National Ecosystem Services Partnership

Methods for Incorporating Ecosystem Services into Decision-Making

ACES Workshop December 2016

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FOR ENVIRONMENTAL POLICY SOLUTIONS

National Ecosystem Services Partnership
Federal Resource Management and Ecosystem Services Project

"Using an ecosystem services perspective is like moving from black and white to full spectrum color in terms of the richness of the analysis and the ability to communicate it to the public."

John Allen, Deschutes National Forest Supervisor

National Ecosystem Services Partnership (NESP)

NESP engages both public and private individuals and organizations to enhance collaboration within the ecosystem services community and to strengthen coordination of policy, market implementation, and research at the national level

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NESP

- Quarterly newsletter
- Community of practice **email list** and **webinars**
- FRMES Online guidebook
  - nespguidebook.com
- Best Practice Guidance
- Policy and Methods Papers
- Workshops

www.nicholasinstitute.duke.edu/nesp

Time	Topic	Presenter
8:00-8:15	Welcome and Introductions	
8:15-9:00	Overview and Introduction to NESP Guidebook and Best Practices	Lydia Olander
9:00-10:00	Causal Chains, Conceptual Diagrams, Classification Systems and Human Well-Being Endpoints	Lydia Olander
10:00 -10:30	BREAK (ACES 10am-10:30am)	
10:30- 11:30	EXERCISE: Developing Conceptual Diagrams	Everyone
11:30-12:00	Ecological Production Functions	Robert Johnston
12:00-1:30	LUNCH (ACES 12-1:30pm)	
1:30-2:30	Quantifying Benefit Relevant Indicators Including Social Context Information	Lisa Wainger
2:30-3:15	EXERCISE: Developing Benefit Relevant Indicators	Lisa Wainger/ Everyone
3:15-3:30	BREAK (ACES 3:00-3:30pm)	
3:30-4:45	Valuation (Benefits Assessments) – Incorporating Preferences	Rob Johnston
4:45-5:00	Wrap-Up and Q&A Includes survey of participants	Lydia Olander

Workshop Leaders

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National Ecosystem Services Partnership
Nicholas Institute for Environmental Policy Solutions
Duke University

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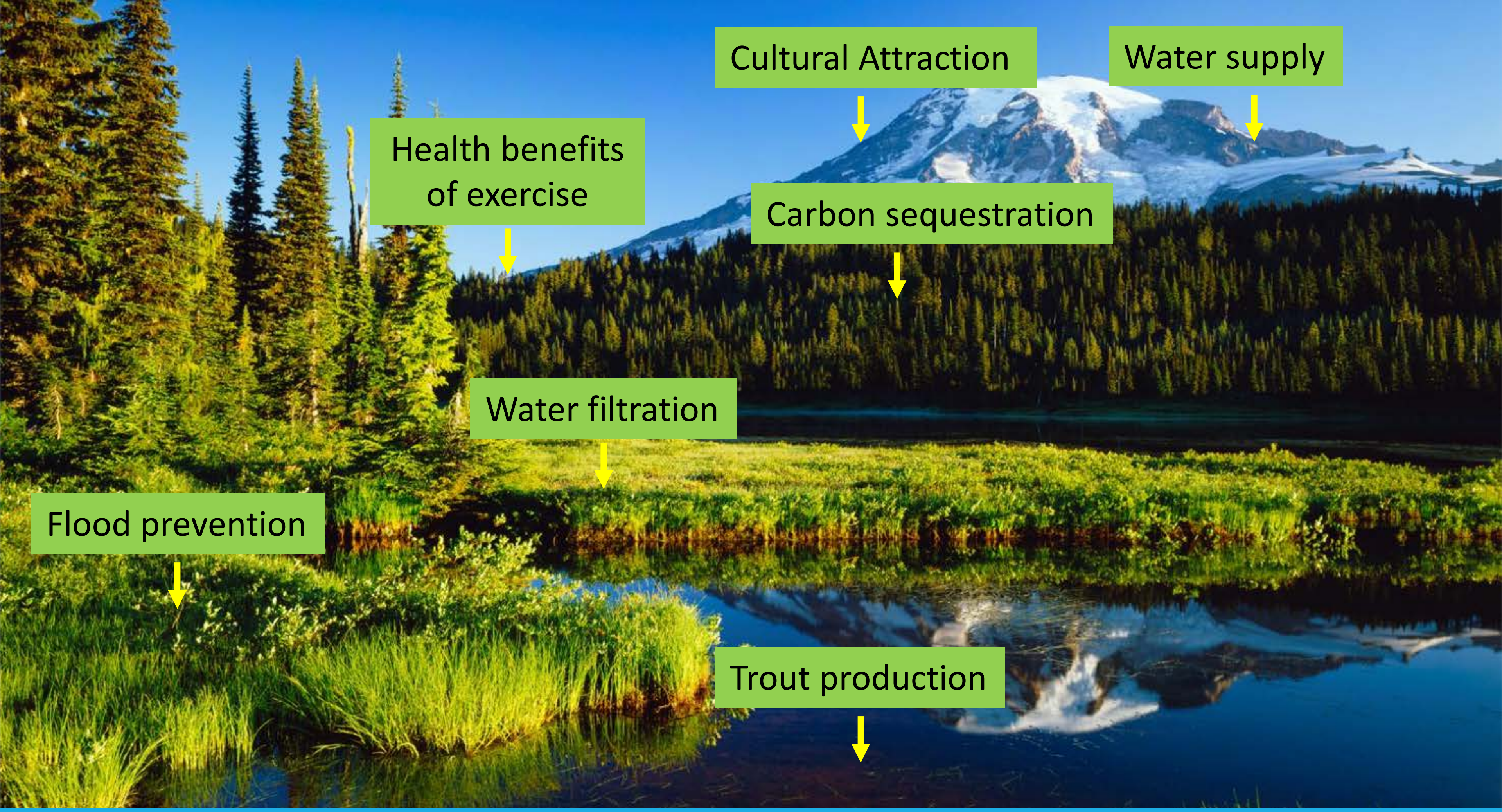
Ecosystem Services Program
Nicholas Institute for Environmental Policy Solutions
Duke University

Lisa Wainger, PhD
Research Professor
University of Maryland Center for Environmental Science

Rob Johnston, PhD
Professor of Economics
Department of Economics
Director and Research Professor
The George Perkins Marsh Institute
Clark University



Introduction to NESP guidebook and Best Practices for ES Assessments

National Ecosystem Services Partnership

Exciting time at the National Level…

1998 — **PCAST report** -
Teaming with Life: Investing in Science to Understand and Use America's Living Capital

2005 — Millennium Ecosystem Assessment

2008 — **Farm Bill**
Establishment of **USDA Office of Ecosystem Services and Markets**
Wetlands Compensatory Mitigation Rule

2010 — **Inter-agency dialogue** on payments and markets for ecosystem services

2011 — **PCAST Report** -
Sustaining Environmental Capital: Protecting Society and the Economy

2012 — **Forest Service Planning Rule**
International Platform on Biodiversity and Ecosystem Services

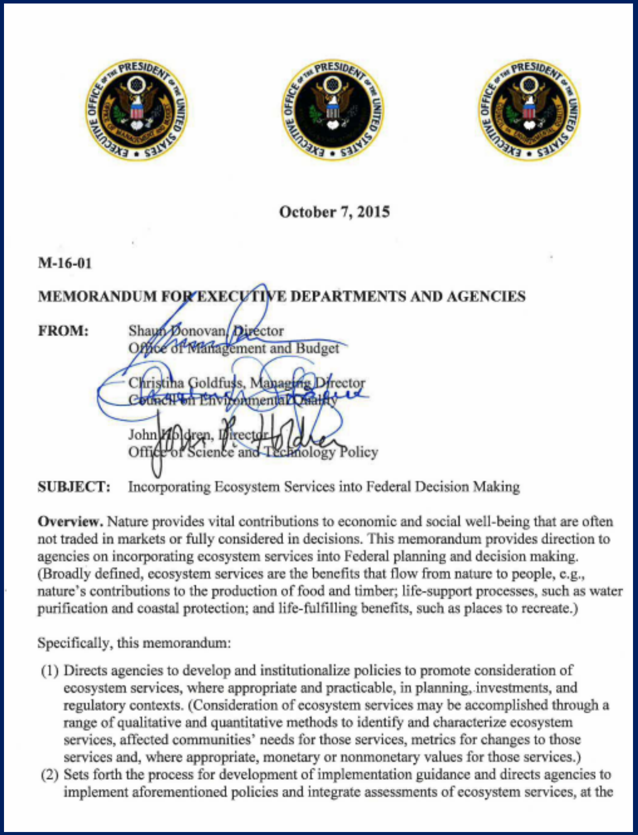
2013 — **CEQ Principles and Requirements for Federal Investments in Water Resources**
FEMA incorporate ES values into BCA

2015 — **White House Memo on integrating ES**
White House Memo on mitigating natural resource impacts
White House Research Agenda on ES and coastal green infrastructure

White House Memo: ES in Federal Decision Making

White House memorandum calling on Federal agencies to incorporate ecosystem services into Federal decision making requests:

- a description of **current agency practice and work plans** to be submitted to the Council on Environmental Quality (CEQ) no later than **March 30, 2016** and
- plans for **implementation guidance** to be developed in collaboration with the agencies by **November 30th, 2016.** (When it will be released for external review)



October 7, 2015

M-16-01

MEMORANDUM FOR EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Shaun Donovan, Director
Office of Management and Budget

Christina Goldfuss, Managing Director
Council on Environmental Quality

John Holdren, Director
Office of Science and Technology Policy

SUBJECT: Incorporating Ecosystem Services into Federal Decision Making

Overview. Nature provides vital contributions to economic and social well-being that are often not traded in markets or fully considered in decisions. This memorandum provides direction to agencies on incorporating ecosystem services into Federal planning and decision making. (Broadly defined, ecosystem services are the benefits that flow from nature to people, e.g., nature's contributions to the production of food and timber; life-support processes, such as water purification and coastal protection; and life-fulfilling benefits, such as places to recreate.)

Specifically, this memorandum:

(1) Directs agencies to develop and institutionalize policies to promote consideration of ecosystem services, where appropriate and practicable, in planning, investments, and regulatory contexts. (Consideration of ecosystem services may be accomplished through a range of qualitative and quantitative methods to identify and characterize ecosystem services, affected communities' needs for those services, metrics for changes to those services and, where appropriate, monetary or nonmonetary values for those services.)

(2) Sets forth the process for development of implementation guidance and directs agencies to implement aforementioned policies and integrate assessments of ecosystem services, at the

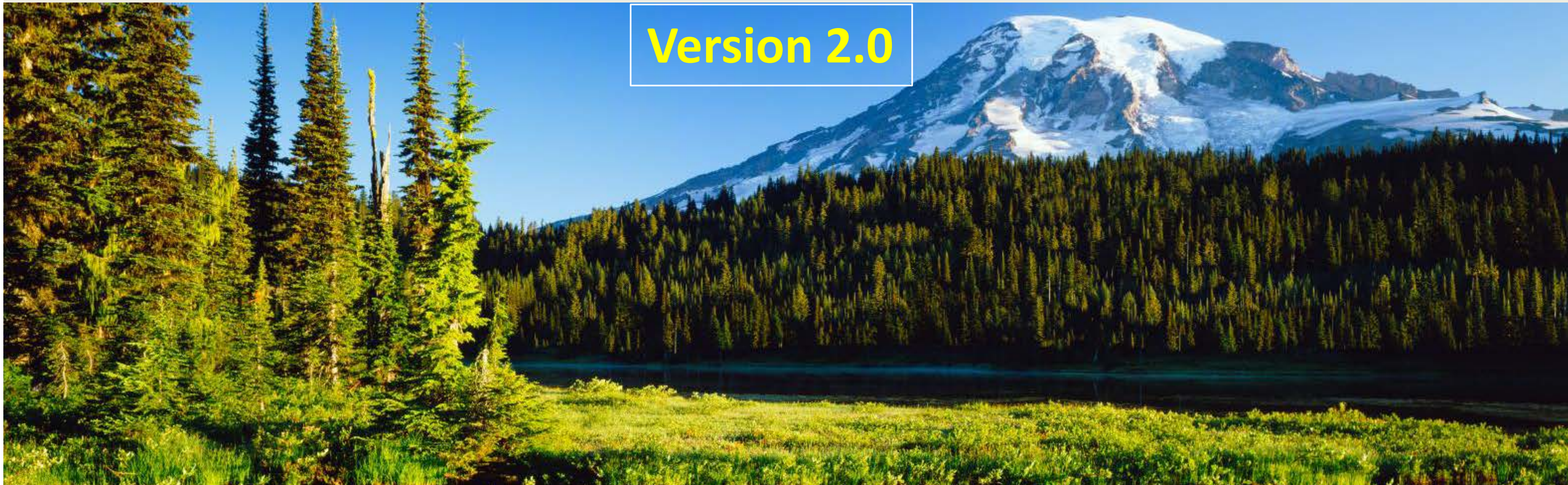
NESP


Cultural Attraction
Water supply
Health benefits of exercise
Carbon sequestration
Flood prevention
Water filtration
Trout production
Telling the full story
Improving communication
Engaging the public and new partners
Better decisions and policies

Goals of the Guidebook Project

- Help to fill the gap between concept and practice
- Educate newcomers & managers on the ground
- Shared learning across agencies
- Connect ecological and social methods for ES evaluation
- Common framework that spans decision contexts and geography
- Bring together agency and academic experts to bring credibility while remaining practical

NESPguidebook.com



Understand the Motivation for Ecosystem Services Approaches

History, definitions, benefits, limitations, FAQs

Explore Agency Use of Ecosystem Services

Agency decision contexts and examples

The Assessment Framework for Ecosystem Services

Methods for connecting ecological and social analyses

About

National Ecosystem Services Partnership Federal Resource Management and Ecosystem Services Project

v1.0 - Over 175 People Engaged

Project Leads

Lydia Olander, Dean Urban, Tim Profeta *(Duke University)*
Lynn Scarlett *(The Nature Conservancy)*
Jim Boyd *(Resources for the Future)*
Sally Collins *(Consultant, Formerly USFS and USDA OEM)*

Funders

Gordon and Betty Moore Foundation
National Center for Ecological Analysis and Synthesis
National Socio-Environmental Synthesis Center
Duke University
USDA Office of Environmental Markets
Seed funding from several agencies

Universities & Consultants

Clark University
Colorado State University
Duke University
University of Maryland
Ohio University
University of Wisconsin
Vanderbilt University
The New School
Institute for Natural Resources
Parametrix
Spatial Informatics Group

Agency Partners

U.S. Forest Service
U.S. Bureau of Land Management
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Department of the Interior
U.S. Environmental Protection Agency
National Oceanic and Atmospheric Administration
U.S. Army Corps of Engineers

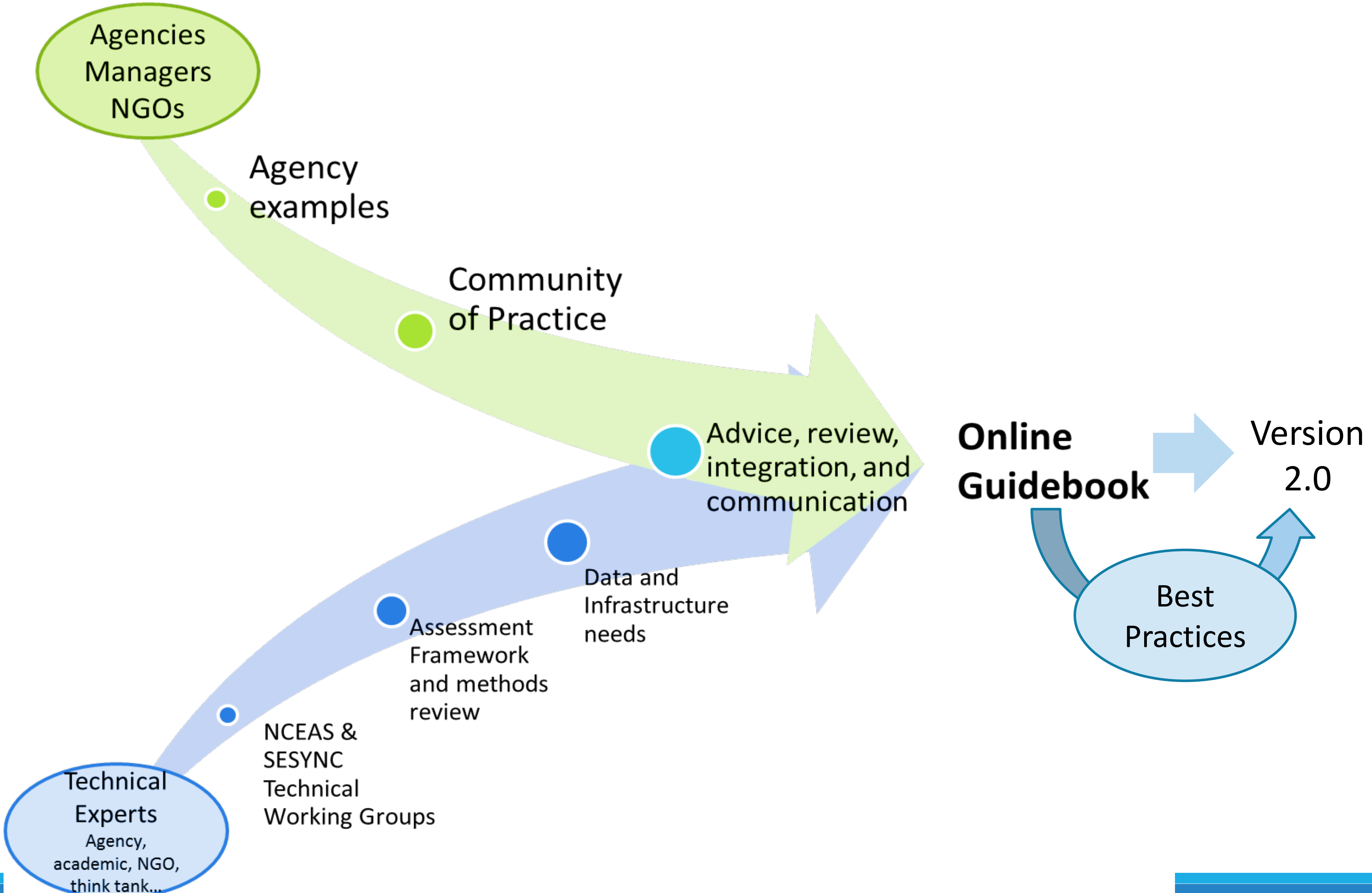
Agency Observers

Council on Environmental Quality
Office of Science and Technology Policy
Office of Management and Budget
USDA Office of Environmental Markets
U.S. Department of State

NGOs

Compass
Defenders of Wildlife
Conservation Science Partners
NatureServe
Resources for the Future
The Nature Conservancy
United Nations Environment Programme

Process

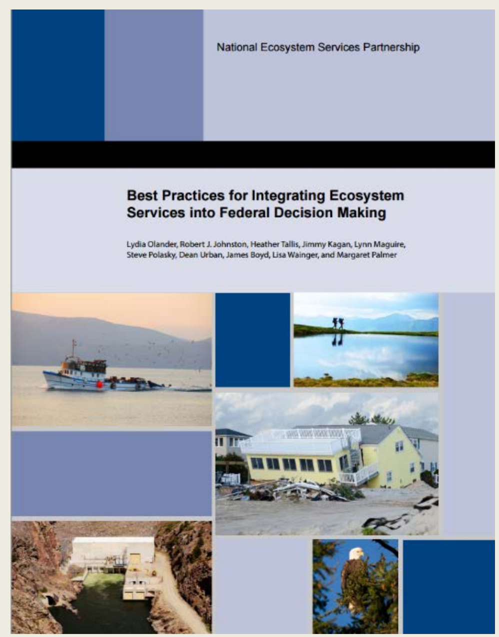


Agencies
Managers
NGOs
Agency
examples
Community
of Practice
Advice, review,
integration, and
communication
Online
Guidebook
Version
2.0
Best
Practices
Data and
Infrastructure
needs
Assessment
Framework
and methods
review
NCEAS &
SESYNC
Technical
Working Groups
Technical
Experts
Agency,
academic, NGO,
think tank…

Best Practices for Integrating Ecosystem Services into Federal Decision Making

Authors

Lydia Olander, Robert J. Johnston, Heather Tallis, Jimmy Kagan, Lynn Maguire, Steve Polasky, Dean Urban, James Boyd, Lisa Wainger, and Margaret Palmer



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Best Practices for Integrating Ecosystem Services into Federal Decision Making

Lydia Olander, Robert J. Johnston, Heather Tallis, Jimmy Kagan, Lynn Maguire, Steve Polasky, Dean Urban, James Boyd, Lisa Wainger, and Margaret Palmer

Institute for Natural Resources

Resources for the Future

Duke Nicholas Institute for Environmental Policy Solutions

The Nature Conservancy

Duke Nicholas School of the Environment

University of Minnesota Driven to Discover

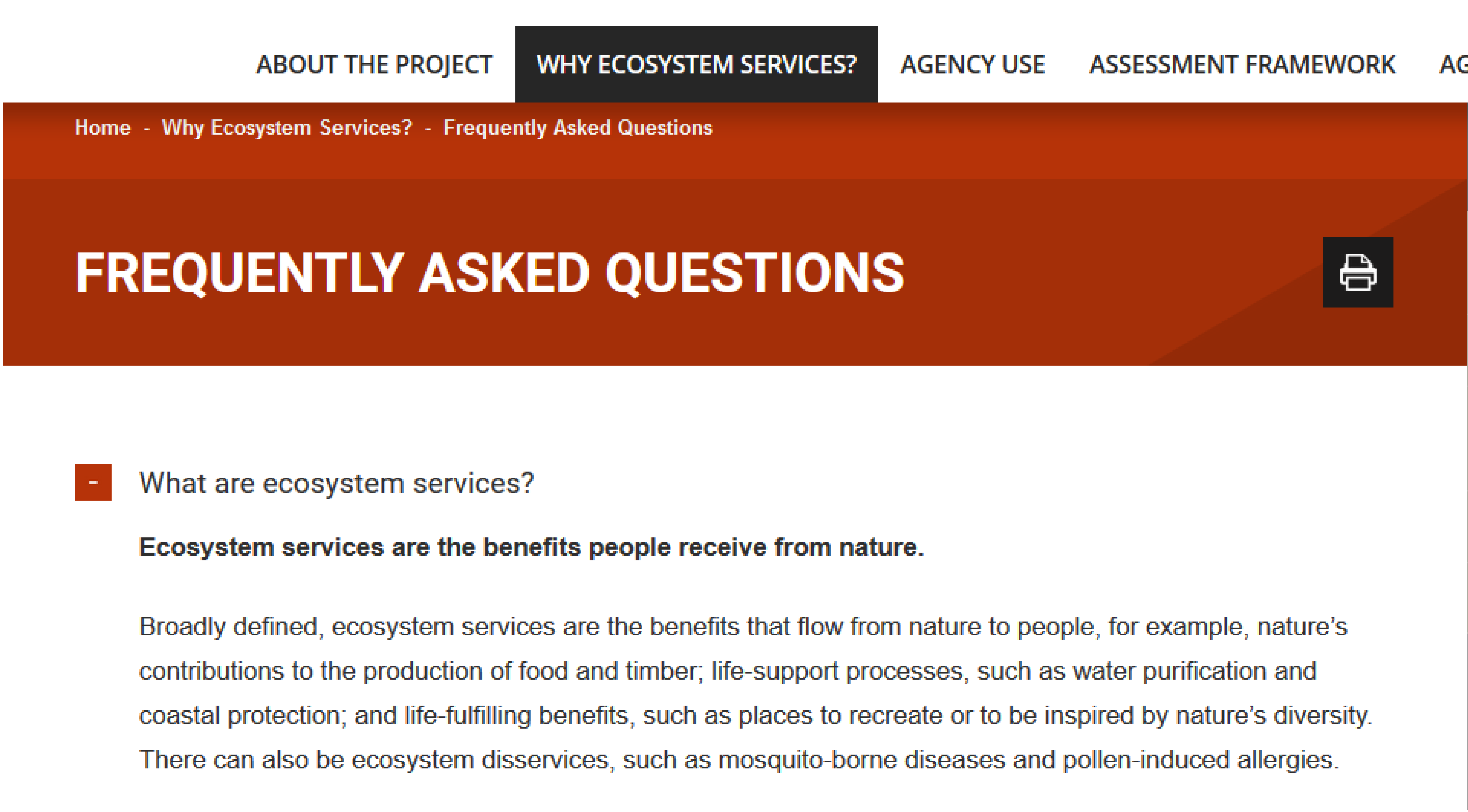
SESYNC

Clark University

University of Maryland

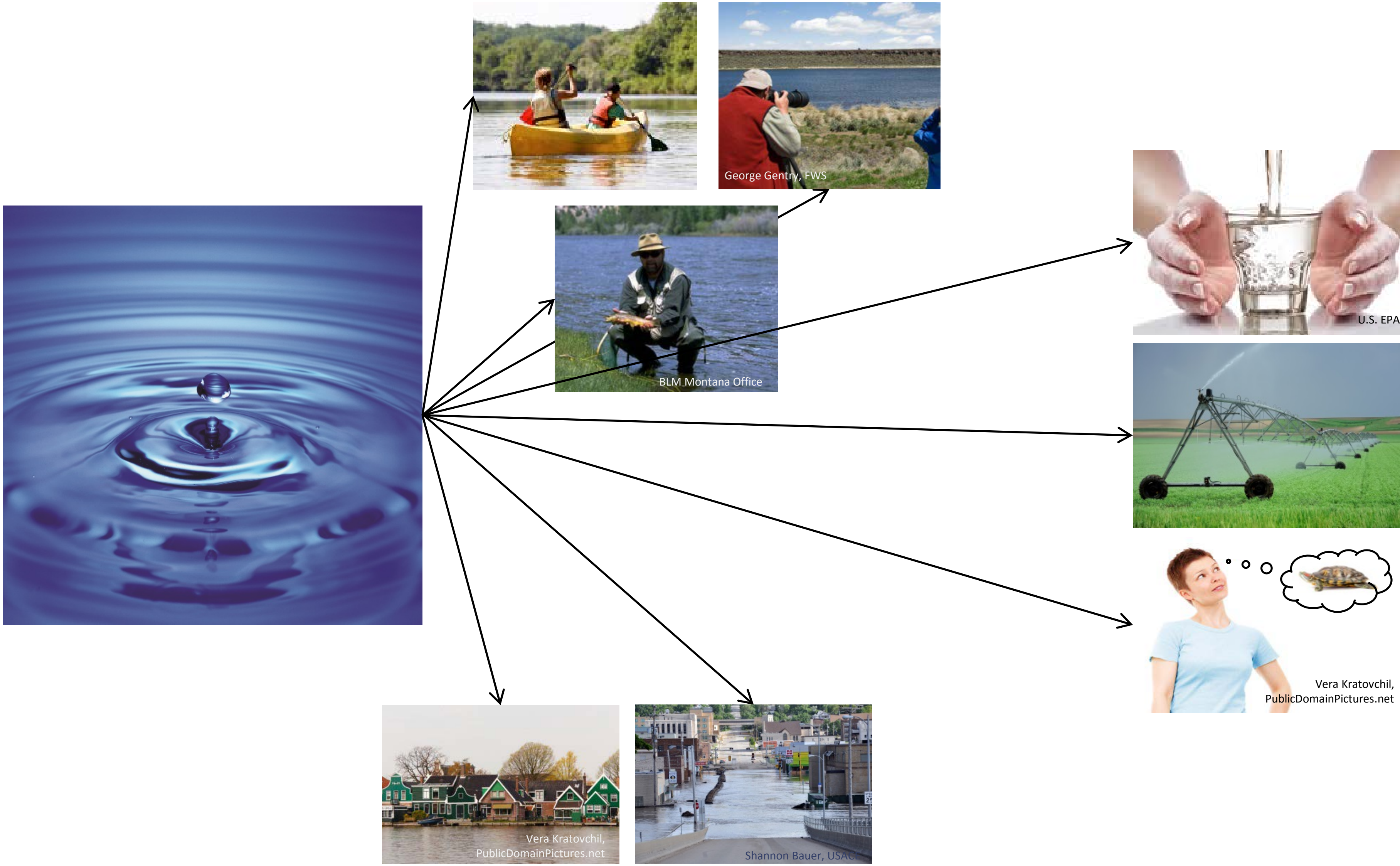
University of Maryland Center for Environmental Science

What are Ecosystem Services



What are ecosystem services related to water?

