is based on $170.55/T of Carbon, or $46.51/T of CO_2 and rounded. (English units: T = tons (2,000 pounds), ac = acres)

Tree Benefit Estimates: Air Pollution (English units)

Abbr.	Description	Amount (lb)	±SE	Value (USD)	±SE
CO	Carbon Monoxide removed annually	150.20	±7.55	$6	±0
NO2	Nitrogen Dioxide removed annually	819.01	±41.15	$11	±1
O3	Ozone removed annually	8,157.02	±409.85	$573	±29
SO2	Sulfur Dioxide removed annually	516.12	±25.93	$2	±0
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	2,732.30	±137.28	$416	±21
PM2.5	Particulate Matter less than 2.5 microns removed annually	396.36	±19.92	$1,184	±60
Total		**12,771.03**	**±641.67**	**$2,192**	**±110**

Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Air Pollution Estimates are based on these values in lb/ac/yr @ $/lb/yr and rounded:
CO 0.902 @ $0.04 | NO2 4.917 @ $0.01 | O3 48.968 @ $0.07 | SO2 3.098 @ $0.00 | PM10* 16.403 @ $0.15 | PM2.5 2.379 @ $2.99 (English units: lb = pounds, ac = acres)


Phil Hardberger Park Wetland

“These things [species] count, whether or not there is anybody to do the counting”

– Holmes Rolston III
Philosopher and theologian who pioneered the field of environmental ethics and environmental philosophy

University Distinguished Professor
Department of Philosophy
Colorado State University

Resources

- teebweb.org
- Millenniumassessment.org

- http://www.aboutvalues.net/case_studies/
- http://www.wbrcouncil.org/Departments/Mosquito-Abatement/Natural-Mosquito-Killers
- http://www.habitat.noaa.gov/abouthabitat/ecosystemservices.html
- https://www.greenfacts.org/en/biodiversity/figtableboxes/3011-ecological-surprises.htm
- https://www.allaboutbirds.org/analysis-the-economic-value-of-birds/
- iTreetools.org
- http://www.ecosystemvaluation.org/dollar_based.htm
- https://www.vox.com/2015/4/7/8352381/anthropocene-NASA-images
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- Morgan, et al. 2001. Benefits of water quality policies: the Chesapeake Bay, *Ecological Economics*, Volume 39, Issue 2, November 2001, pp. 271-284.
- http://www.globalvaluexchange.org/valuations/8279e41d9e5e0bd8499f5956
- https://news.mongabay.com/2005/11/developing-countries-pay-us-to-save-rainforests/