What are ecosystem services related to water?



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How can Ecosystem Services be used?

- By adding a clear (and as much as possible) quantified consideration of how changes in ecosystems affect people.

- Information on ecosystem services (the link between ecological and social systems) can be added to many different types of assessments used in decision making – risk assessment, cumulative effects analysis, benefit – cost analysis, cost-effectiveness analysis, etc..

What is an ES approach?

FREQUENTLY ASKED QUESTIONS

- What are the characteristics of a robust decision assessment that includes ecosystem services (what some call an "ES approach")?

- **Ecosystem changes are connected to changes in human well-being.** The decision (or assessment informing the decision) considers how the action will ultimately affect human well-being, through its impacts on the ecosystem.
- **All relevant ecosystem services affected by the decision are considered.** The decision (or assessment informing the decision) considers all relevant ecosystem services—that is, services important to stakeholders and expected to be significantly changed, either directly or indirectly, by the decision or management action. Because it may not be possible to conduct appropriate and high-quality analysis of all relevant services, decision makers should explain how services will be considered when they are not all incorporated into the assessment in the same manner.
- **Changes in the well-being of different stakeholders (beneficiaries) are considered and compared.** The decision (or assessment informing the decision) considers and compares changes in the well-being of different stakeholders, who are influenced by changes in ecosystem services flows.

Assessment of ecosystem services will, at a minimum, consider stakeholder values and priorities and may involve direct stakeholder engagement.

Frequently Asked Questions

Does incorporating ecosystem services….

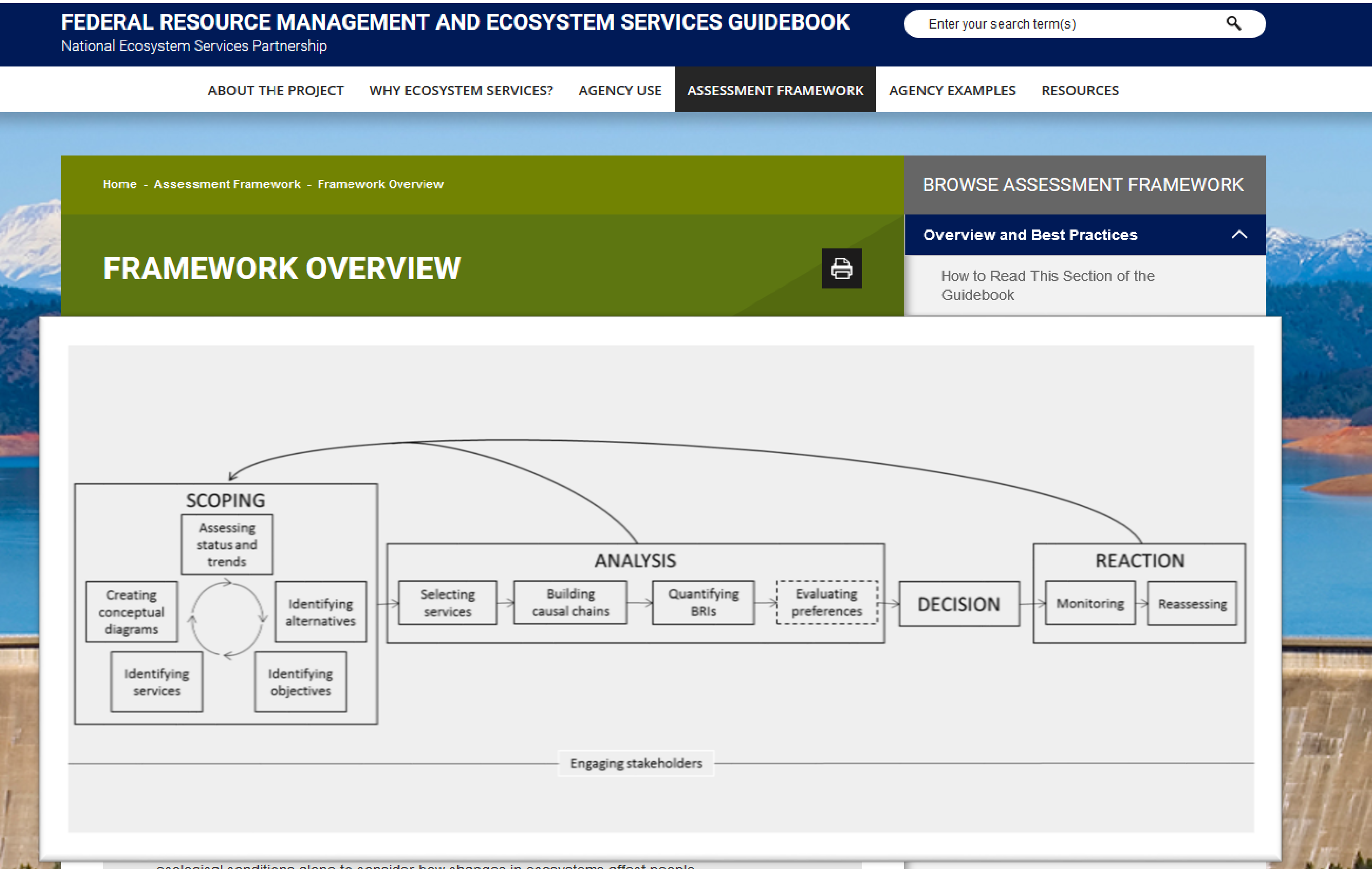
1. Need to happen for all management decisions? → No
2. Replace assessments of traditional economic benefits? → No
3. Favor easy to quantify services? → No
4. Require monetization of all services? → No
5. Always change the outcome of a decision? → No
6. Replace existing agency priorities? → No

Integrating ecosystem services complements existing processes by **providing additional information.**

Potential Challenges

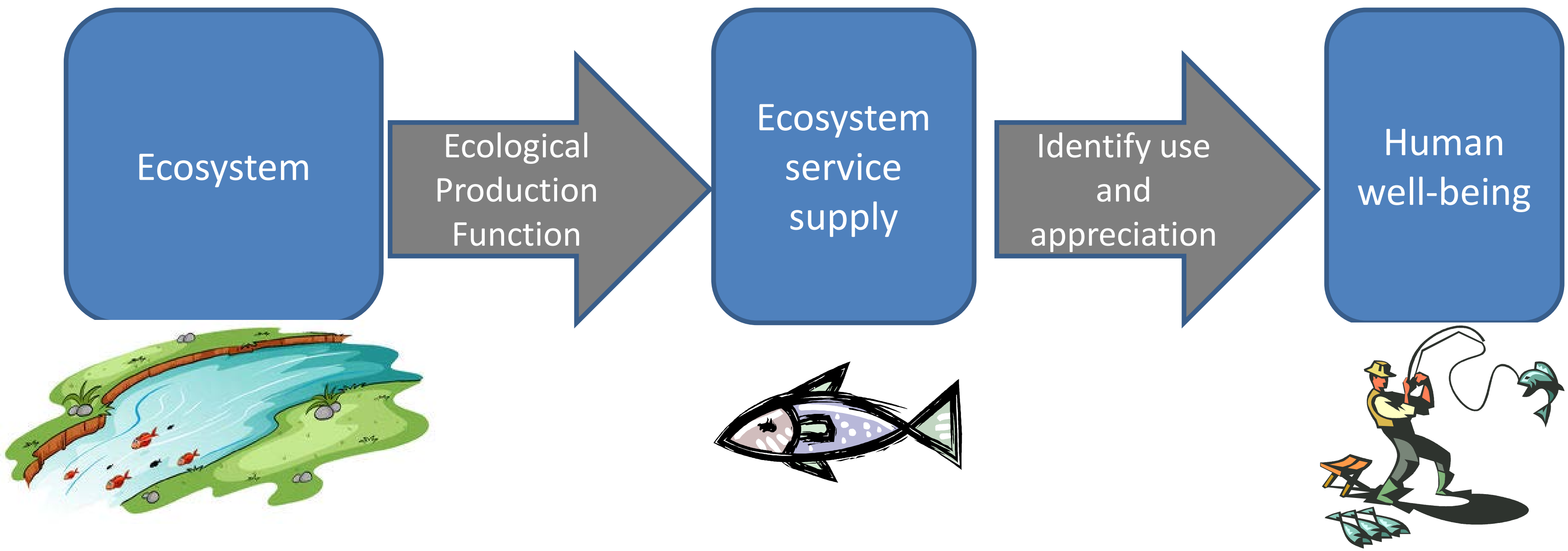
- Technical terminology may cause confusion
- Gaps in data and modeling for ecosystem services could limit quantification
- Insufficient in-house technical capacity
- Managing greater engagement with a larger number of stakeholders
- Concern that significant effort is required for potentially small impact on decisions

Overview of Methods



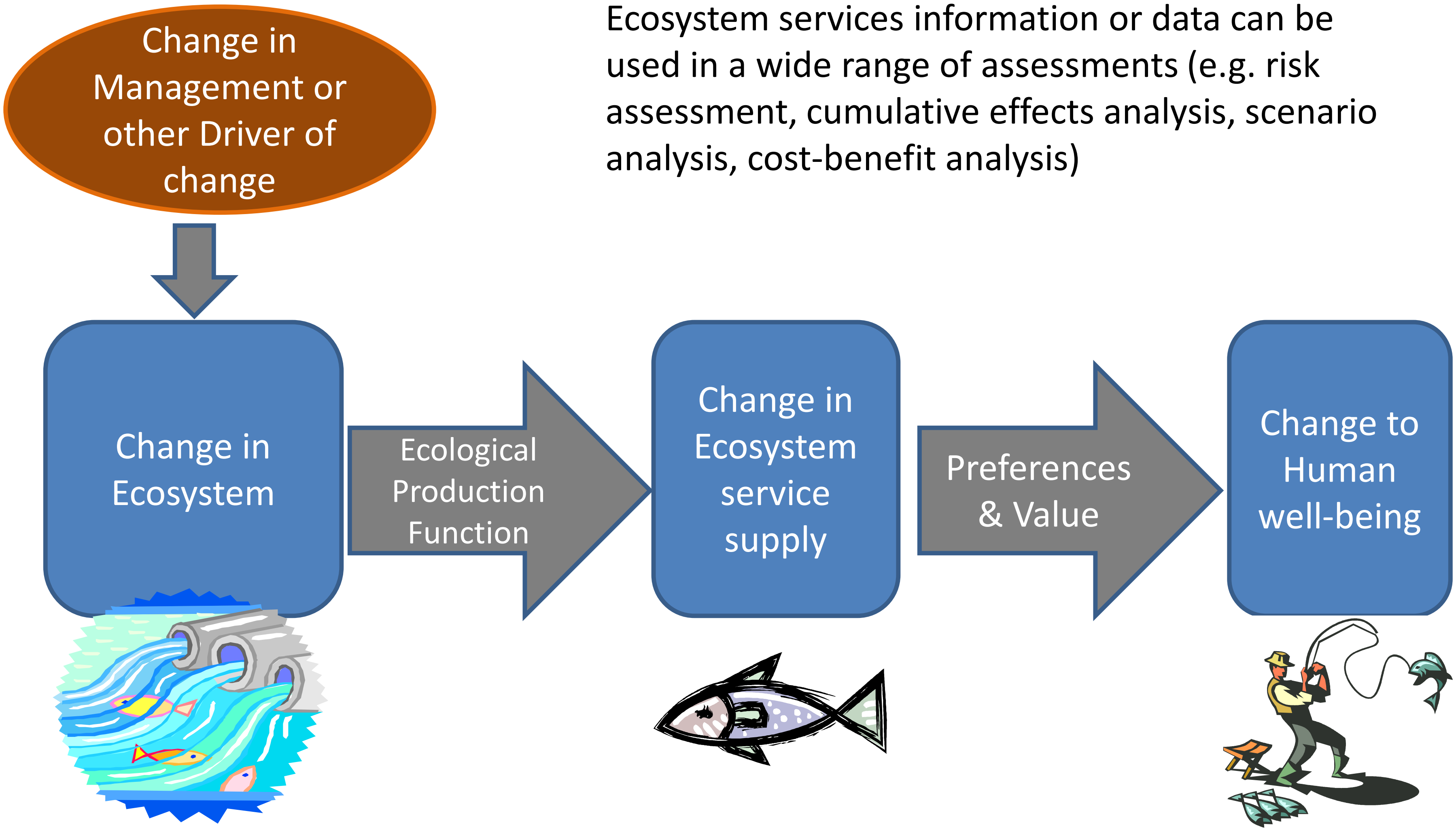
How does ecosystem services information get used in planning?

Baseline (current conditions, business as usual)



How does ecosystem services information get used in planning?

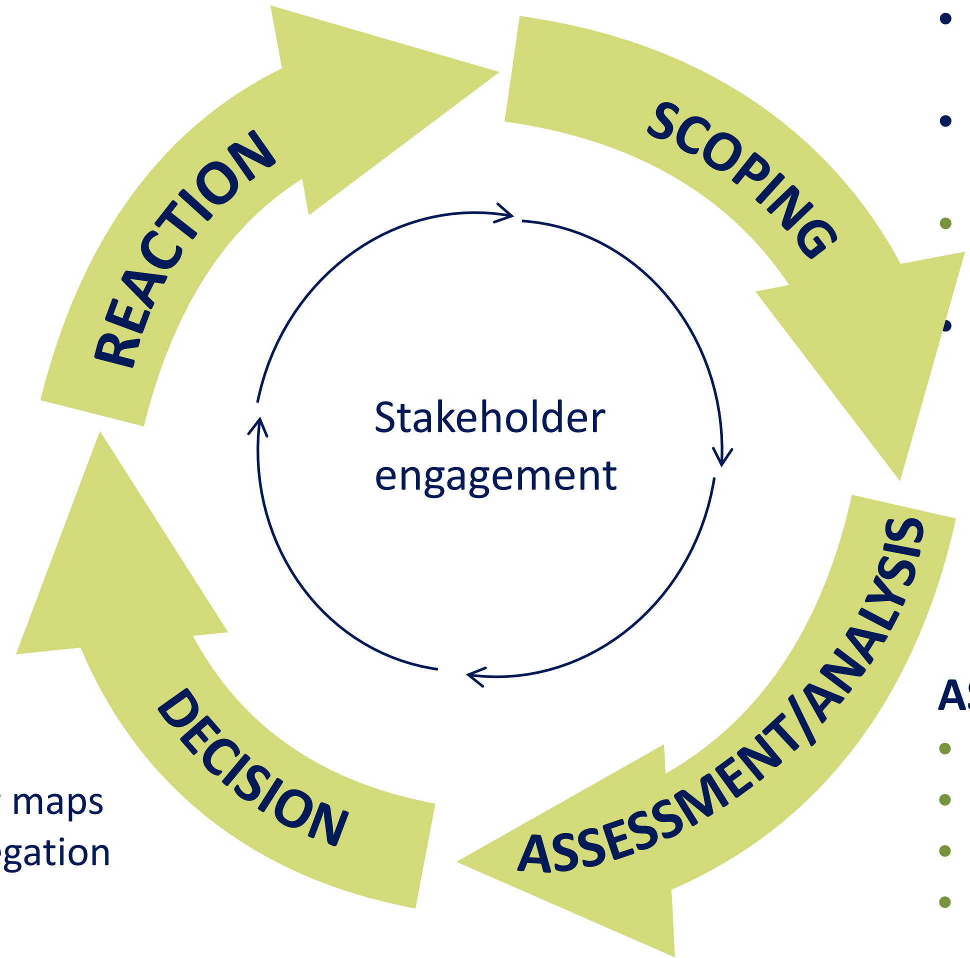
Ecosystem services information or data can be used in a wide range of assessments (e.g. risk assessment, cumulative effects analysis, scenario analysis, cost-benefit analysis)



Assessment Framework

REACTION
- Monitoring BRIs

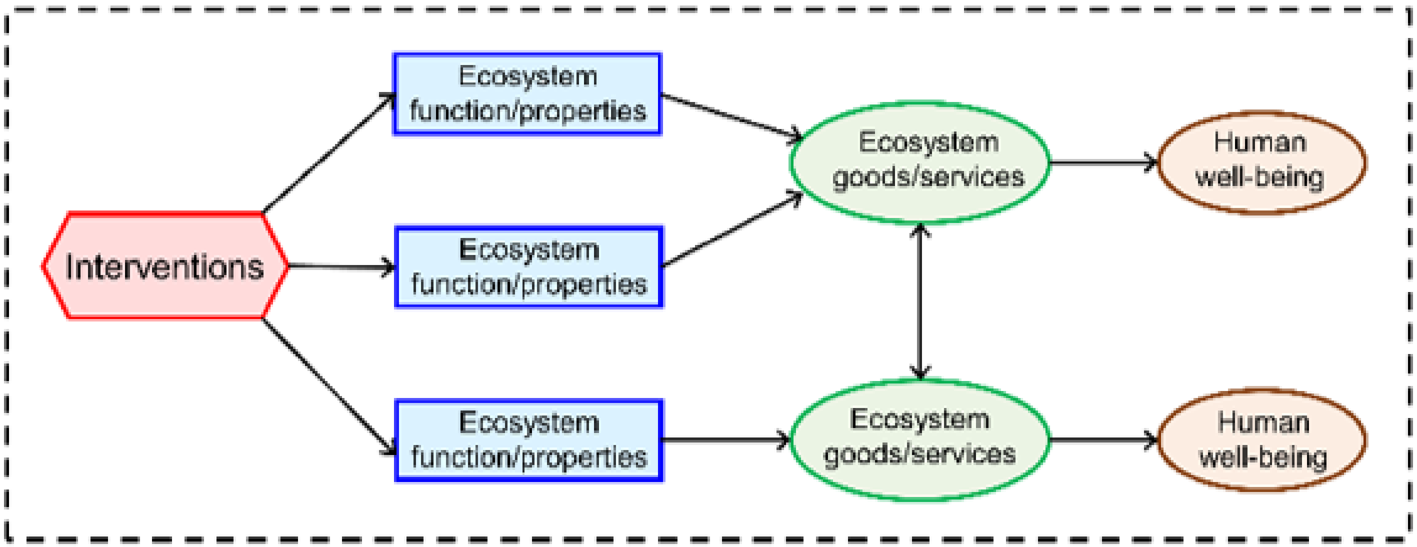
SCOPING
- Assessing status and trends
- Understanding socio-cultural context
- **Conceptual mapping**
- **Identifying services**
- Identifying alternatives

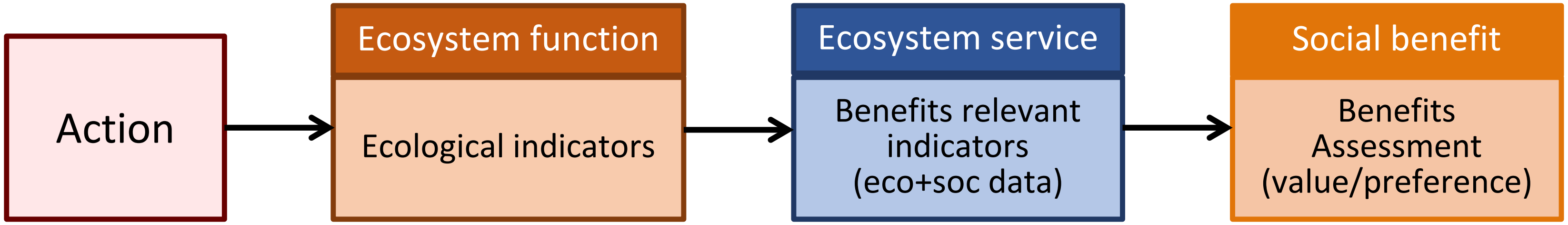


DECISION
- Displaying results- alternative matrix or maps
- Weighting and aggregation

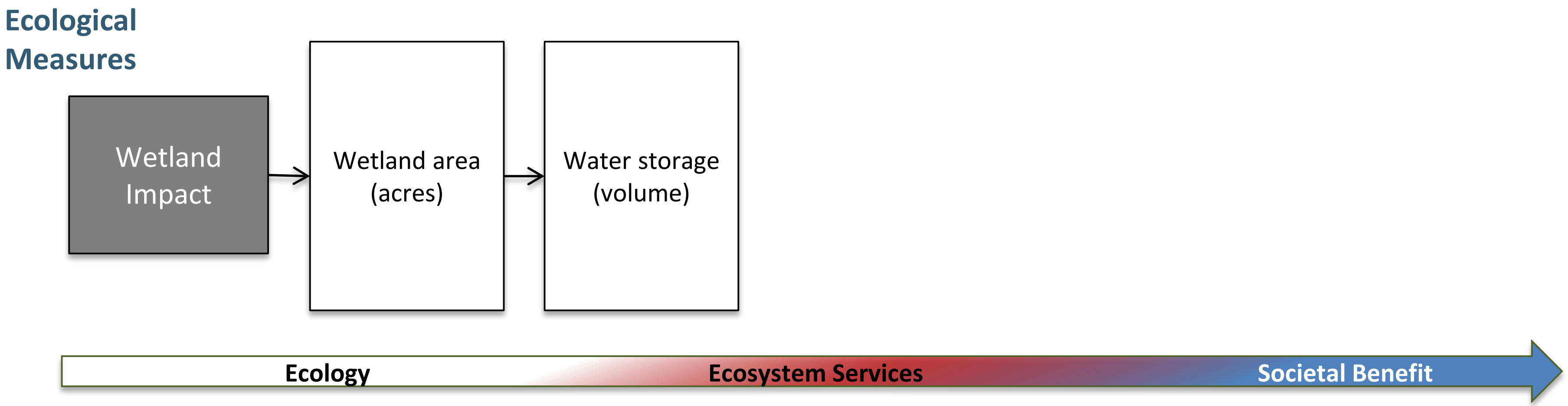
ASSESSMENT/ANALYSIS
- Causal chains
- Selecting services
- Quantifying BRIs
- Benefits assessment (Monetary or non-monetary)

In the guidebook –
we suggest the use of conceptual models built with causal chains connecting an action or intervention through the resulting changes in the biophysical or social systems to outcomes that matter to people.

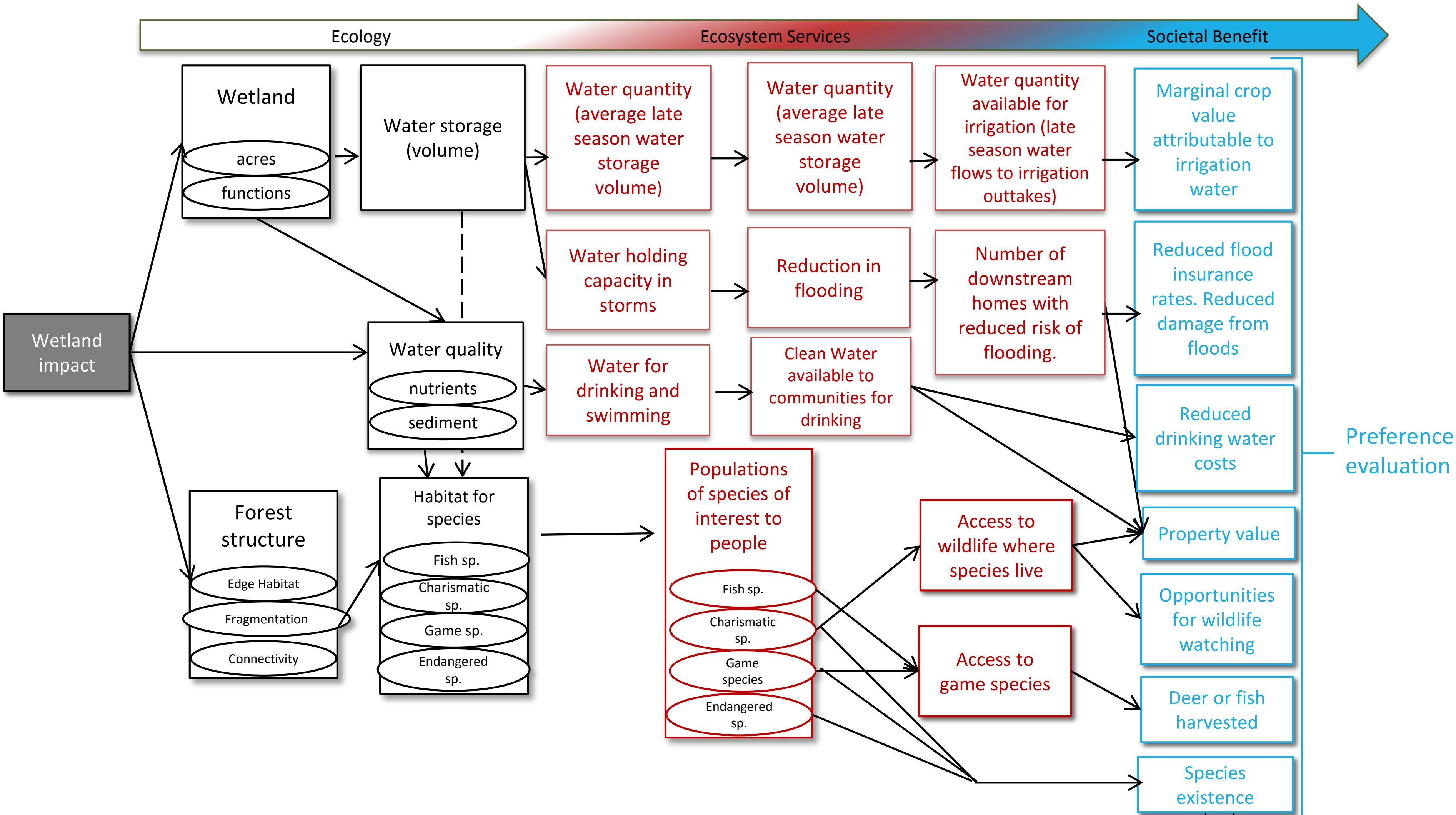




ES Causal Chain - Connects to people



ES Conceptual Diagram (logic model)



Including all significant changes

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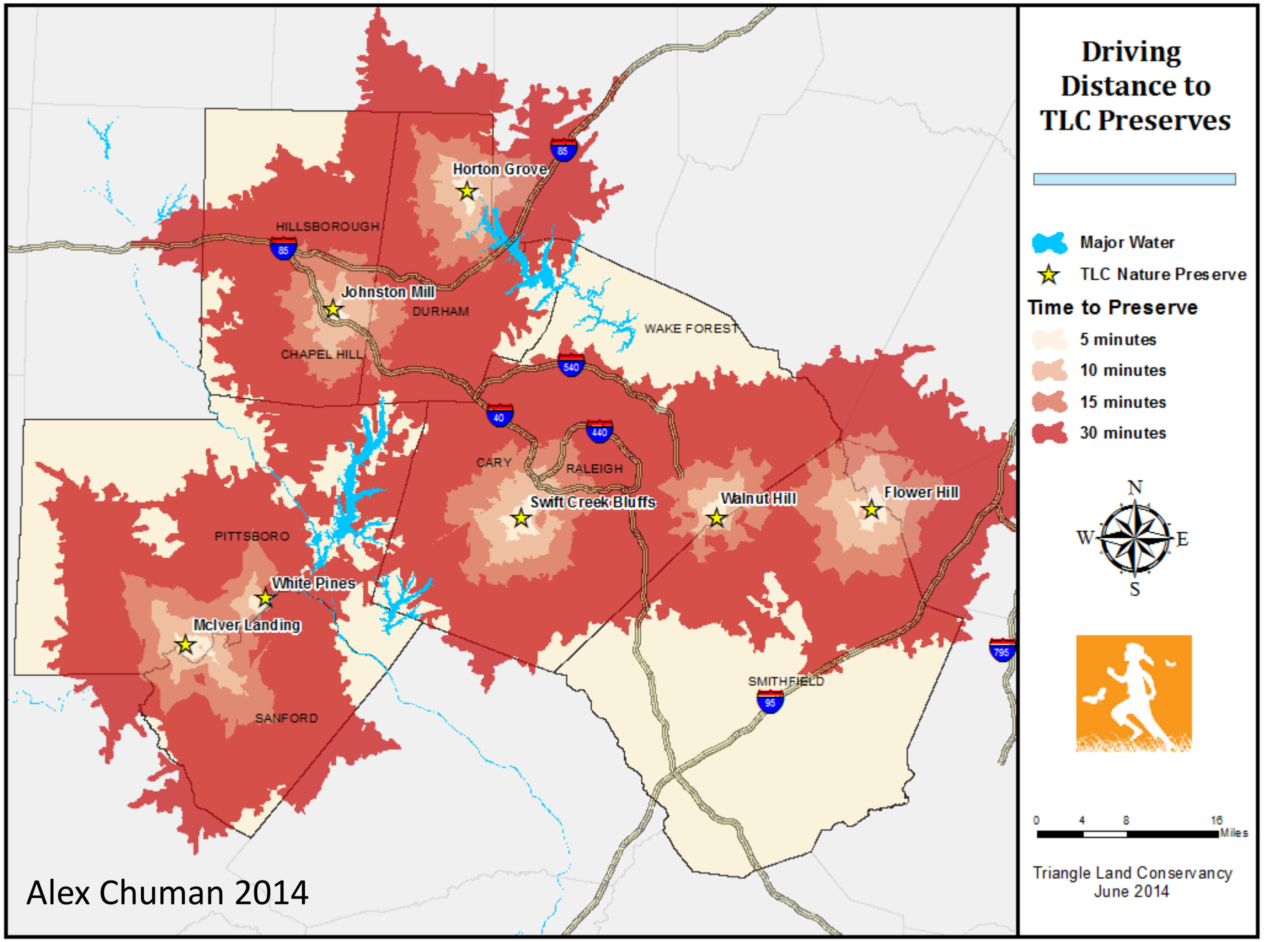
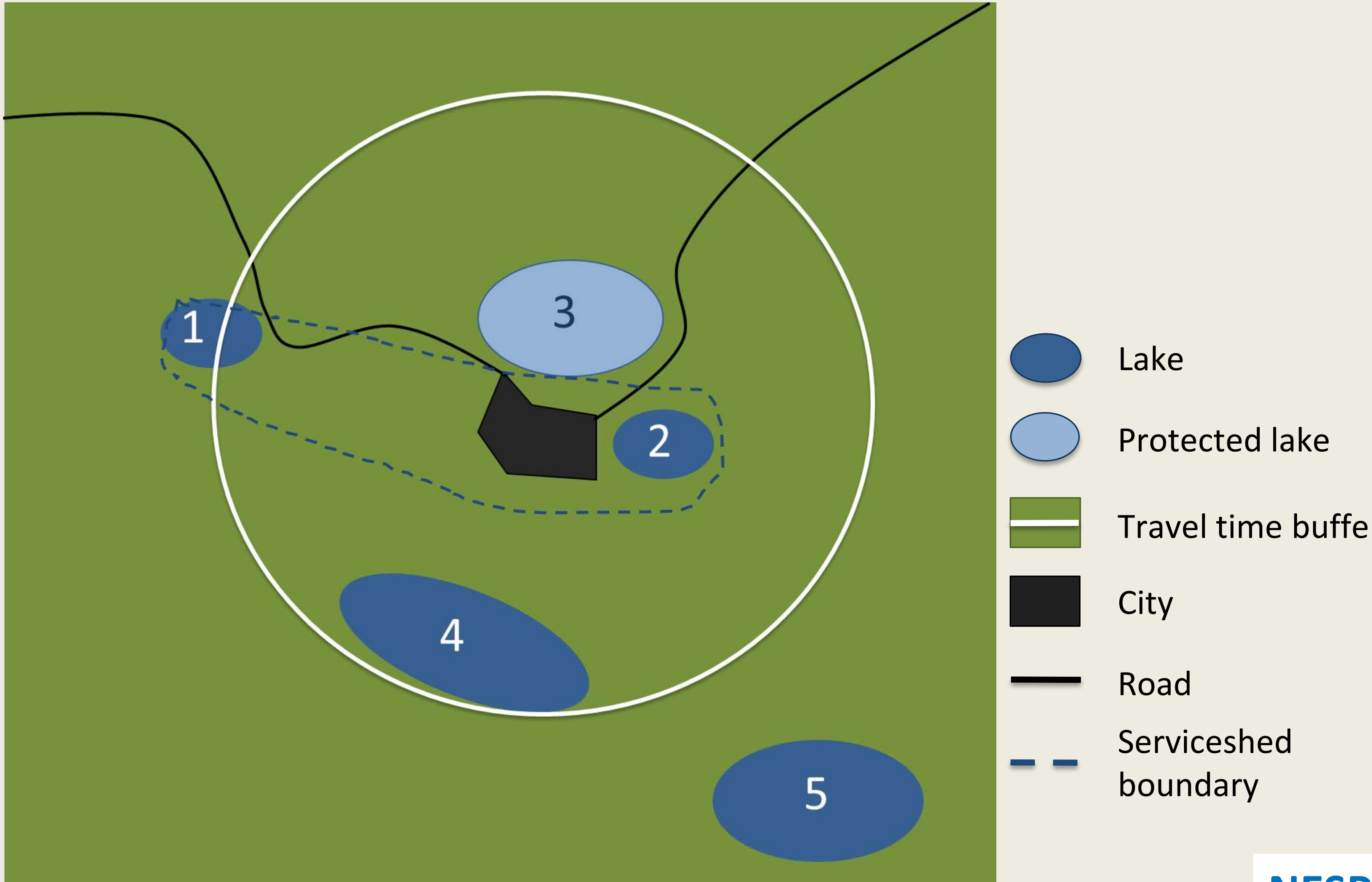
Who Benefits



Analysis of who has access and benefits from changes in services can be the basis for understanding distributional or equity implications

Servicesheds



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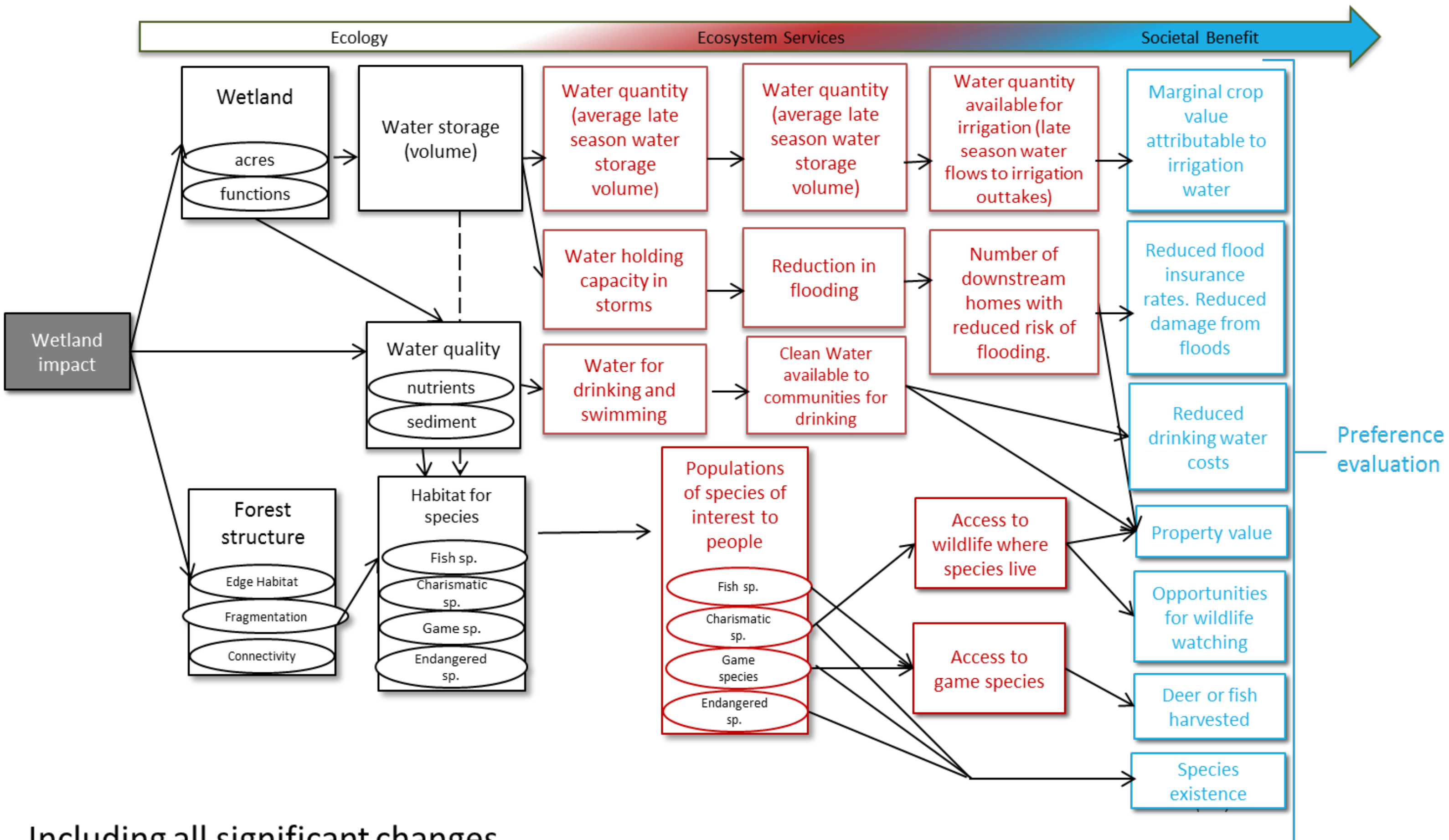
Do we need to quantify all these services? Which ones should be selected?



Including all significant changes

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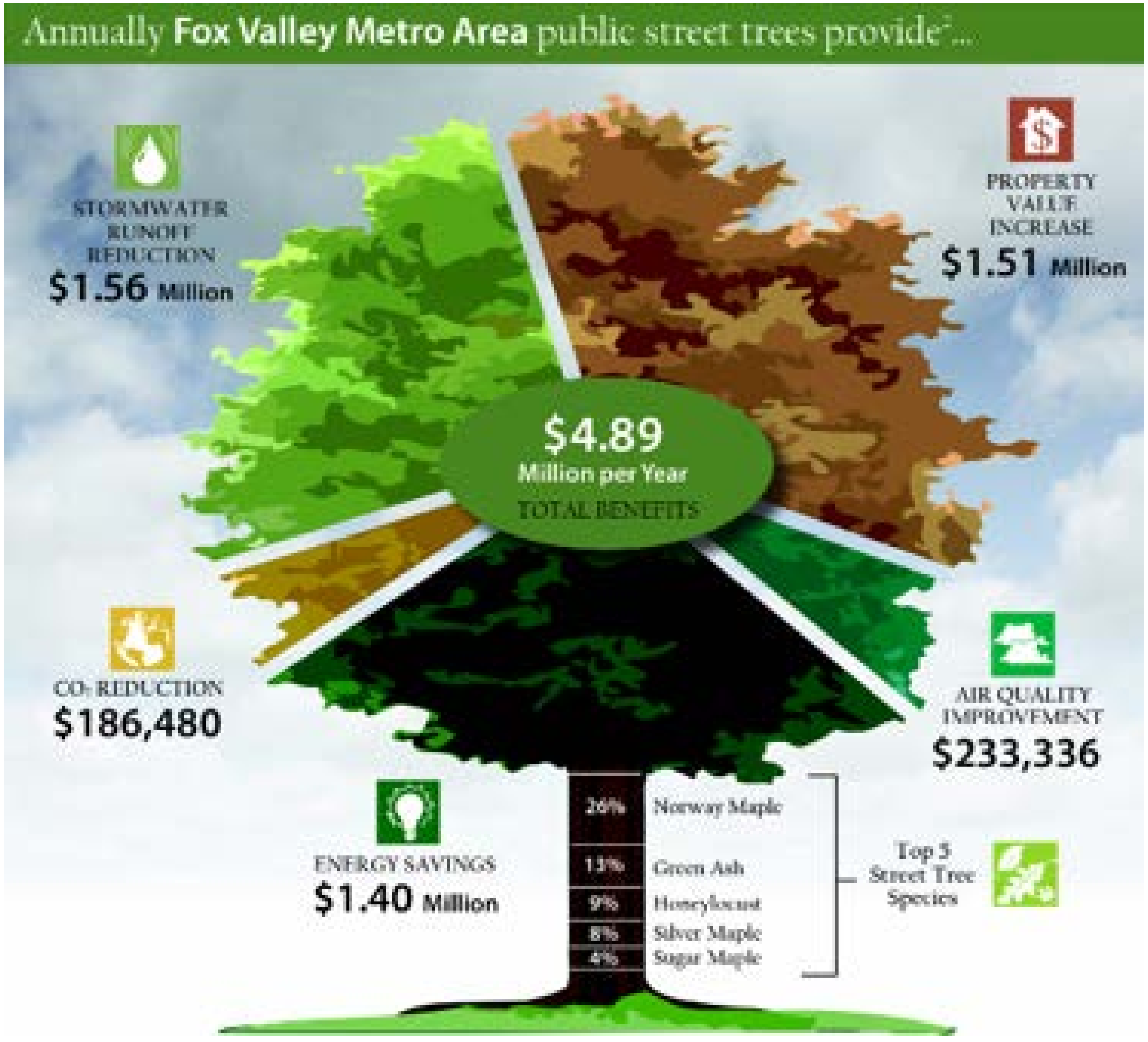
Selecting Services

Questions used to identify which services to assess

1. Is an impact on the ES likely to be large *and* strongly driven by the proposed activity?
2. Are the expected changes to the ecosystem service going to matter to a lot of people (#,access, proximity, etc…) or to groups of special concern (vulnerable children, elderly ill…)?

How do we quantify ecosystem services?

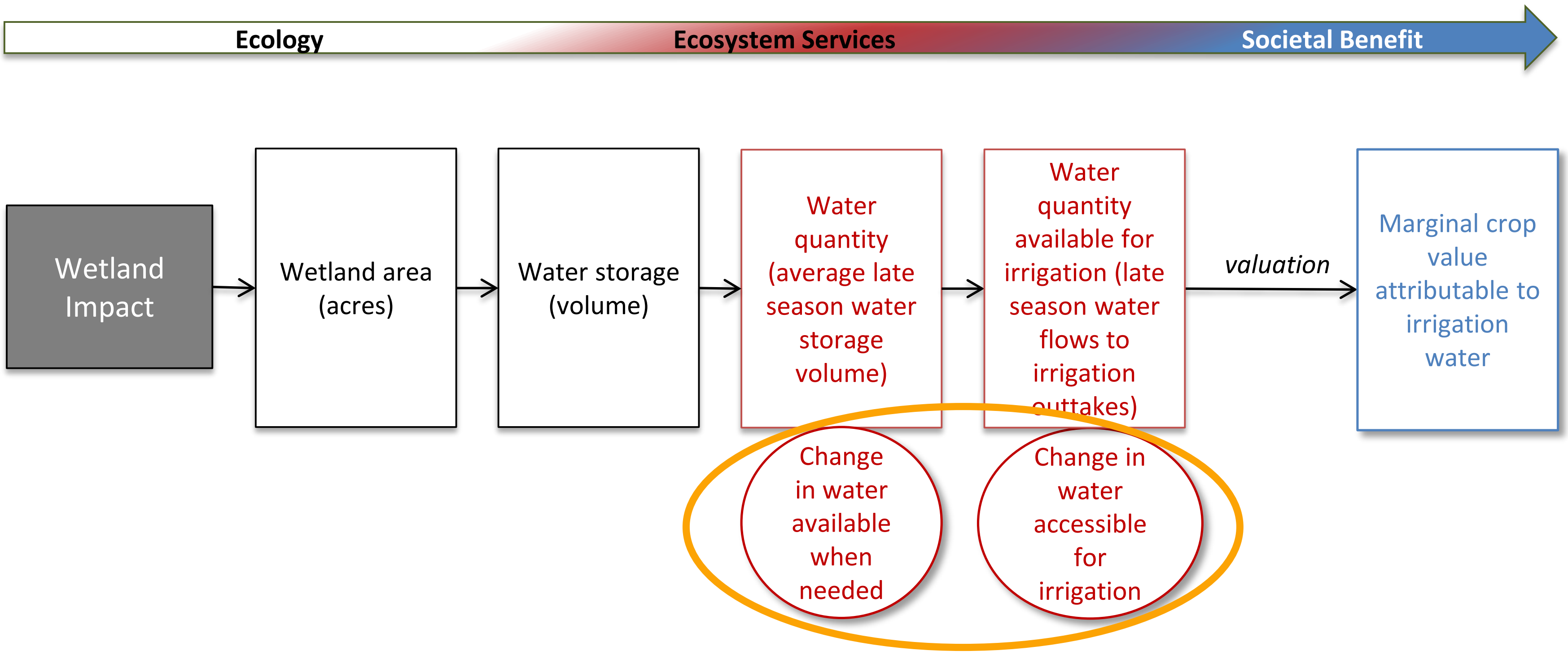
Monetary valuation is not the only option…



Benefit Relevant Indicators

What are well-defined measures of ecosystem services?

- Benefit Relevant Indicators (BRIs)



What is a BRI?

Examples of what would and would not qualify as a BRI

Ecosystem Service	Not BRI	BRI
Existence or abundance of wolves	People donating to general conservation organizations*	Numbers of wolves x Number of people holding existence value for wolves
Ecological production of recreationally harvested fish	Fish abundance	Abundance of recreationally targeted fish, in areas used by recreational anglers
Flood regulation	Flood frequency	Number of vulnerable people (elderly, ESL) in areas with flood risk reduced by management action
Water quality regulation	Nitrogen concentration (proxy measure)	"swimmable days" x number of people with ready access to the swimming sites

* Donating to general conservation organizations is not a BRI because (1) there is no direct link between conservation donations and wolf populations—individuals may donate for reasons other than values for wolves—and (2) wolf existence is a public good—each individual can in principle obtain this benefit without paying for it—so individuals will free-ride on payments made by others, and free riders will thus not be accounted for by only considering donations.

Variation in BRIs

Fishing related BRIs

Better BRIs ↓

- Increased abundance of fish in a lakes used by recreational anglers
- Number of recreational anglers with access to lakes with improved fish abundance
- Change in number of recreational fishing days due to improved fish abundance in lakes
- Additional catch by anglers due to improved fish abundance in lakes

Flood risk related BRIs

Better BRIs ↓

- Reduced frequency of river flooding in heavily populated areas
- Number of residents in areas experiencing reduced frequency of river flooding
- Value of residential properties in areas experiencing reduced frequency of river flooding
- Avoided property damages due to reduced frequency of river flooding in heavily populated areas

Thanks to George VanHoutven for these examples

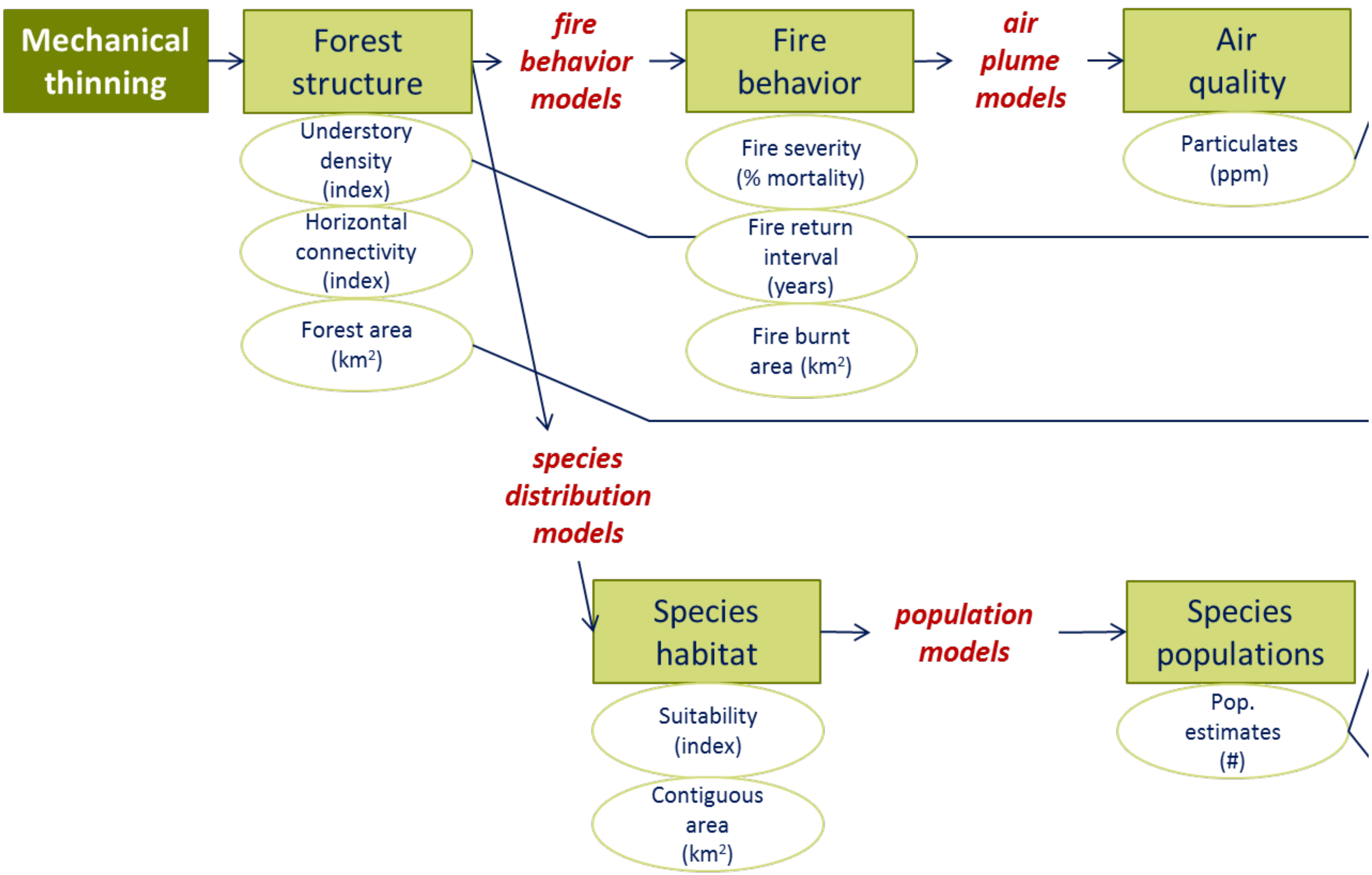
Quantifying BRIs

Measure Change in ES

- Narrative descriptions (does **NOT** meet best practices standard)
- Expert elicitation (informal, formal, Bayesian belief networks)
- Empirical models (existing or new) – e.g., USFS fire models

\- What are ecological production functions?

Ecological production functions are relationships that can be measured or modeled and that estimate the effects of changes in the structure, function, and dynamics of an ecosystem on outputs that are directly relevant to people. They can take many forms, from conceptual relationships established through expert opinion to complex simulation models. However, they are often a series of statistical relationships connecting ecosystem condition to outputs.


Mechanical thinning
Forest structure
Understory density (index)
Horizontal connectivity (index)
Forest area (km²)
fire behavior models
Fire behavior
Fire severity (% mortality)
Fire return interval (years)
Fire burnt area (km²)
air plume models
Air quality
Particulates (ppm)
species distribution models
Species habitat
Suitability (index)
Contiguous area (km²)
population models
Species populations
Pop. estimates (#)

Quantifying BRIs

Measure Change in ES

- Narrative descriptions (NOT meet best practices standard)
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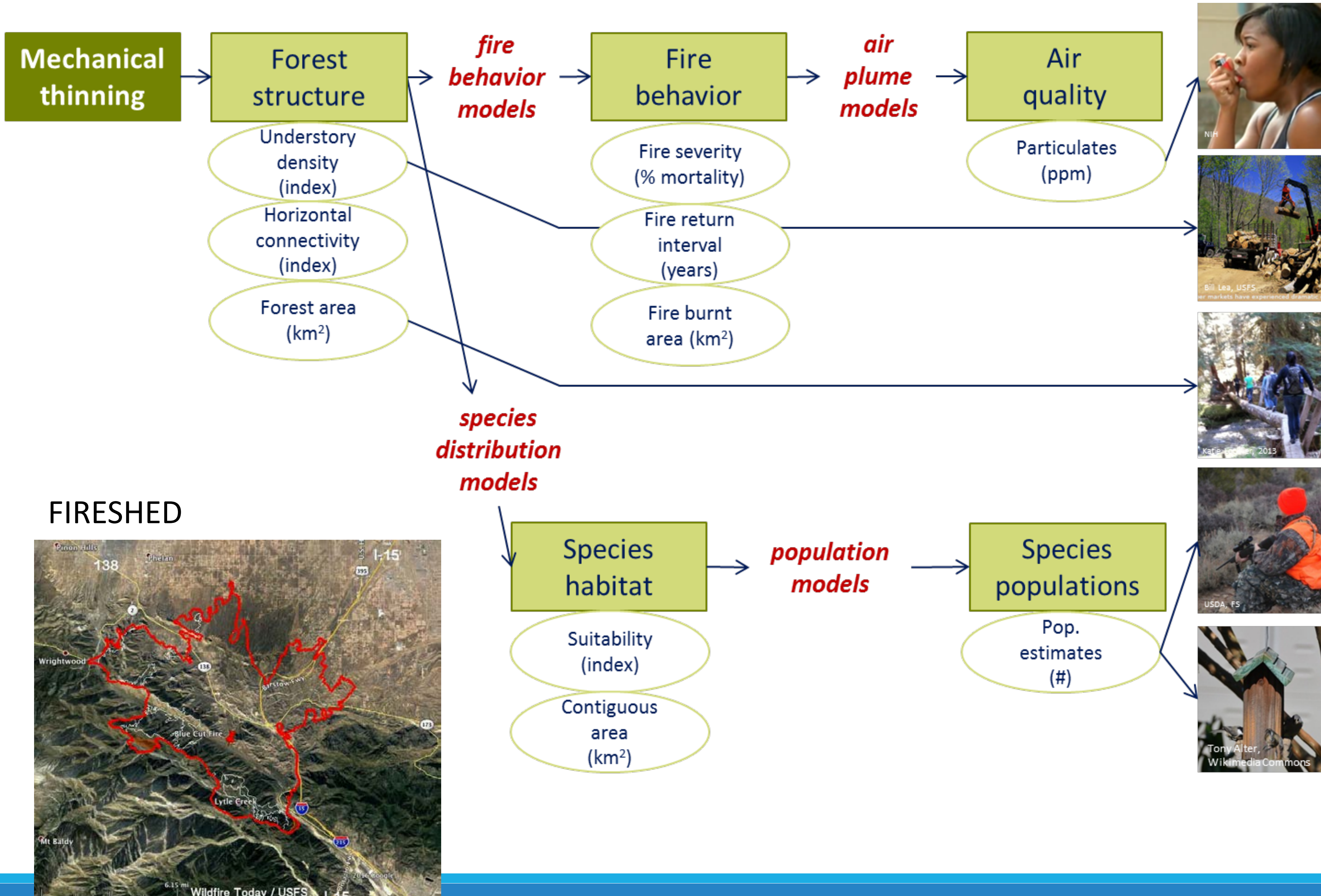
Identify & Quantify Who is Affected

- Define the serviceshed and flow of services



Mechanical thinning
Forest structure
Understory density (index)
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fire behavior models
Fire behavior
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Contiguous area (km²)
population models
Species populations
Pop. estimates (#)
NIH
Bill Lea, USFS
USDA, FS
Tony Alter, Wikimedia Commons
FIRESHED
Pinon Hills
138
Phelan
I-15
Wrightwood
Blue Cut Fire
Lytle Creek
Mt Baldy
Wildfire Today / USFS
I-15

Quantifying BRIs

Measure Change in ES

- Narrative descriptions of changes in ES (NOT meet best practices standard)
- Expert elicitation (informal, formal, Bayesian belief networks)
- Empirical models (existing or new) – e.g., USFS fire models

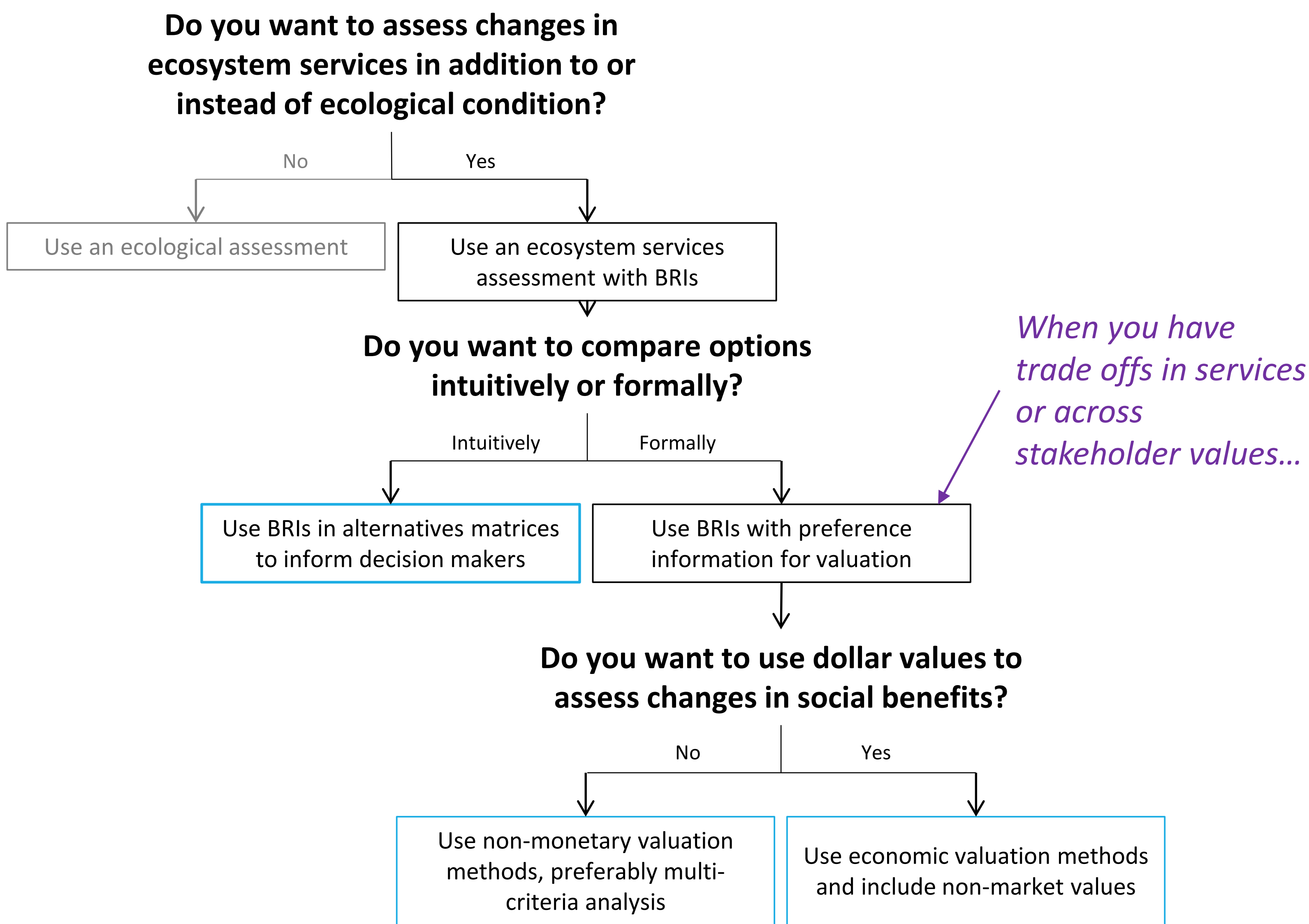
Identify & Quantify Who is Affected

- Define the serviceshed and flow of services
- Social and Economic Context

Assessing Benefits – Valuation & Preference Methods

- Monetary and Non-monetary valuation

Decision Tree for methods



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BRIs in intuitive decision making

ALTERNATIVES MATRIX FOR CONSIDERING ECOSYSTEM SERVICES IN INTUITIVE DECISION MAKING

Policy or Management Alternative			Option A	Option B	Option C
Ecosystem Service Benefit Relevant Indicator	BRI 1	Vegetation density in areas upstream of flood prone area with people or property of interest			
	BRI 2	Aquifer volume accessible by households			
	BRI 3	Amount of fish landed commercially			
	BRI 4	Acres of wetland habitat supporting recreationally important bird or fish species			

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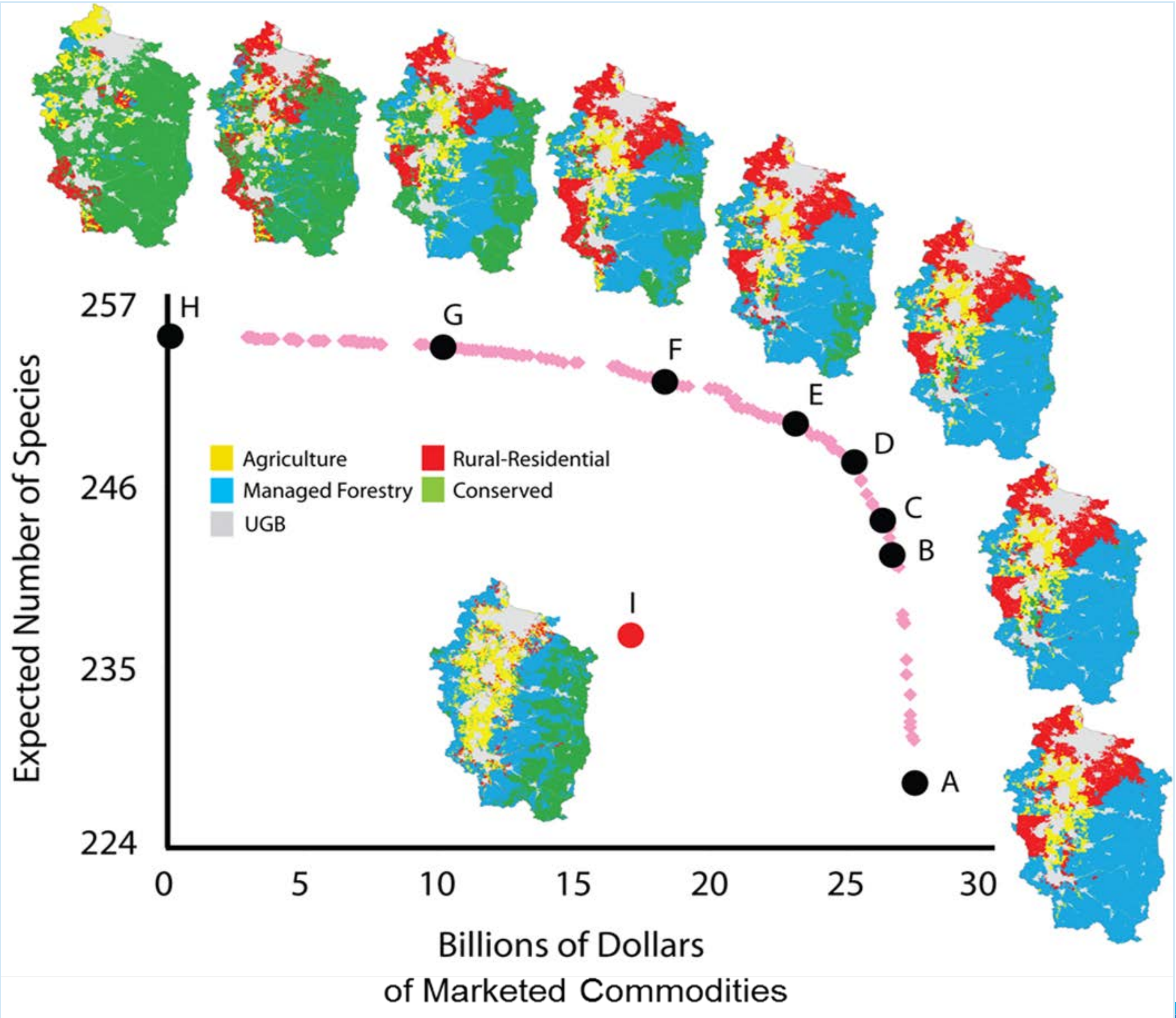
Evaluating trade-offs with BRIs



Source: S. Polasky, et al. “Where to Put Things? Spatial Land Management to Sustain Biodiversity and Economic Returns,” Biological Conservation 141(6) (2008):1505–1524

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Monetary Valuation

What is measured:

- Willingness to pay (WTP)

Techniques:

- Revealed preference
  (Travel cost, property values)
- Stated preference
  (Surveys asking WTP)

Yields:

- Dollar value of ES provided (or change in ES)
- Allows BCA

Requires:

- Quantified ecological outcome to value

Caveats:

- Some services difficult or deemed unsuitable to monetize
- Difficult but possible to transfer values

Medical expenses

Travel Costs

Vera Kratovchil, PublicDomainPictures.net

Survey for WTP

Multi-Criteria Decision Analysis

What is expressed:

- Relative value for each service and overall value for each alternative

Techniques:

- In-person elicitation
- Surveys

Requires:

- Quantified ecological outcome and capacity to elicit stakeholder preferences

Caveats:

- Elicitation can be time-consuming
- Results not transferable to different decision contexts

What can be valued vs quantified?

Table 1
Ecosystem services potentially affected by CEPP, criteria used to determine whether their value could be monetized, and methods used to value them.[a]

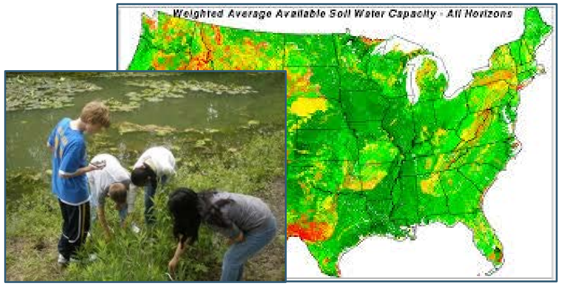
Proposed ecosystem service	Will CEPP change it?	Is there a tool or data to estimate the amount of change?	Is there existing economic data on the value of the change?	Valuation method used
Esthetics	Y	N	N	
Biodiversity and species composition	Y	Y	N	
Climate regulation from carbon sequestration in restored and conserved peat soils	Y	Y	Y	Benefit transfer
Coastal stabilization and storm protection in Everglades National Park	Y	?	N	
Ecological connectivity of landscapes	Y	Y	N	
Education	Y	N	N	
Fishing – commercial in Florida Bay	Y	Y	Y	Market prices
Fishing – recreational in Florida Bay	Y	Y	Y	Benefit transfer
Fishing – recreational in canals	?	N	Y	
Fishing – recreational in Lake Okeechobee	?	N	Y	
Fishing – recreational in Northern Estuaries	?	N	Y	
Frogging	Y	Y	N	
Real estate values near natural areas associated with CEPP	?	?	Y	
Recreation activities impacted by high-water and dry-condition closure days	Y	Y	Y	Benefit transfer
Reduced overall rate of ecosystem degradation	Y	Y	N	
Threatened and endangered species and habitat conservation	Y	Y	N	
Water quality – ground water purification/prevention of salt water intrusion	N	N	Y	
Water quality – reduction in phosphorous	Y	Y	N	
Water quality – sediment reduction	Y	Y	Y	Alternative cost
Water quality – water filtration by oysters	Y	?	?	
Water supply – Lower East Coast	Y	Y	Y	Point expansion method/ benefit transfer
Water supply: Lake Okeechobee Service Area irrigation	N	Y	Y	
Wildfire management	Y	Y	N	
Wildlife photography, tours, viewing	Y	N	Y	

[a] Y = yes; N = no; ? = uncertain.

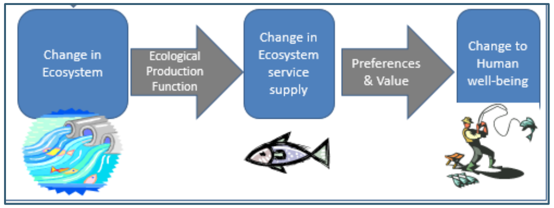
Leslie Richardson, Kelly Keefe, Christopher Huber, Laila Racevskis, Gregg Reynolds, Scott Thourot, and Ian Miller. 2014. Assessing the value of the Central Everglades Planning Project (CEPP) in Everglades restoration: An ecosystem service approach. Ecological Economics 107:366-377.

Data and modeling resource

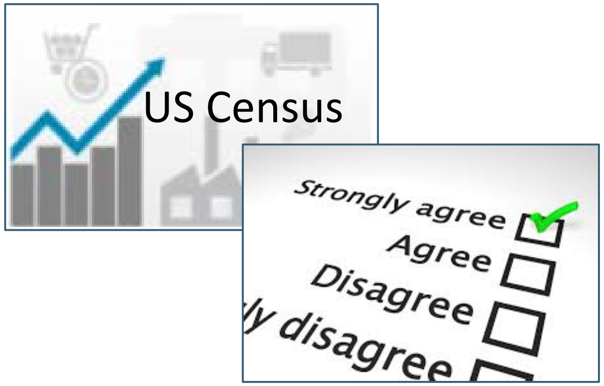
Ecosystem (BRI) Data



Ecological production functions



Use and value data



CONTENTS

- Ecological data and models for **biodiversity, water quality, water quantity, coastal, and urban** related services
- Data and models for ecosystem services that regulate and reduce risks related to **fire, flooding and climate change**
- Social and economic data and models for **wildlife, biodiversity, terrestrial and freshwater recreation, water supply, water quality, coastal and marine, urban and climate related services**
- Data and modeling infrastructure – current efforts and challenges

Consistency Brief

The question we explore in this brief is how to achieve consistency in the use of ecosystem services, primarily in terms of which ecosystem services are selected for assessment and how they are quantified.

National Ecosystem Services Partnership

Policy Brief 16-01
November 2016

www.nicholasinstitute.duke.edu/nesp

Proposal for Increasing Consistency When Incorporating Ecosystem Services into Decision Making

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Dean Urban, Nicholas School for the Environment, Duke University
Robert J. Johnston, George Perkins Marsh Institute and Department of Economics, Clark University
George Van Houtven, RTI International
James Kagan, Oregon State University

Introduction

After decades of research and demonstration, use of ecosystem services in decision making is being translated into policy guidance for practitioners.[1] In October 2015, the U.S. Executive Offices of the President—the Office of Management and Budget, the Council on Environmental Quality, and the Office of Science and Technology Policy—released a memo "Incorporating Ecosystem Services into Federal Decision Making" directing federal agencies to develop work plans and implementation guidance by the end of 2016.[2] But many practical questions remain about how ecosystem services can most effectively be used in decision making. The question we explore in this brief is how to achieve consistency in the use of ecosystem services, primarily in terms of which ecosystem services are selected for assessment and how they are quantified.

An initial idea for promoting consistency might be to require all decision makers to consider a common set of ecosystem services, each with a pre-defined metric. Although this strategy might seem logical, it may not provide relevant or useful information for decision makers because even fairly constrained categories of these services—say those for maintaining air and water quality, managing water quantity, and reducing risks from fire, storms, and droughts—when further refined break up into many more services that are defined by who is affected and how they are affected. For example, a water quality management issue results in a change in water quality for downstream stakeholders—which can alter services such as municipal water supplies, irrigation, fishing, swimming, and so on. Each of these services involves different

What Are Ecosystem Services?

"Ecosystem services are the benefits people receive from nature. They encompass nature's contributions to the production of food and timber; life-support processes, such as water purification and coastal protection; and life-fulfilling benefits, such as places to recreate or to be inspired by nature's diversity. There can also be ecosystem disservices, such as mosquito-borne diseases and pollen-induced allergies."

Source: Federal Resource Management and Ecosystem Services Guidebook.

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[1] See, for example, Department of Environment, Food & Rural Affairs, *Guidance for Policy and Decision Makers on Using an Ecosystems Approach to Valuation Ecosystem Services* (updated 2014), https://www.gov.uk/guidance/ecosystems-services; United Nations Environment Programme, *Guidance Manual for the Valuation of Regulating Services*, by Pushpam Kumar, Madhu Verma, Michael D. Wood, and Dhaval Negandhi, United Nations Office at Nairobi (Nairobi-Kenya, 2010), http://www.unep.org/pdf/Guidance_Manual_for_the_Regulating_Services.pdf; National Ecosystem Services Partnership, *Federal Resource Management and Ecosystem Services Guidebook*, 2nd ed. (Durham, NC: NESP, Duke University, 2016), https://nespguidebook.com; Patrick ten Brink, ed., The Economics of Ecosystems and Biodiversity (TEEB) in *National and International Policy Making* (London and Washington: Earthscan, 2011); Heidi Wittmer and Haripriya Gundimeda, ed., *The Economics of Ecosystems and Biodiversity (TEEB) in Local and Regional Policy and Management* (London and Washington: Earthscan, 2012).

[2] Memorandum for Executive Departments and Agencies M-16-01 of October 7, 2015, Incorporating Ecosystem Services into Federal Decision Making, Office of Management and Budget, https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf.

Consistency in use of non-monetary measures

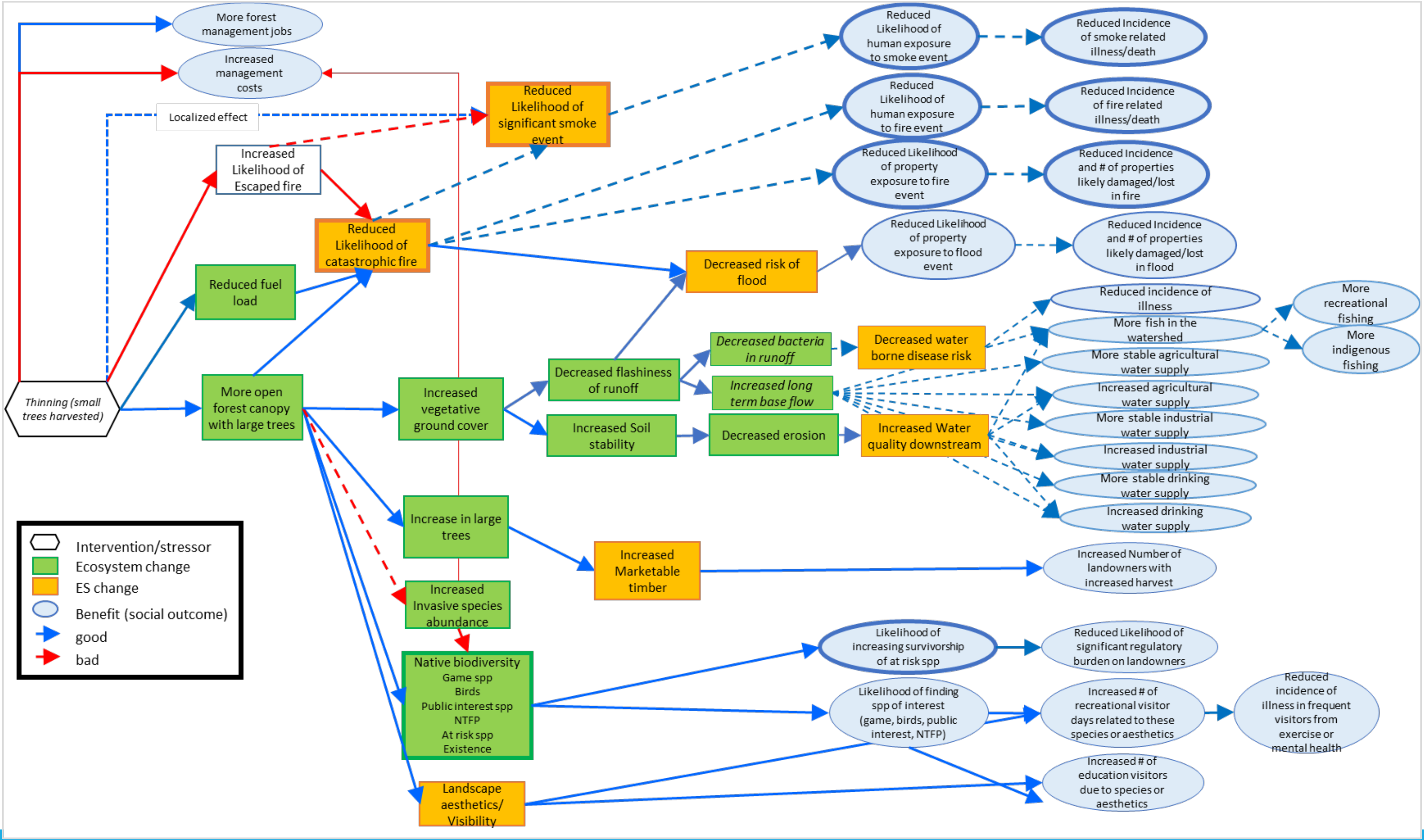
Monetary valuation and MCDA generate consistent units (dollars or utils) that can be directly compared or aggregated to generate estimate of change in public welfare, but what if you are using non-monetary measures (BRIs) for some or all measures?

Table 1. Typical goals and actions for national forests

Goal	Actions
Fire risk reduction (reduce frequency and severity)	**Thinning, prescribed burns, chemical treatment**
Wildlife support	Habitat restoration, road removal
Timber production	Harvest, thinning, replanting
Drinking water provision	Fire suppression, riparian zone management, thinning to reduce evapotranspiration
Healthy forest system	Invasive species and pest management
Increase recreational opportunities	Improving access (paths, docks), improving viewsheds or siting opportunities.

Consistency in use of non-monetary measures

Figure 2. Common conceptual model developed for forest thinning for fire risk reduction in western US forests. [Ecosystem changes are green, ecosystem services changes are orange, and changes in societal benefits are blue.] Thicker boundaries indicate BRIs.

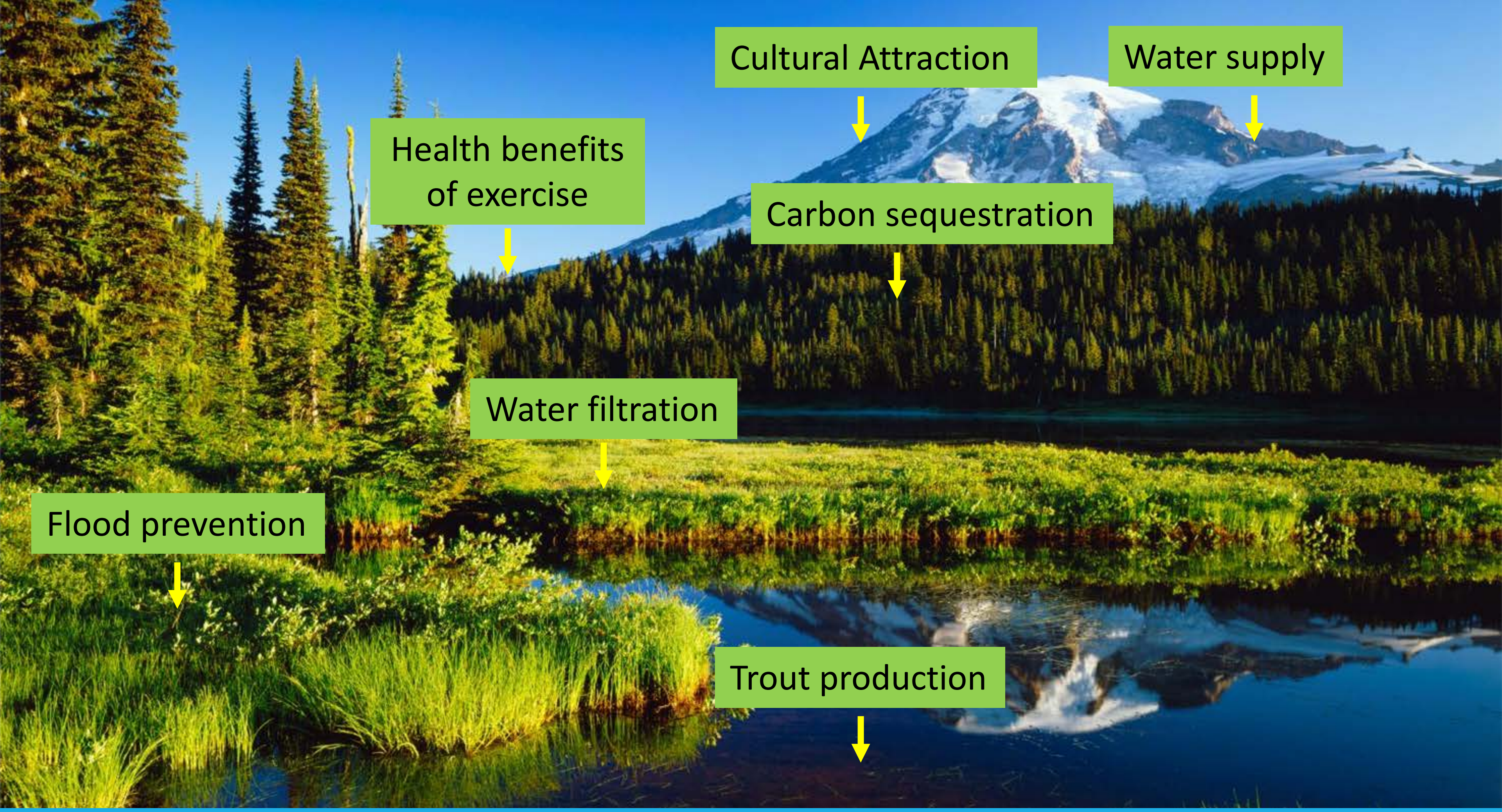


This work led by TNC, Duke, in collaboration with many other organizations

What is common across a set of non-value based ecosystem services measures (BRIs) from the eastern and western forest fire management models.

- Dark green indicates the same measure could be used across contexts
- Light green suggests the category would be the same but the specific measures may differ (e.g., due to different species of importance)
- White indicates the measure is only relevant in one context.

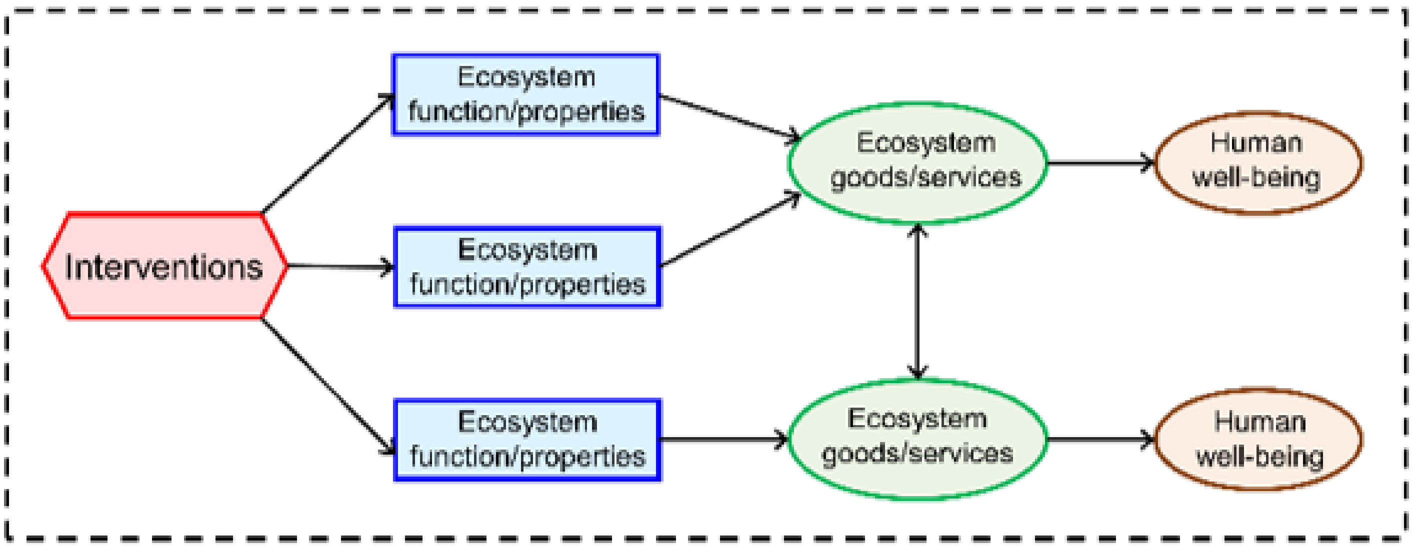
BRIs (assess changes in the indicators)	Common measure? Western forests	Common measure? Eastern forests
Incidence of fire-related death in fire-prone areas	Dark green	Dark green
Incidence of fire-related injury or illness	Dark green	Dark green
Incidence of properties damaged by fire in fire-prone areas	Dark green	Dark green
Smoke-related mortality in airshed of forest fire	Dark green	Dark green
Incidence of smoke-related morbidity (respiratory issues) in airshed of fire-prone area	Dark green	Dark green
Flood-related mortality in watershed of forest fire	Dark green	White
Flood-related property damage in watershed of forest fire	Dark green	White
Post-fire sedimentation damage to water treatment for municipal users —for agricultural users —for industrial users	Dark green	White
Population viability of important wildlife species 1 (a widespread species) affected by change in understory (existence)	Dark green	Light green
Population viability of important wildlife species 2 (locally important)– affected by change in fire frequency (existence)	Light green	Light green
Population viability of wildlife species 1 (a widespread species)for hunting	Dark green	Light green
Population viability of locally important wildlife species 2 for hunting	Light green	Light green
Merchantable timber for public sector	Dark green	Dark green
Non-timber non-market forest product collection	Dark green	Light green
Nature visitation	Dark green	Dark green
Education visitation	Dark green	Dark green

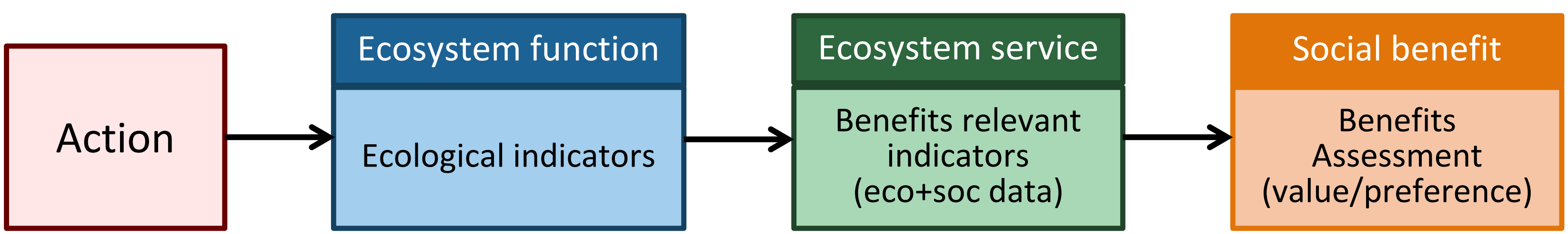


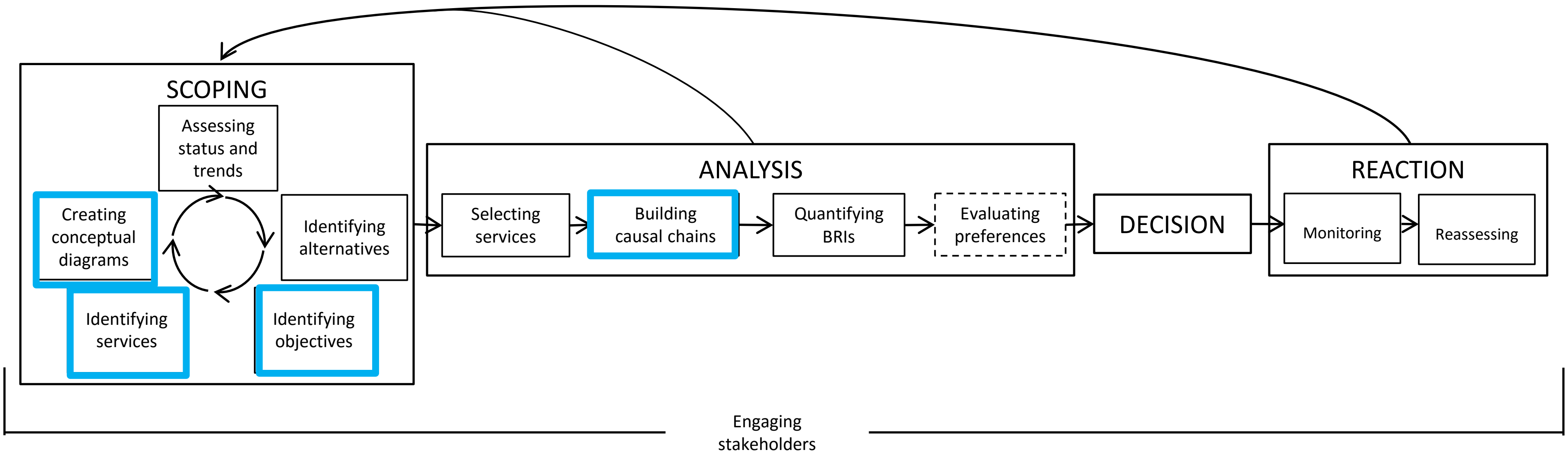
Causal Chains and Conceptual Diagrams

National Ecosystem Services Partnership

In the guidebook –
we suggest the use of conceptual models built with causal chains connecting an action or intervention through the resulting changes in the biophysical or social systems to outcomes that matter to people.







Used for:

- Scoping alternatives
- Identifying services and beneficiaries
- Engaging stakeholders
- Communication
- Foundation for quantification
- Foundation for analytical models

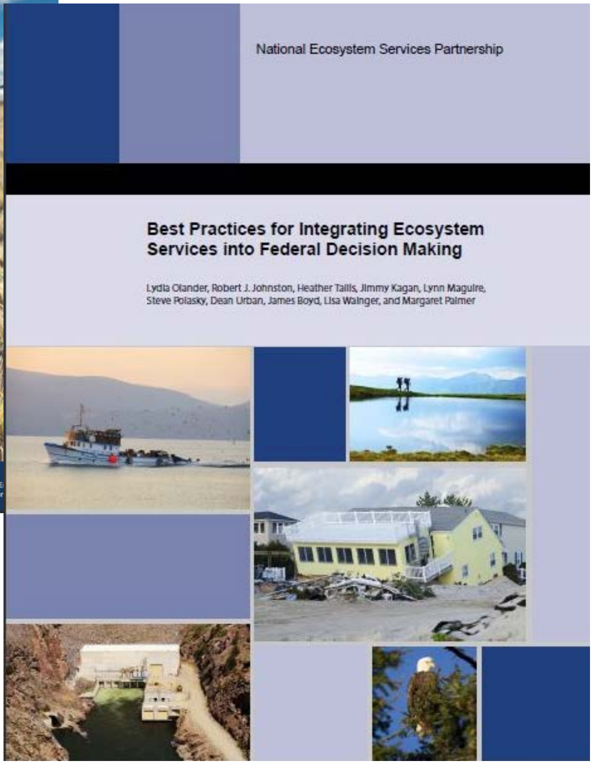
Everyone uses them – opportunity for cross disciplinary coordination

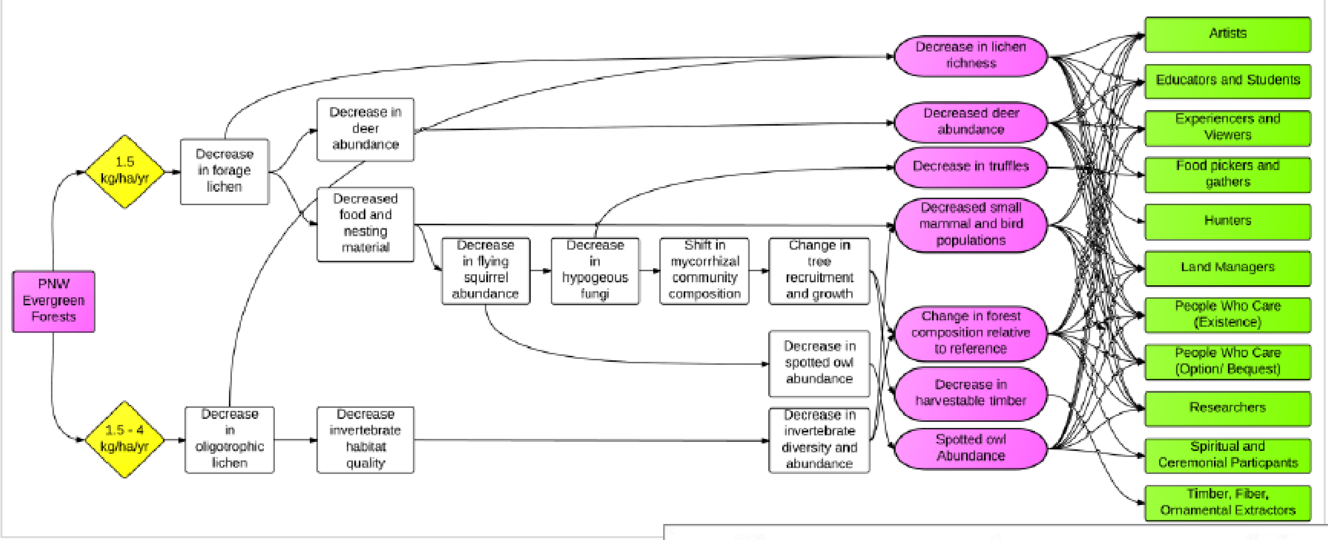
Causal chains like models are not *de novo*, and have rich intellectual roots, and this concept has been used in a wide range of disciplines albeit with different terminologies and contexts

- **Theory of change** (Weiss 1995; 1997): examine whether the expected outcomes actually materialize and to what extent they can be attributed to interventions.
- **Conceptual or logit models** (McLaughlin and Jordan 1999), logical frameworks ('logframe')
- **Path analysis**
- '**Ecosystem service cascade**' (Haines-Young and Potschin 2010)
- **DPSIR**: driver-pressure-state-impact-response (EEA 1995; EPA)
- **DAG** (directed acyclic graph in public health)
- **Results chains** – World Bank
- **Means-ends diagrams or influence diagrams** (MCDA, structured decision making)

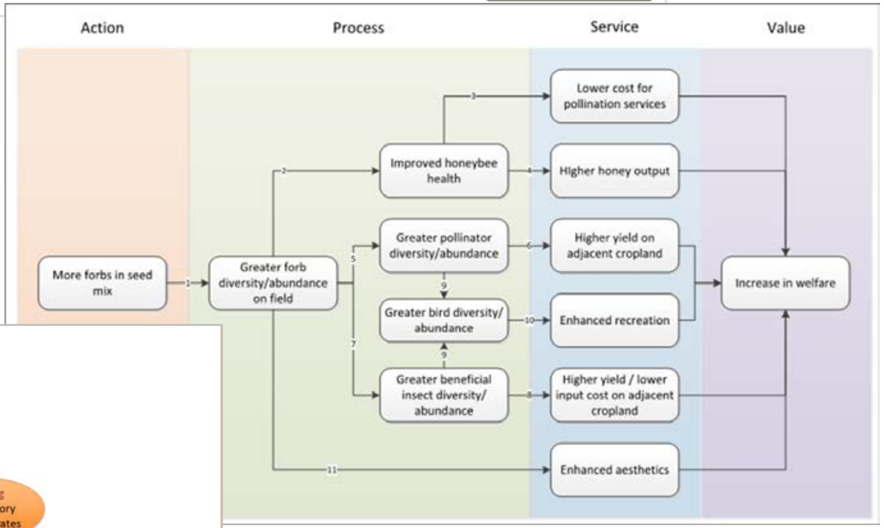
From TNC Guidance and NESP Best Practices

Work on causal chains best practice funded in part by The David and Lucille Packard Foundation

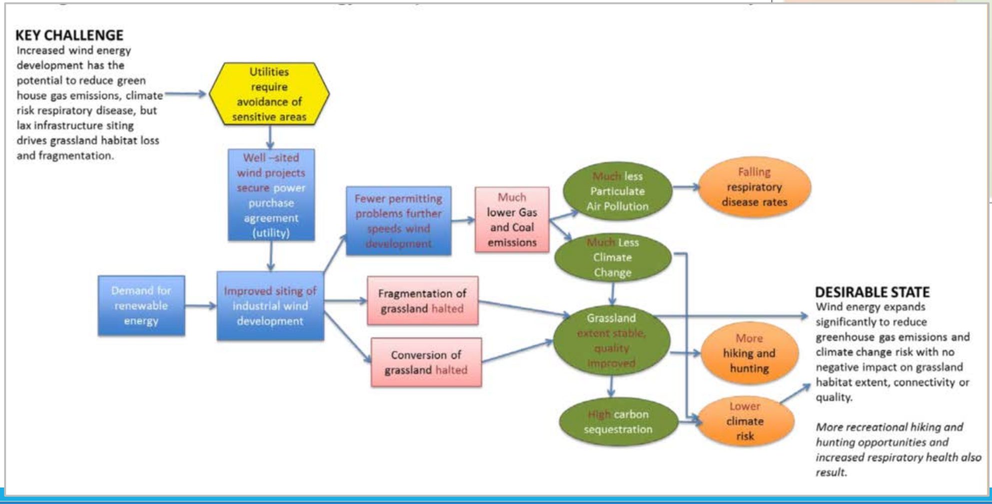




EPA/NPS



USDA



TNC

Benefits of using causal chains

1) Systematic

2) Transdisciplinary

3) Quantitative/Testable

4) Transferable (economies of scale)

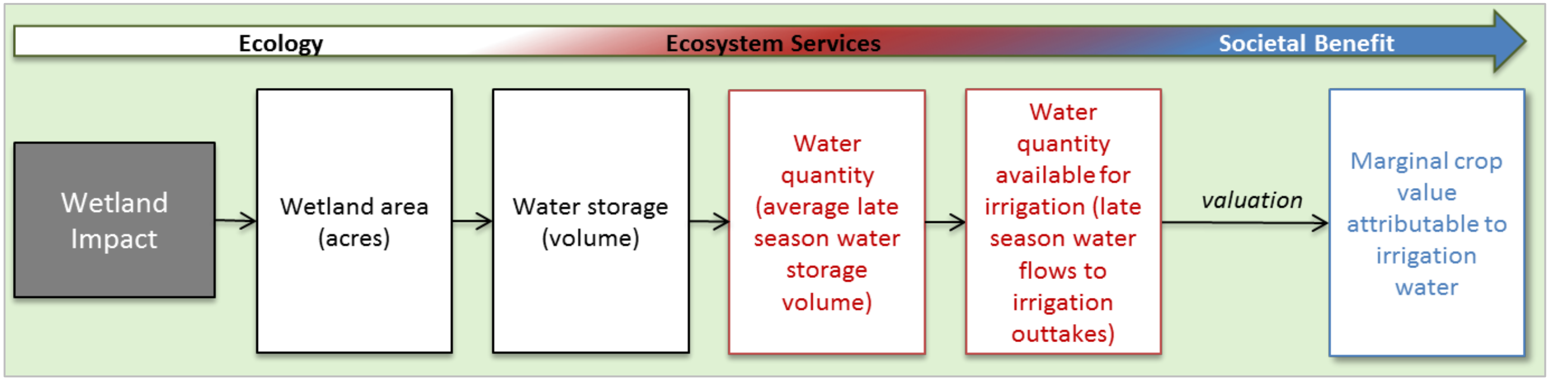
5) Adaptive (to knowledge and application)

6) Transparency

7) Informative

To ensure best practices are used in building conceptual models and causal chains with ecosystem , the following questions should be considered sequentially

1. How does a policy, management decision, or program action affect ecological conditions?
2. How do changes in ecological conditions lead to changes in the delivery of ecosystem services (defined as ecological changes that directly influence people)?
3. How do those changes in the delivery of ecosystem services affect benefits or costs to individuals or groups?



NESP

Connecting the Means and the Ends

MEANS: management, project, or policy choices (at various locations)



ENDS: what people care about (ecosystem services)



Building a conceptual model
Understanding Context: Situational Analysis

Define the following:

- What are the **objectives**?
- Who is the **audience/ stakeholders**? Ideally consult with representatives from all stakeholder groups.
- What is the **geographic scope**? What defines the region you are working in/ whose wellbeing is included?
- What is the **temporal scope**? What is the timescale of the outcomes you will be examining: months, years, decades? Direction of outcome can be different depending on time scale

Identify **Primary Interests**:

- What are the primary interests of all stakeholder groups? – doesn't necessarily have to be directly tied to your management intervention

Situational analysis
Eastern US Forest Fire Management

Primary Objectives:

1. Restore healthy long leaf pine habitat to protect rare and at risk habitat, species, and cultural associations
2. Increase resilience of forest systems to climate change, drought, and fire.

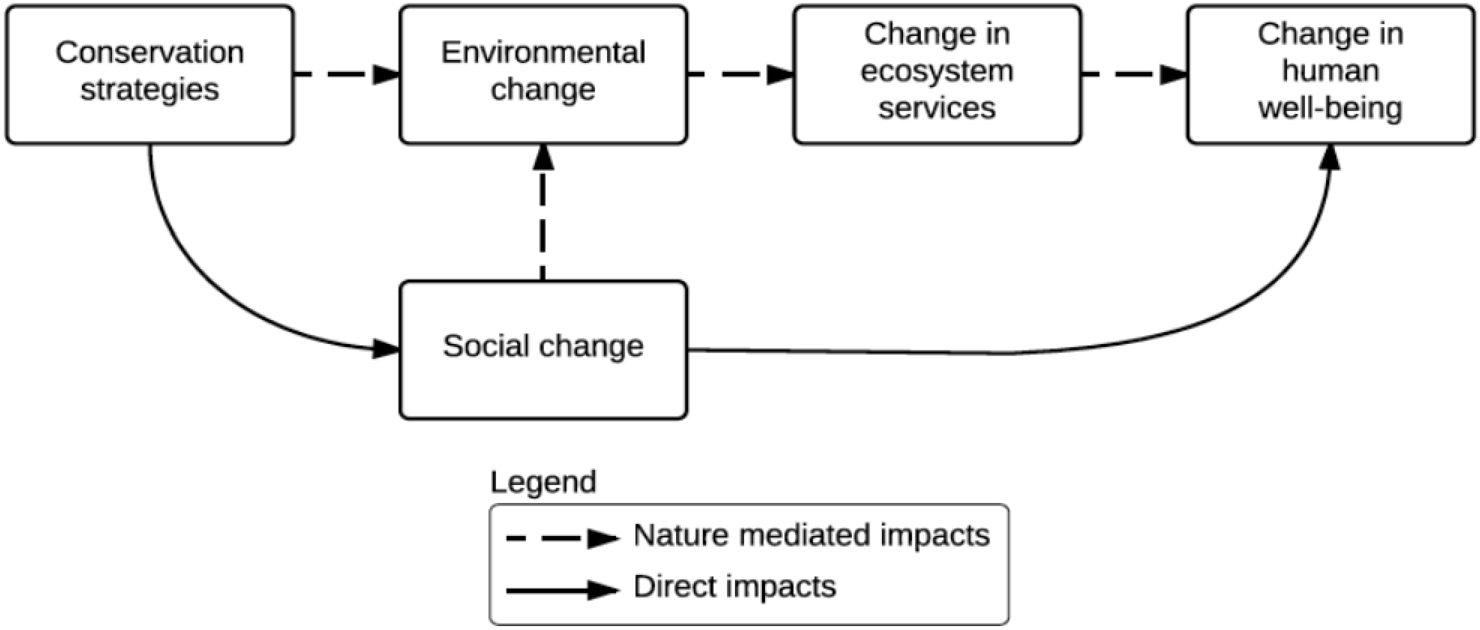
Baseline: Long leaf pine that is not being actively managed to maintain long leaf pine

Time span: Long term10+ yr, short term 3 months or less

Spatial extent: landscape scale (but noting significant localized effects that may affect decisions/ behavior

Simple model (effects that are likely to be small are removed)

Figure 8: Direct and nature-mediated pathways between conservation and human well-being in simplified results chain



Parts of these chains

Intervention
- Regulation
- Incentive
- Education
- Etc…

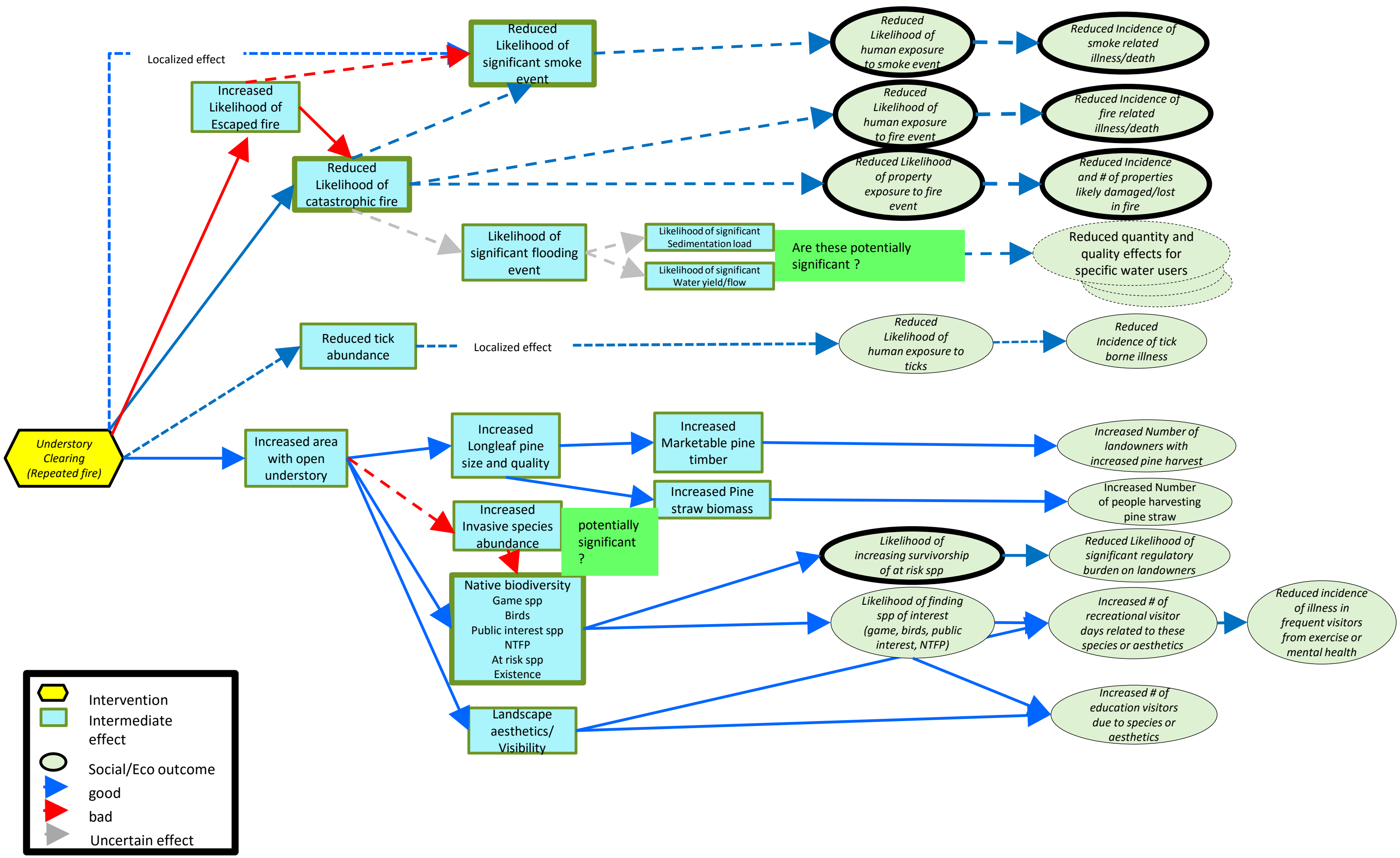
Action
- On the ground actions that affect ecosystems or people

Resulting effects
- Biophysical structure/ function
- Ecological structure/ function
- Human interaction/ action

Outcomes
- Direct and environmentally mediated effects of the action (cascade)
- End with benefit relevant indicators; FEGS; things that can be valued

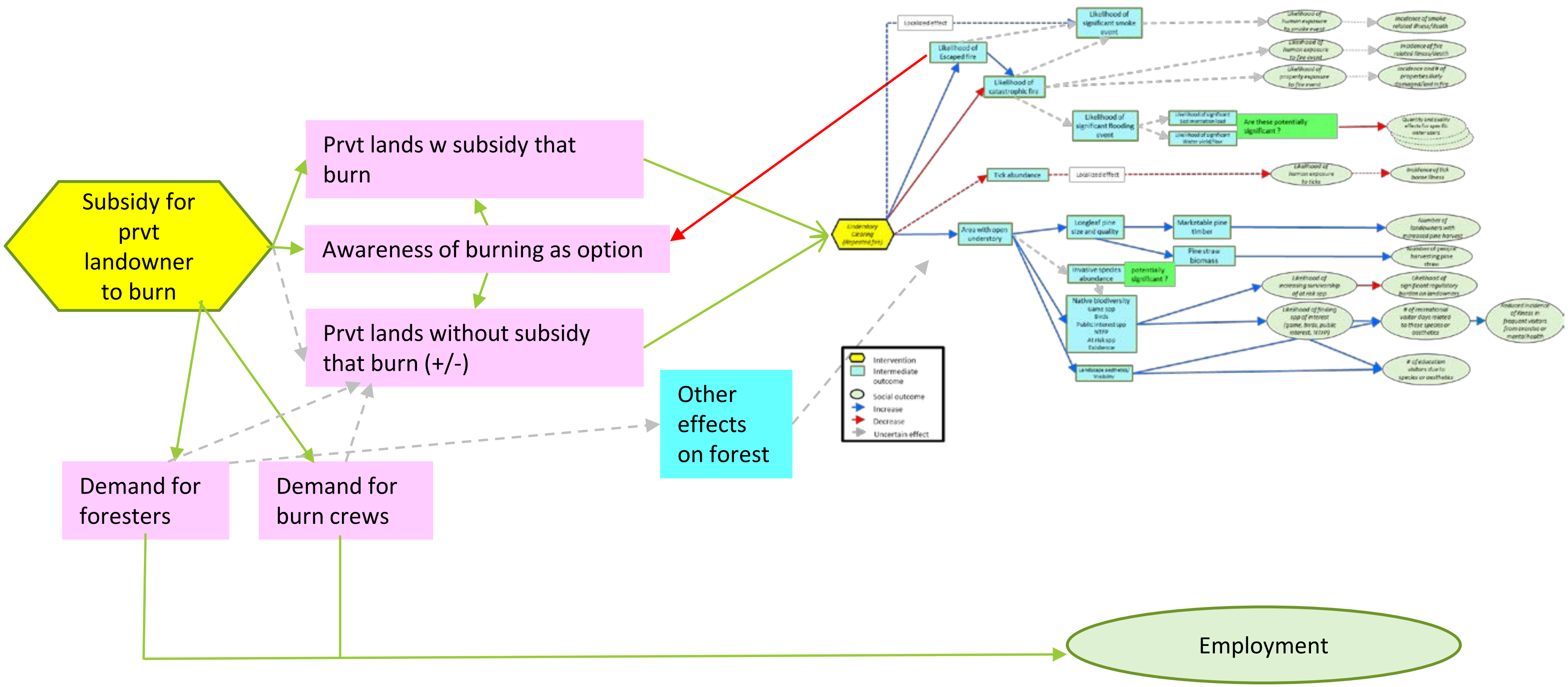
Human Welfare
- Economic implications
- Effects on critical players (e.g., landowners)
- Other well being endpoints
- Equity

Example model (center) – Longleaf pine management



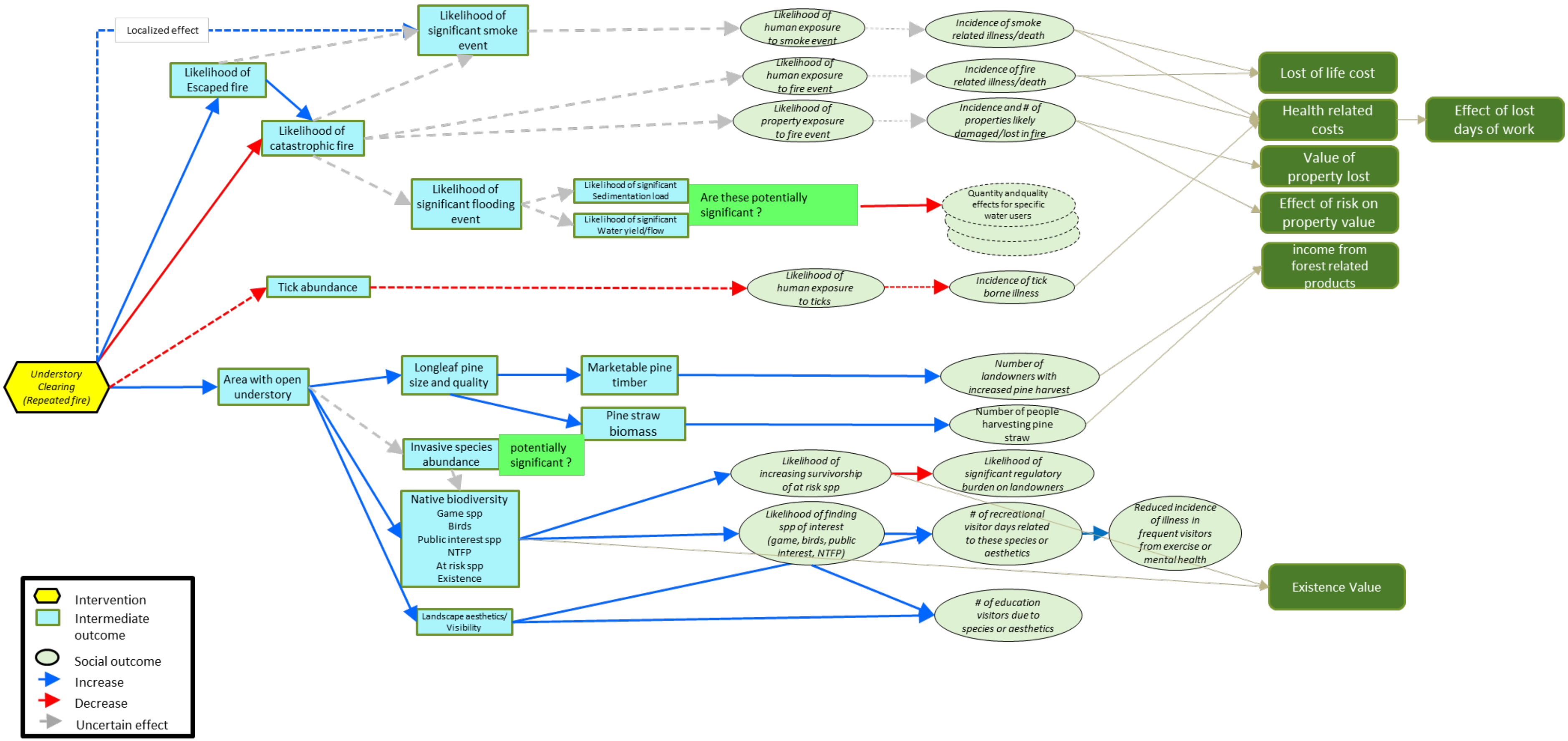
Modified by Lydia, August 31 2016
Policy/Comm Version – long term
Hypothesized outcomes

Example model (front) – Longleaf pine management



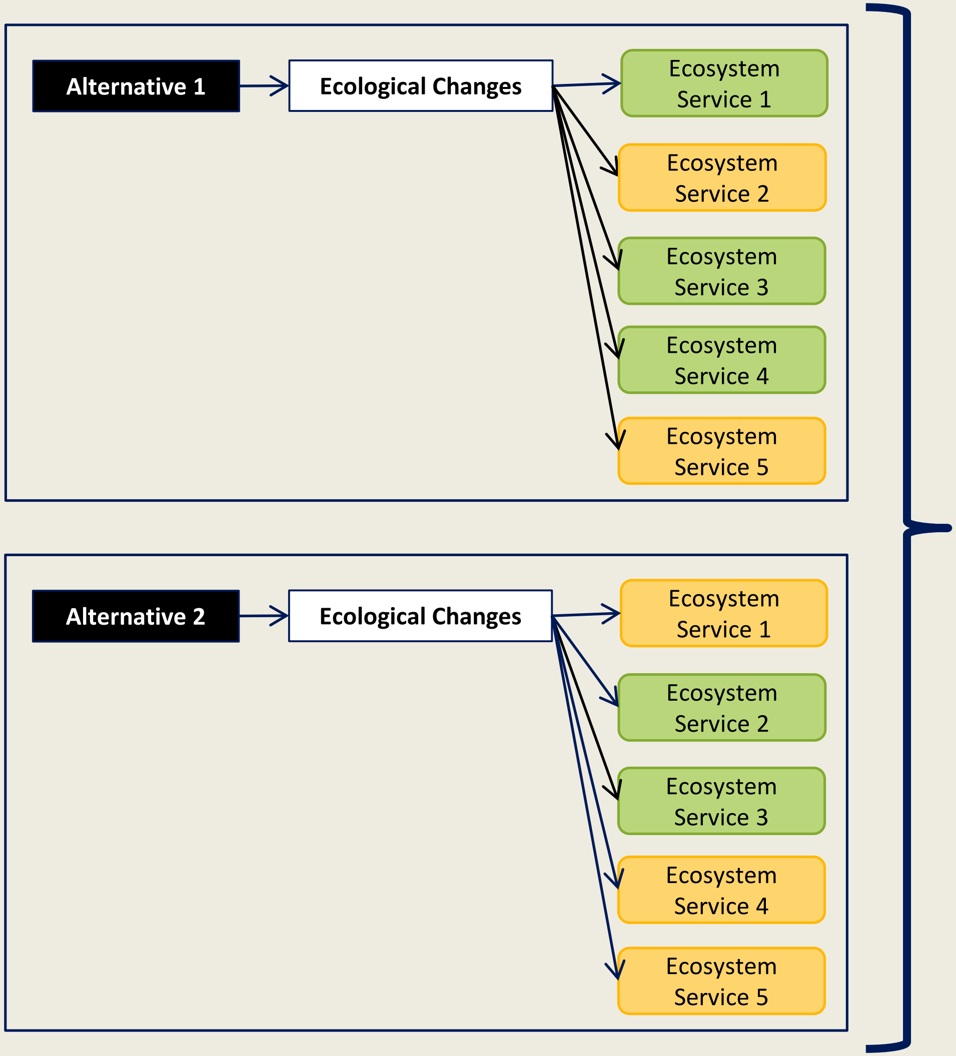
Modified by Lydia, August 31 2016
Analytical version – long term
Interventions (front end)

Example model (back) – Longleaf pine management



Modified by Lydia, August 31 2016
Analytical version – long term
Linked to values

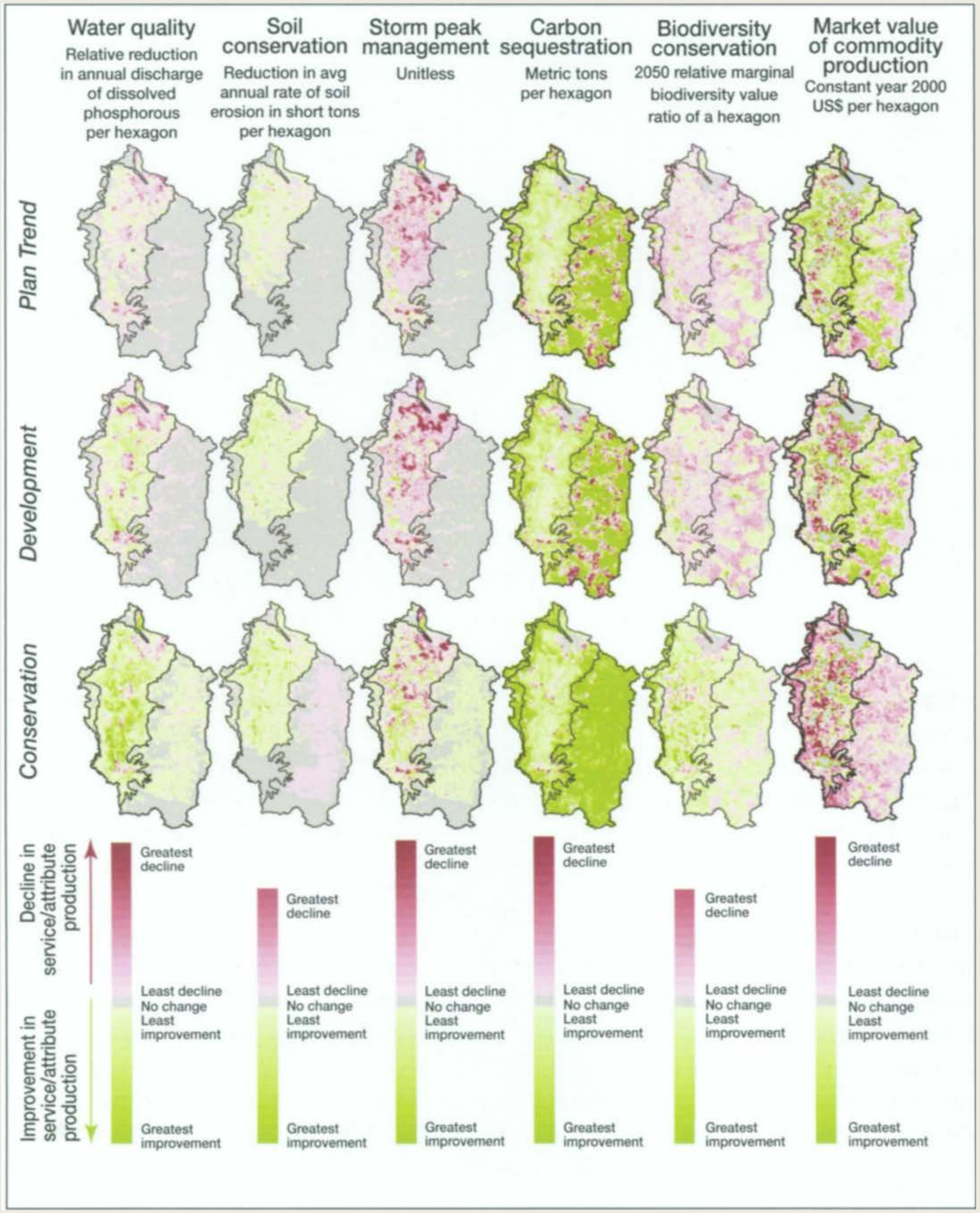
How Do They Enable Comparisons?



Ecosystem Service	Alternative 1	Alternative 2
Service 1	Increase	Decrease
Service 2	Decrease	Increase
Service 3	Increase	Increase
Service 4	Increase	Decrease
Service 5	Decrease	Decrease

But what about space? Isn't ***spatial context*** important?

Considering Space



Nelson *et al*. 2009





Creating Diagrams: An Example

Hypothetical Example

Task: reduce risk of catastrophic wildfire to urban areas and improve air quality

Fuel conditions result in a low threat to community
Visibility and healthy air maintained
Riparian areas resilient to fire

Hypothetical Example

Task: reduce risk of catastrophic wildfire to urban areas and improve air quality

Fuel conditions result in a low threat to community
Visibility and healthy air maintained
Riparian areas resilient to fire
Hunting/wildlife watching opportunities improved
Hiking/camping opportunities maintained
Timber harvest sustained
Habitats/species protected

Hypothetical Example

Task: reduce risk of catastrophic wildfire to urban areas and improve air quality

	POTENTIAL MANAGEMENT ALTERNATIVES					
	ALT. 1	**ALT. 2**	**ALT. 3**	**ALT. 4**	**ALT. 5**	**ALT. 6**
	Mechanical Thinning (Site A - Lowland)	**Prescribed Burning (Site A - Lowland)**	**Mechanical Thinning (Site B - Upland)**	**Prescribed Burning (Site B - Upland)**	**Chemical Cheatgrass Removal (Site C)**	**Chemical Cheatgrass Removal (Site D)**
Fuel conditions result in a low threat to community						
Visibility and healthy air maintained						
Riparian areas resilient to fire						
Hunting/wildlife watching opportunities improved						
Hiking/camping opportunities maintained						
Timber harvest sustained						
Habitats/species protected						

Hypothetical Example

Task: reduce risk of catastrophic wildfire to urban areas and improve air quality

	POTENTIAL MANAGEMENT ALTERNATIVES					
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6
	Mechanical Thinning (Site A - Lowland)	**Prescribed Burning (Site A - Lowland)**	**Mechanical Thinning (Site B - Upland)**	**Prescribed Burning (Site B - Upland)**	**Chemical Cheatgrass Removal (Site C)**	**Chemical Cheatgrass Removal (Site D)**
Fuel conditions result in a low threat to community	✓	✓	✓	✓		
Visibility and healthy air maintained	✓	✓	✓	✓	✓	✓
Riparian areas resilient to fire	✓	✓				
Hunting/wildlife watching opportunities improved	✓	✓				
Hiking/camping opportunities maintained	✓	✓	✓			
Timber harvest sustained	✓		✓			
Habitats/species protected	✓	✓	✓	✓	✓	✓

Hypothetical Example

Task: reduce risk of catastrophic wildfire to urban areas and improve air quality

	POTENTIAL MANAGEMENT ALTERNATIVES					
	ALT. 1	**ALT. 2**	**ALT. 3**	ALT. 4	ALT. 5	ALT. 6
	Mechanical Thinning (Site A - Lowland)	**Prescribed Burning (Site A - Lowland)**	**Mechanical Thinning (Site B - Upland)**	Prescribed Burning (Site B - Upland)	Chemical Cheatgrass Removal (Site C)	Chemical Cheatgrass Removal (Site D)
Fuel conditions result in a low threat to community	✓	✓	✓	✓		
Visibility and healthy air maintained	✓	✓	✓	✓	✓	✓
Riparian areas resilient to fire	✓	✓				
Hunting/wildlife watching opportunities improved	✓	✓				
Hiking/camping opportunities maintained	✓	✓	✓			
Timber harvest sustained	✓		✓			
Habitats/species protected	✓	✓	✓	✓	✓	✓

Building a Conceptual Diagram

OUTCOMES

Management Alternative	Intermediate Changes	Ecosystem Services

Mechanical Thinning (Site A – Lowland)

Respiratory Health

Commuter Visibility

Reduction of Fire Risk

Timber

Hiking

Camping

Recreational Hunting

Wildlife Watching

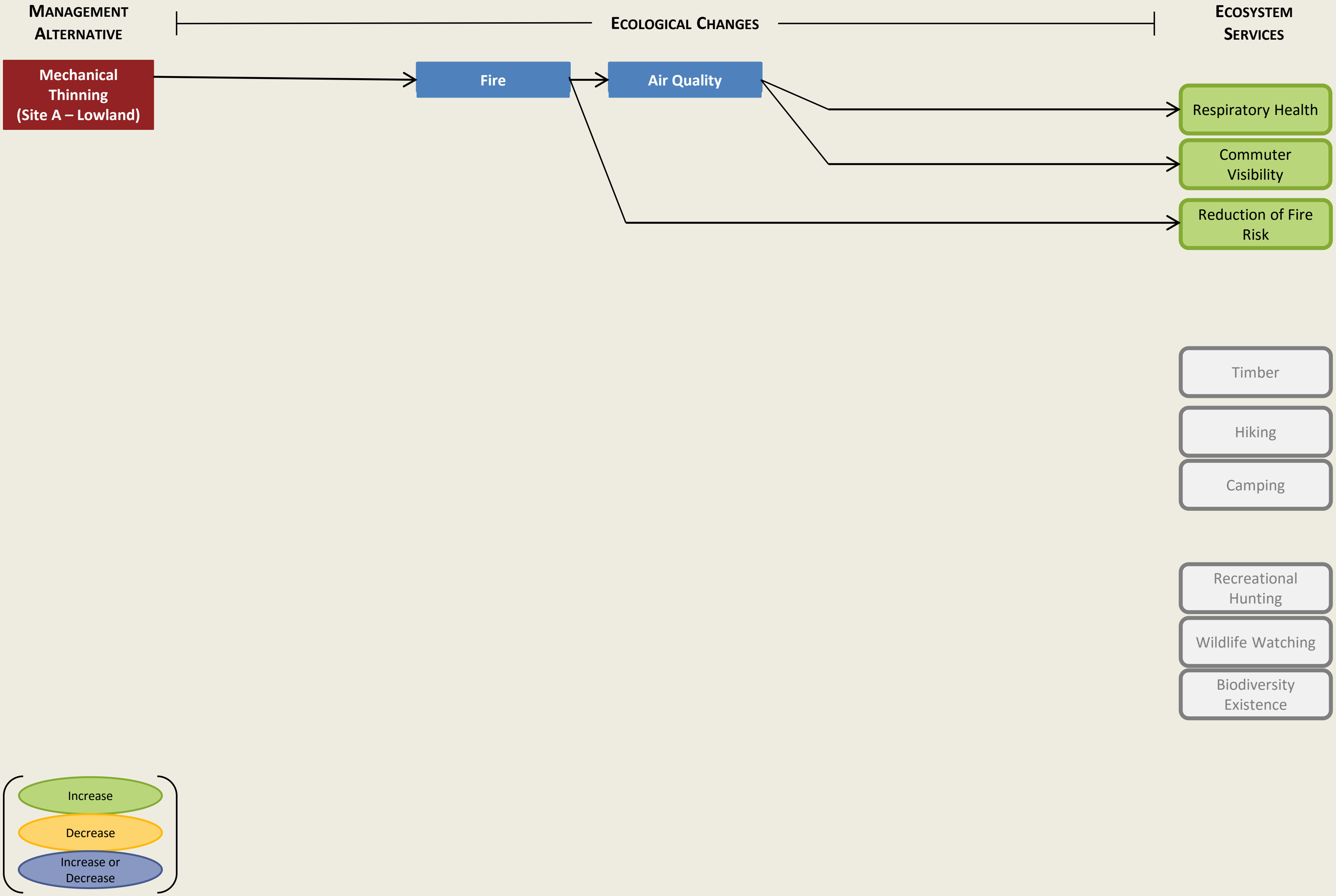
Biodiversity Existence

Increase

Decrease

Increase or Decrease

Building a Conceptual Diagram



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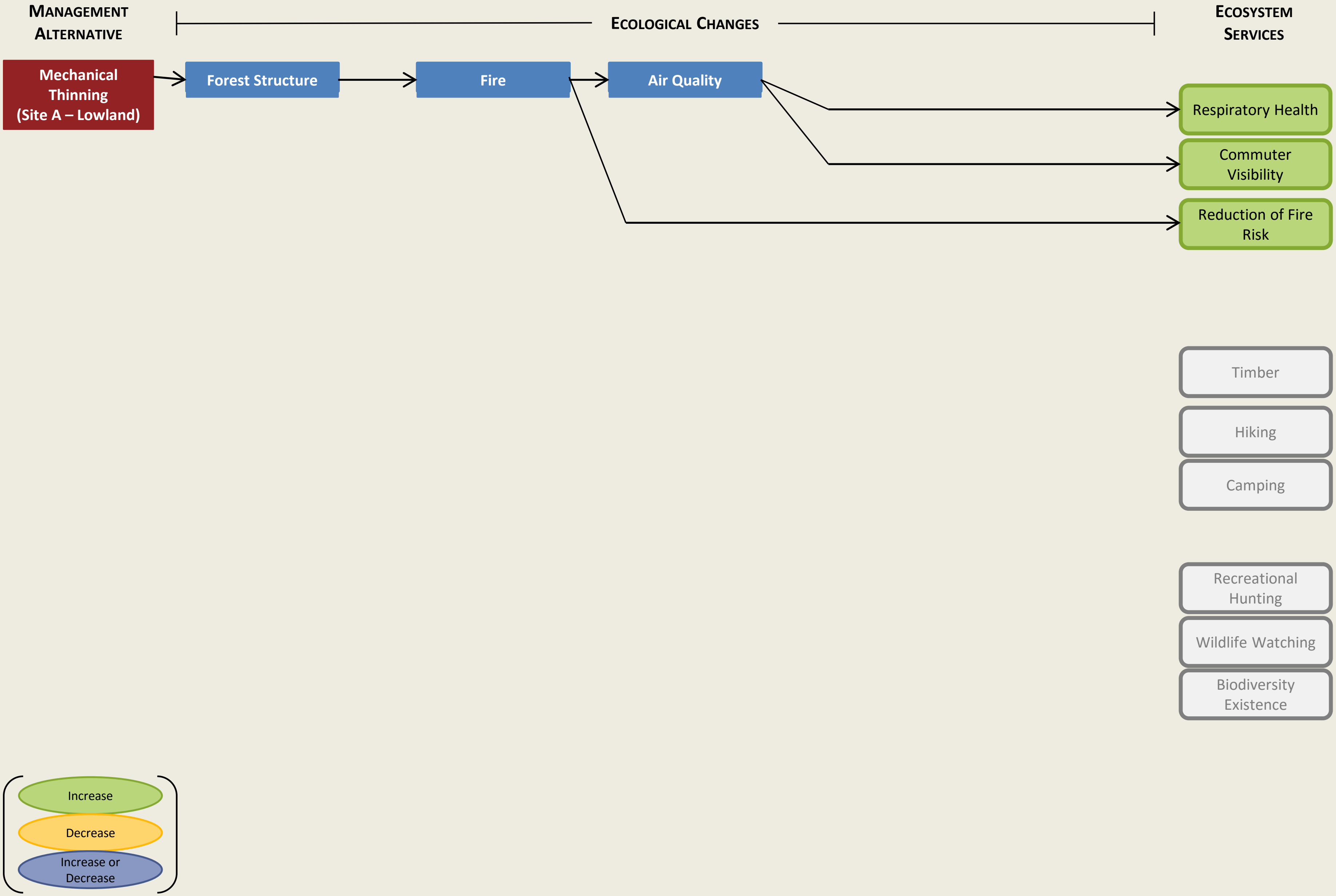

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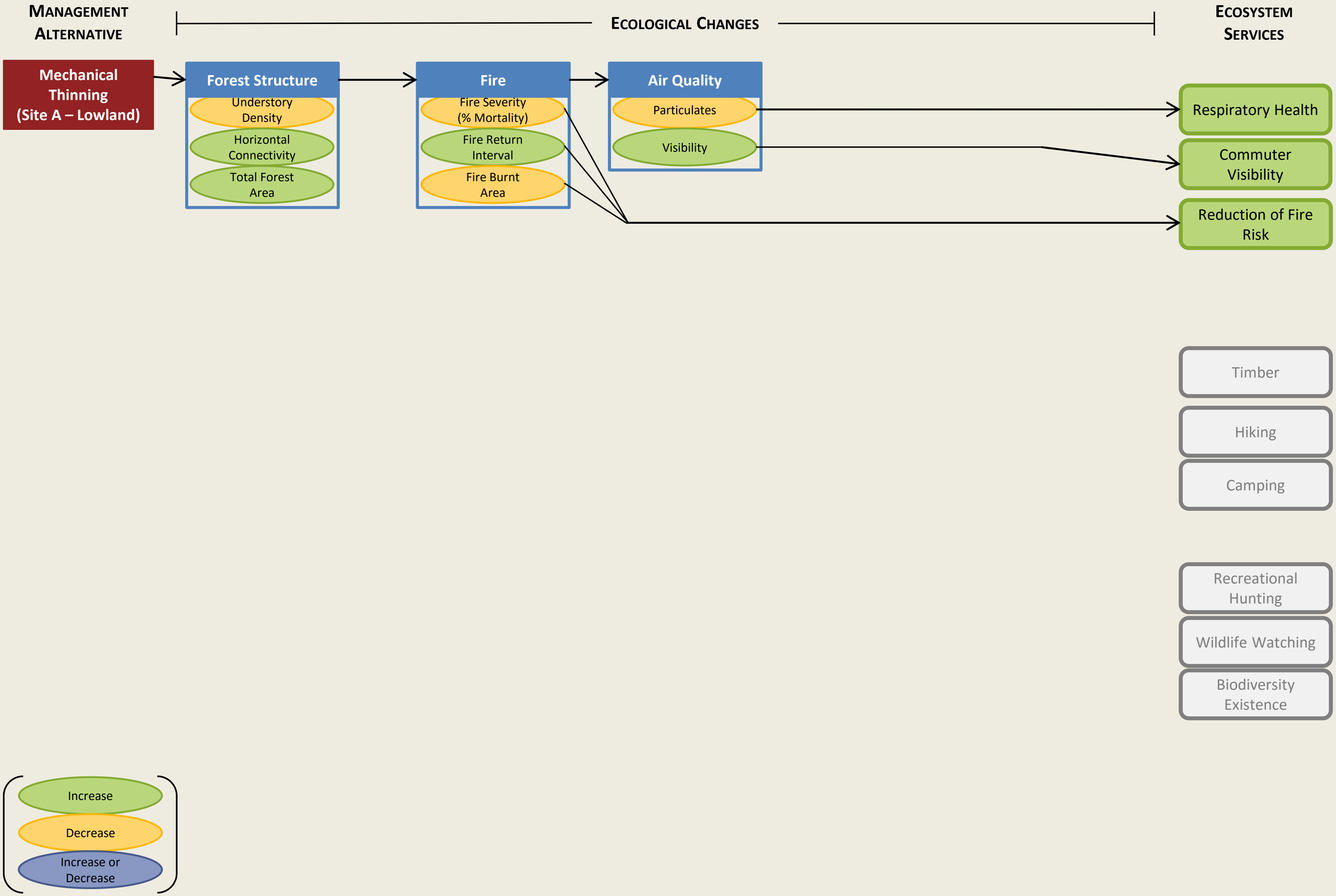

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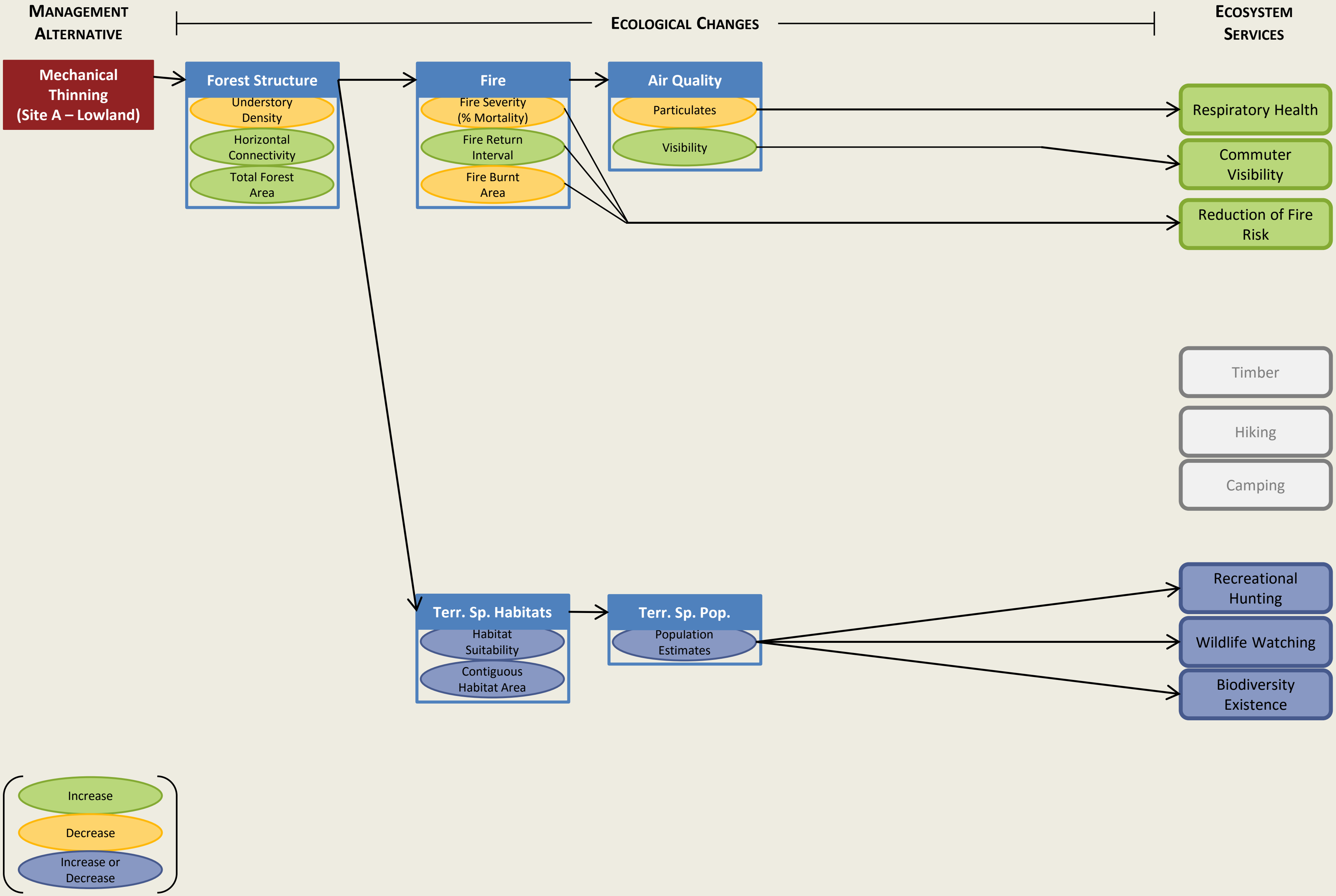

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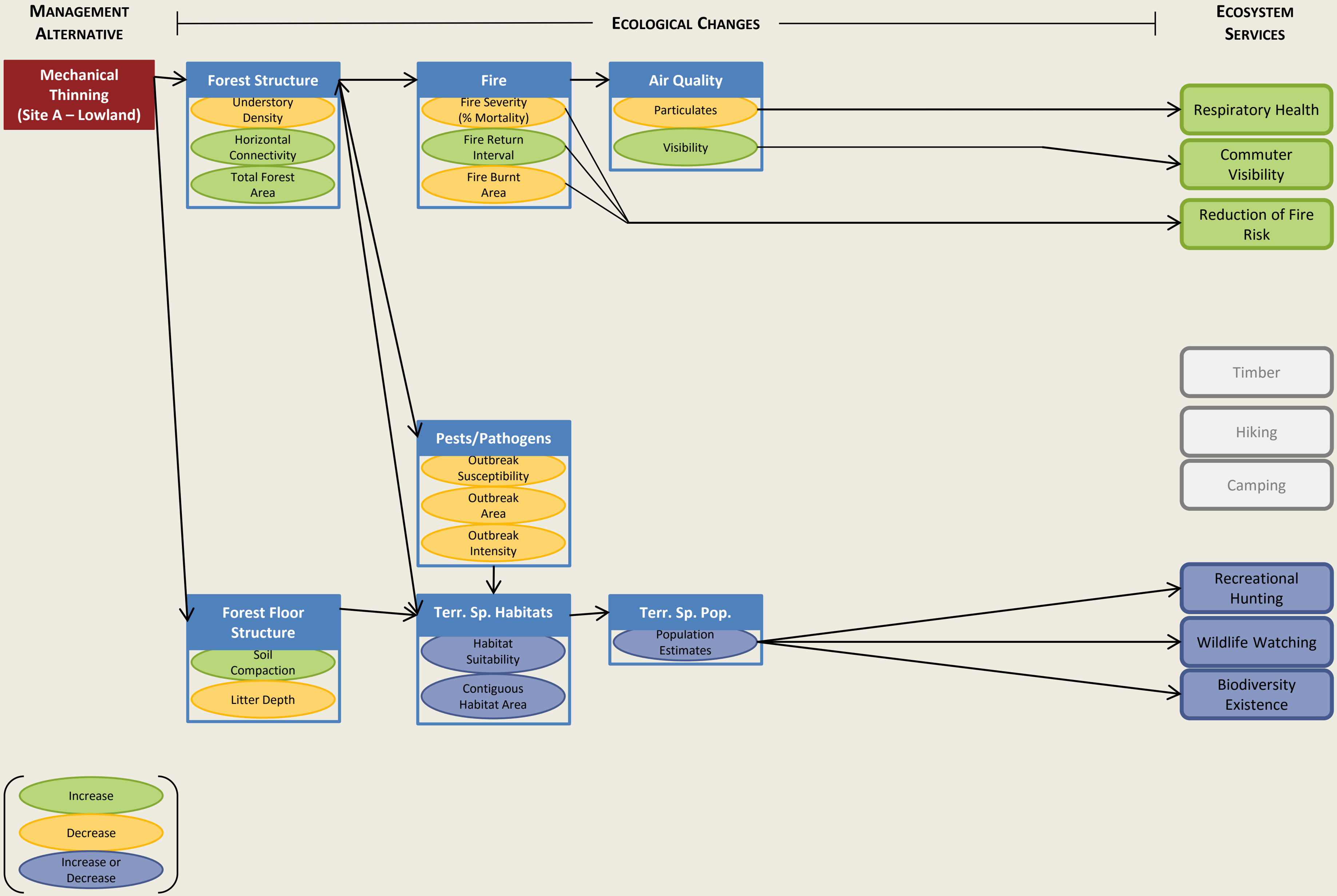

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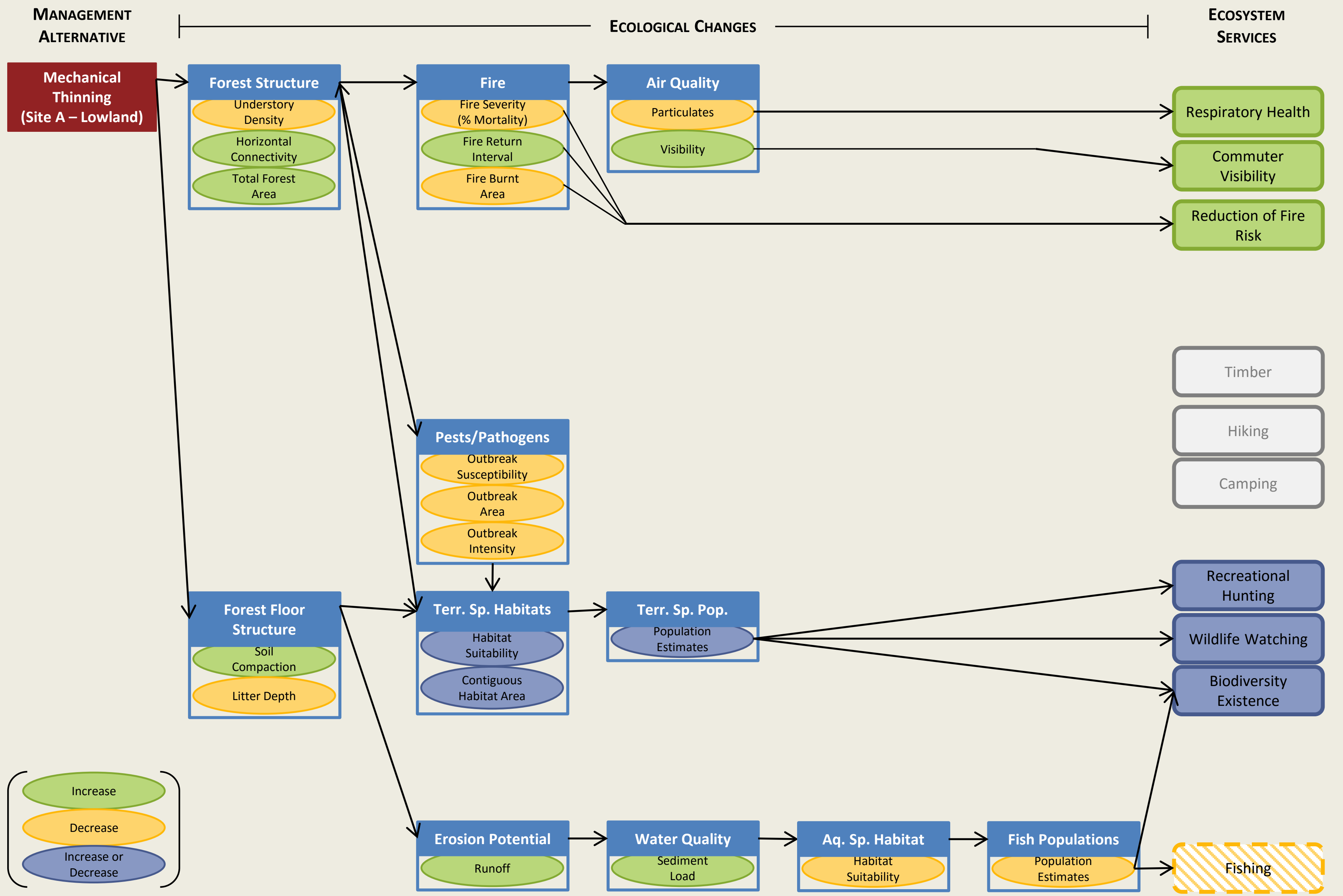

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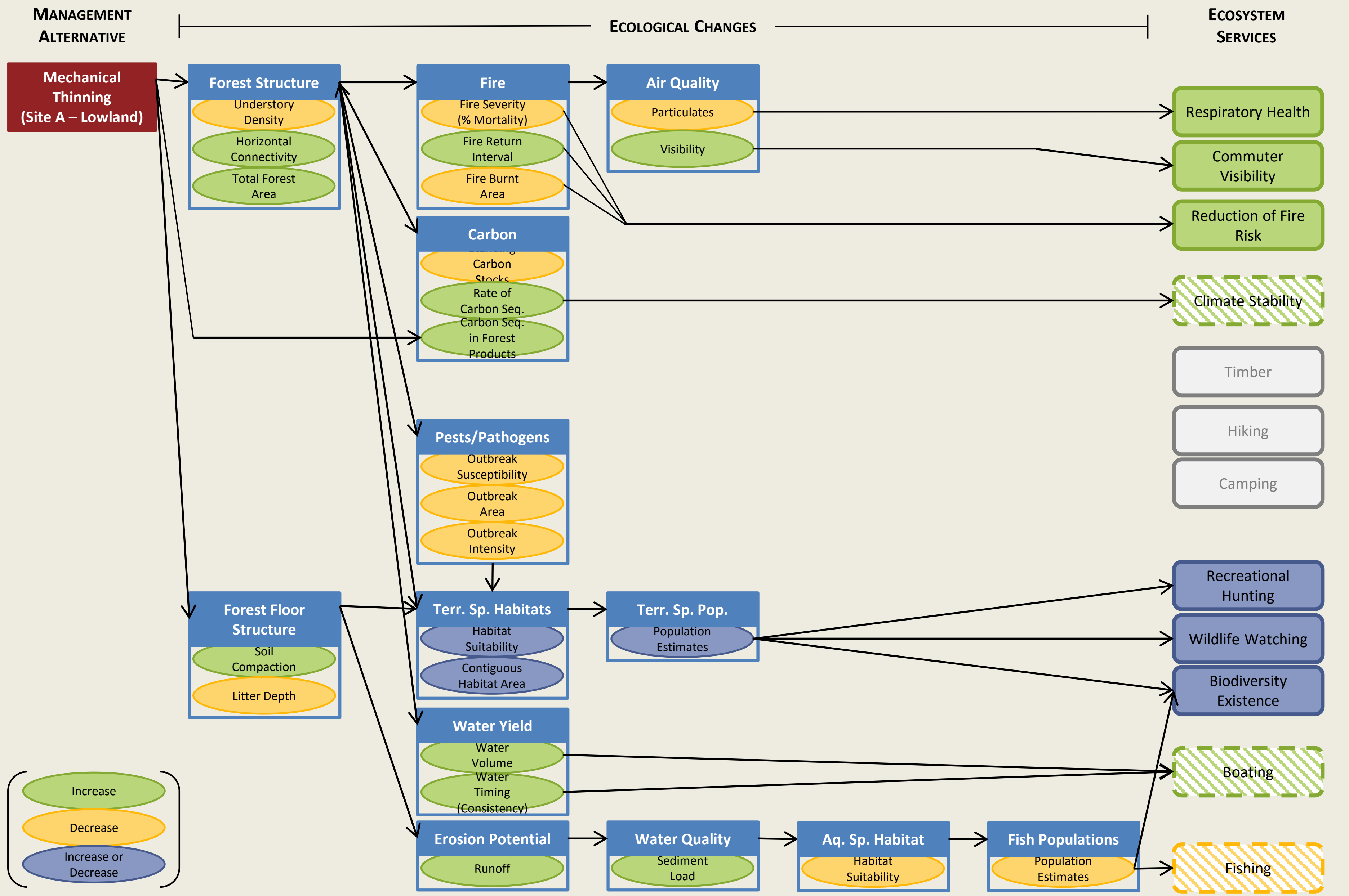

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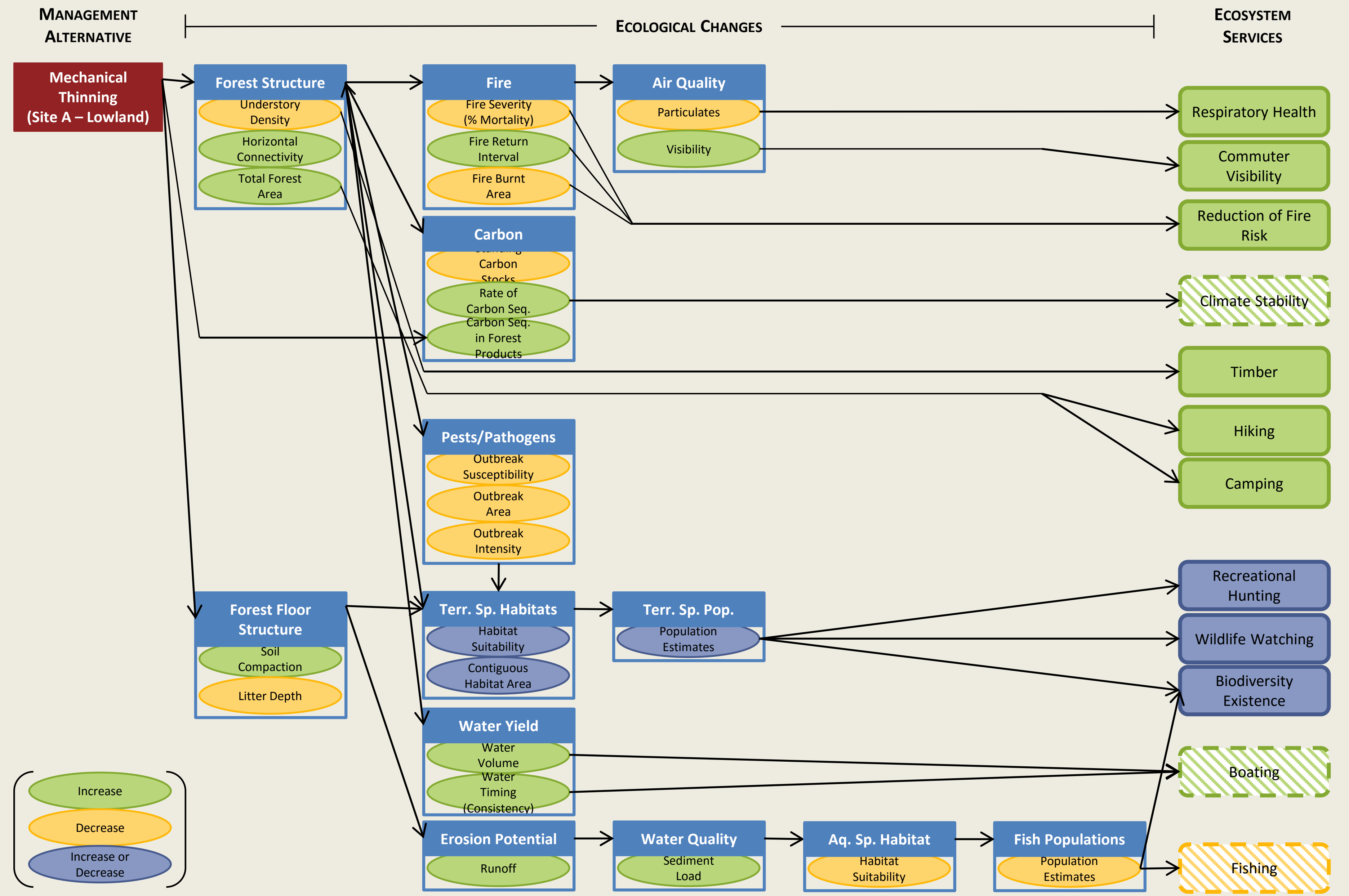
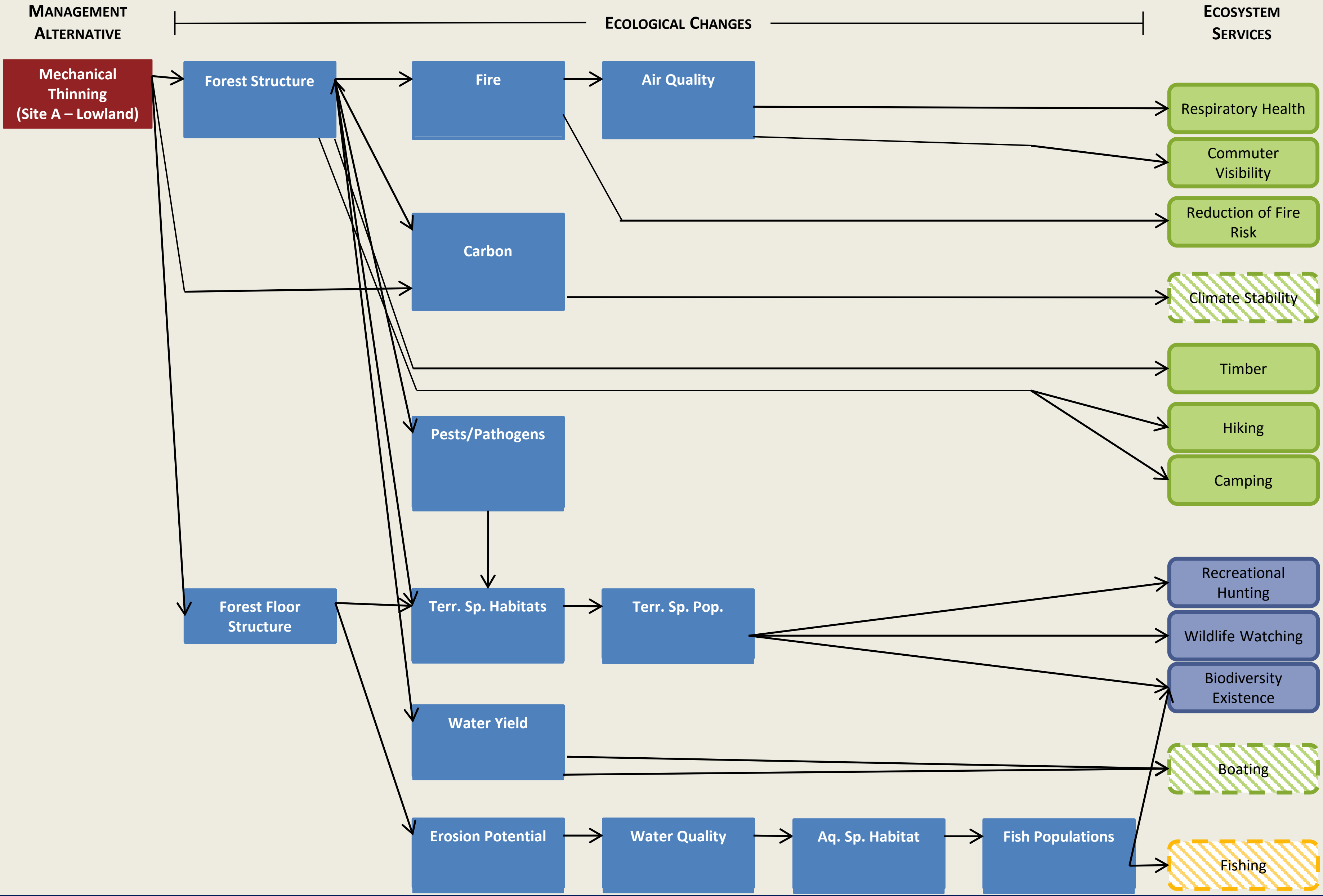
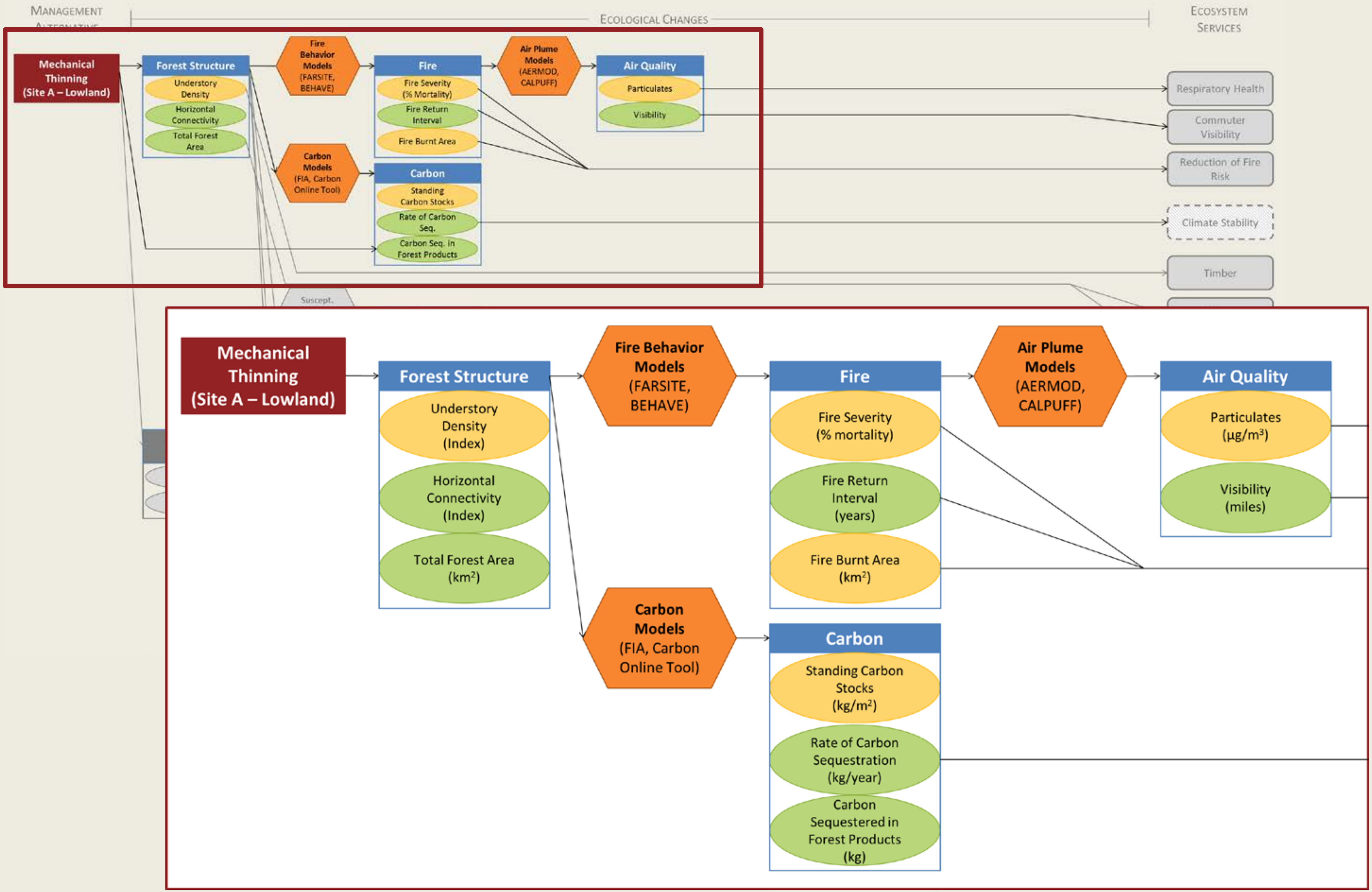


Building a Conceptual Diagram



Qualitative versus Quantitative Diagrams



Comparing Alternatives

Ecosystem Service	Mechanical Thinning (Upland)	Mechanical Thinning (Lowland)	Prescribed Burning (Lowland)
Respiratory Health	+	+	+
Commuter Visibility	+	+	+
Fire Risk Reduction	+	+	+
Climate Stability	+	+	+
Timber	**+**	**+**	**No change**
Hiking	+	+	+
Camping	+	+	+
Recreational Hunting	+/-	+/-	+/-
Wildlife Watching	+/-	+/-	+/-
Biodiversity Existence	**+**	**++**	**++**
Boating	+	+	+
Fishing	**No change**	**-**	**-**

How Are These Diagrams Useful?

- Identify the ***cascade of ecological interactions*** caused by a management, project, or policy
- Helps identify ***indicators*** to measure those changes
- Provide a visual representation of ***benefits and tradeoffs***
- Show ***analysis steps*** and ***data/models needed***
- Highlight what is ***known and not known*** integrating data and models

Adding the social stuff

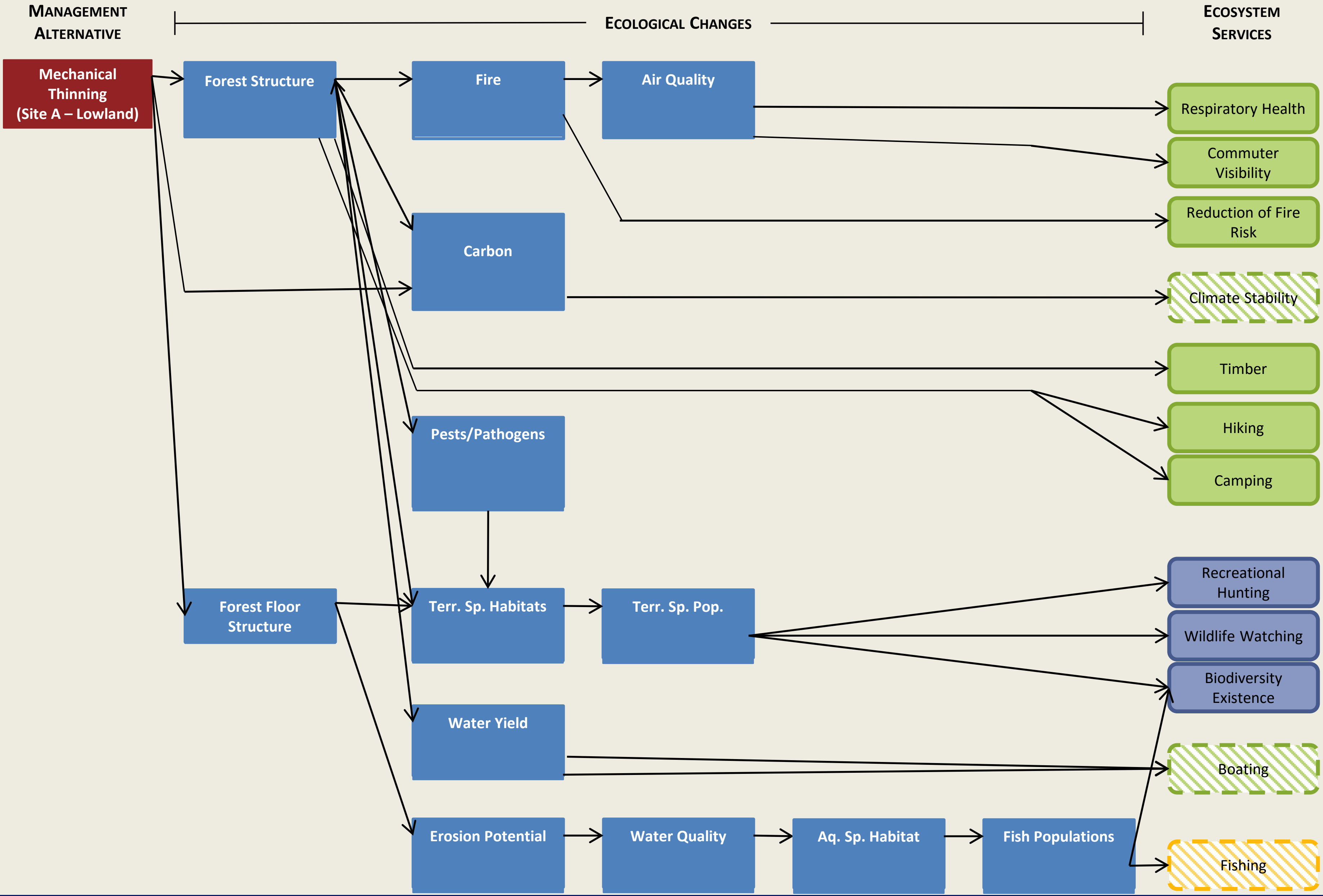
Improving the right side of the chains

Identifying the BRIs

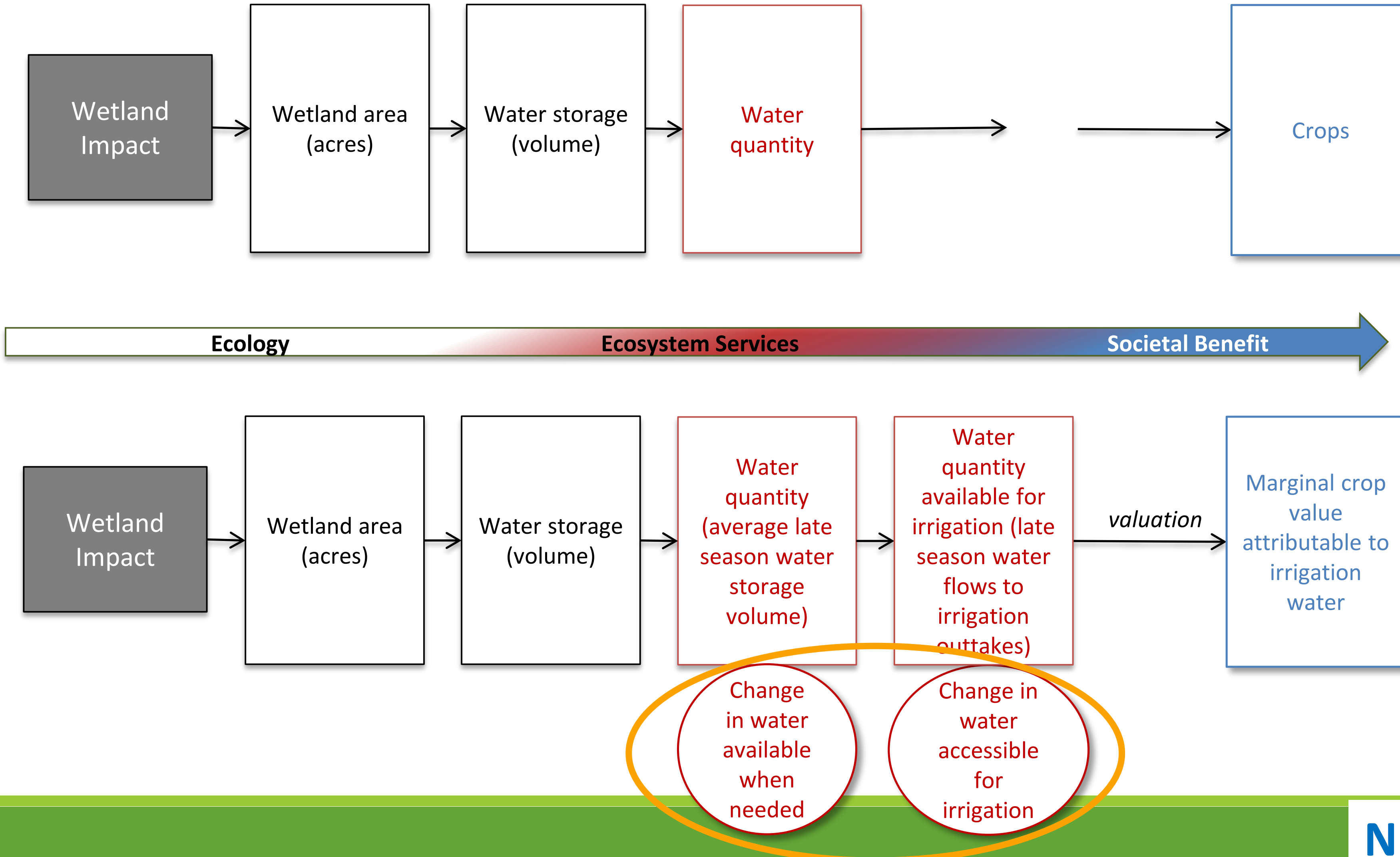
Who is affected (who are the beneficiaries)?

How are they affected?

Building a Conceptual Diagram



Benefit Relevant Indicators



NESP

Conceptual models & BRI quantification

Measure Change in ES

- Narrative descriptions of changes in ES (NOT meet best practices standard)
- Expert elicitation (informal, formal, Bayesian belief networks)
- Empirical models (existing or new) – e.g., USFS fire models

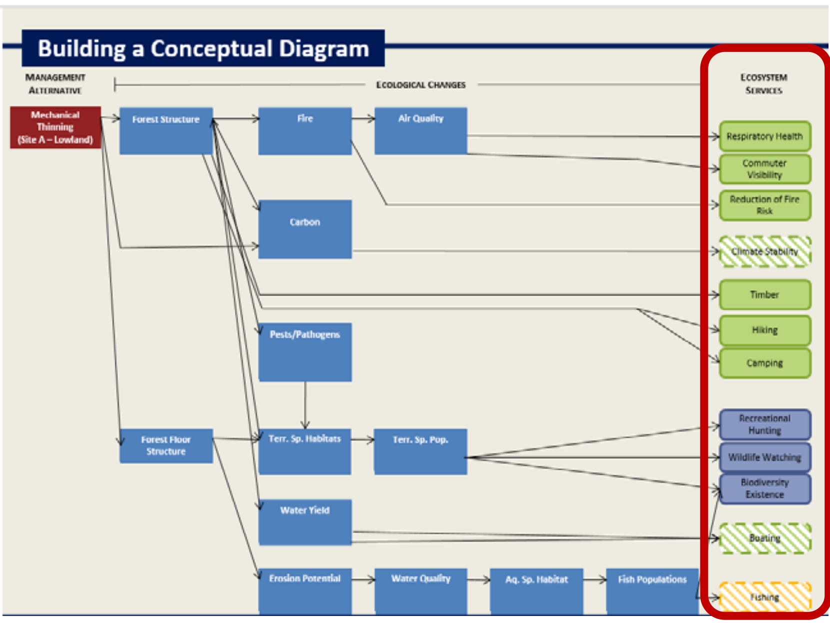
Identify & Quantify Who is Affected

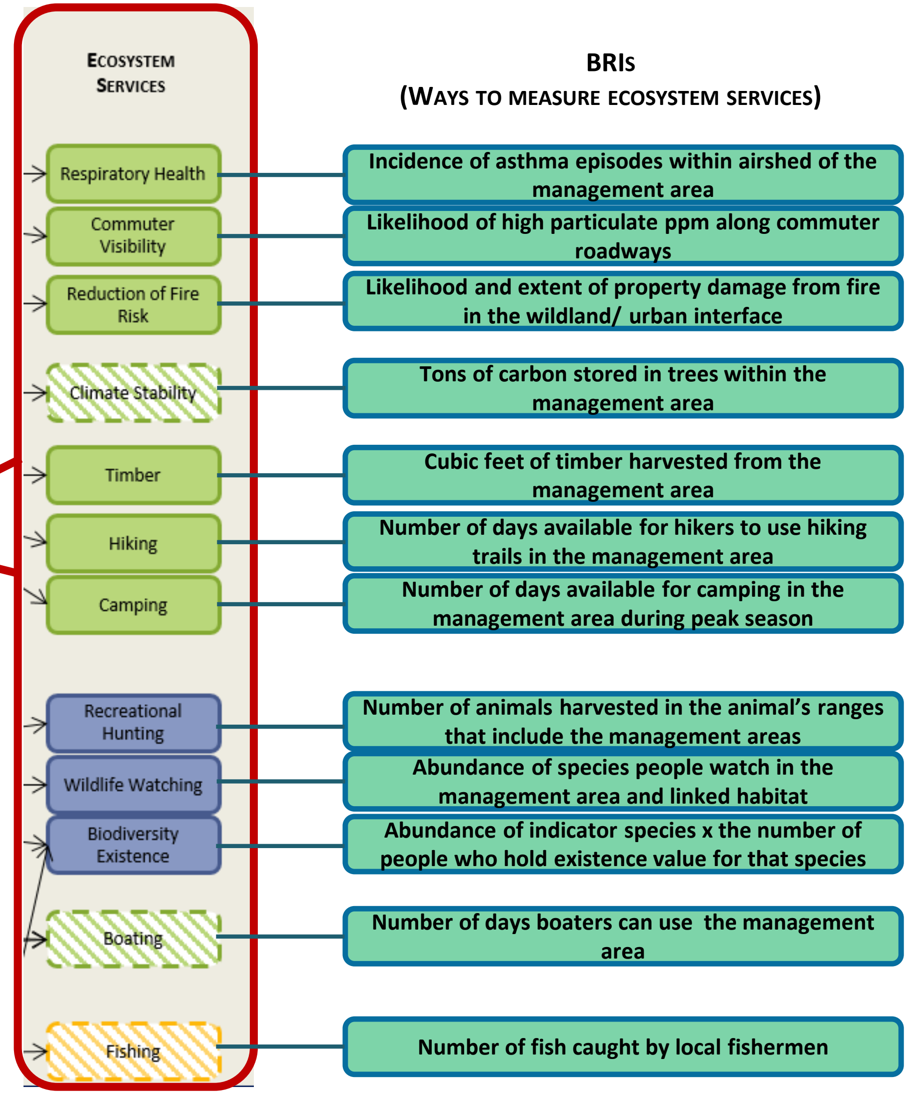
- Define the serviceshed and flow of services
- Social and Economic Context

Assessing Benefits – Valuation & Preference Methods

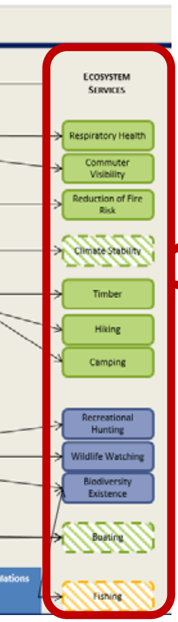
- Monetary and Non-monetary valuation

Extending to BRIs
(Benefit Relevant Indicators)





Extending to BRIs and to Values



Ecosystem Services	BRIs (Ways to measure ecosystem services)	Values
Respiratory Health	Incidence of asthma episodes within airshed of the management area	Likelihood and cost of additional hospitalizations and missed days of work
Commuter Visibility	Likelihood of high particulate ppm along commuter roadways	Likelihood and cost of traffic and collisions
Reduction of Fire Risk	Likelihood and extent of property damage from fire in the wildland/ urban interface	Likelihood and cost of property damage from fire in the wildland/ urban interface
Climate Stability	Tons of carbon stored in trees within the management area	Social Cost of carbon stored in trees within the management area
Timber	Cubic feet of timber harvested from the management area	Timber value harvested from the management area
Hiking	Number of days available for hikers to use hiking trails in the management area	Value to hikers for an extra day X Number of days available for hikers to use hiking trails
Camping	Number of days available for camping in the management area during peak season	Value to campers for an extra day X Number of days available for camping during peak season
Recreational Hunting	Number of animals harvested in the animal's ranges that include the management areas	Value to hunters of additional animal harvested X Number of animals harvested
Wildlife Watching	Abundance of species people watch in the management area and linked habitat	Value to visitors of additional animals viewed X Abundance of species people like watching
Biodiversity Existence	Abundance of indicator species x the number of people who hold existence value for that species	Existence value held X Abundance of indicator species
Boating	Number of days boaters can use the management area	Value of additional boater days X Number of days boaters can use the management area
Fishing	Number of fish caught by local fishermen	Value of additional fish caught x Number of fish caught by local fishermen

Conceptual models & quantification

Measure Change in ES

- Narrative descriptions of changes in ES (NOT meet best practices standard)
- Expert elicitation (informal, formal, Bayesian belief networks)
- Empirical models (existing or new) – e.g., USFS fire models

Identify & Quantify Who is Affected

Tools to help?

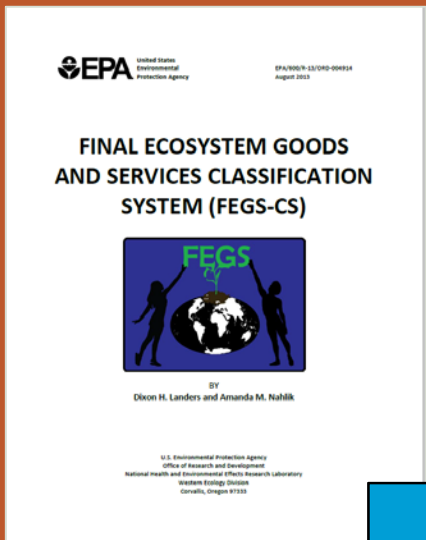
- Define the serviceshed and flow of services
- Social and Economic Context

Assessing Benefits – Valuation & Preference Methods

- Monetary and Non-monetary valuation

ES Classification Systems

Example : Recreational Fishing

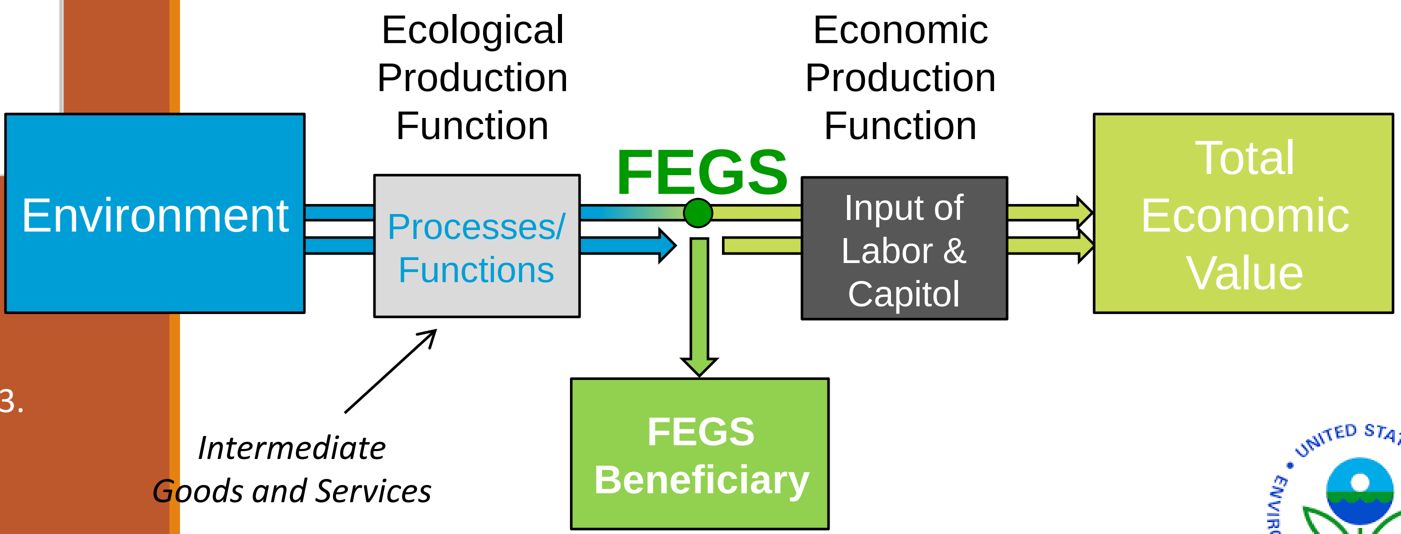

EPA United States Environmental Protection Agency

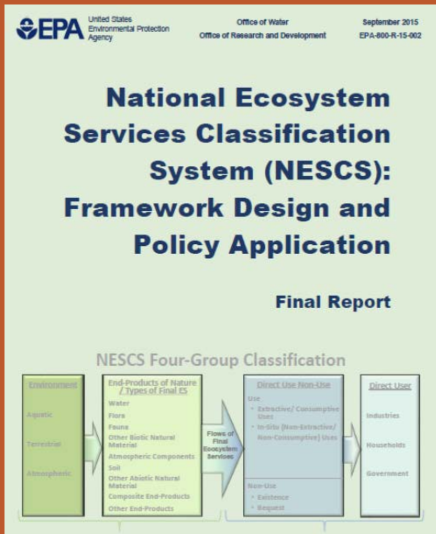
FINAL ECOSYSTEM GOODS AND SERVICES CLASSIFICATION SYSTEM (FEGS-CS)

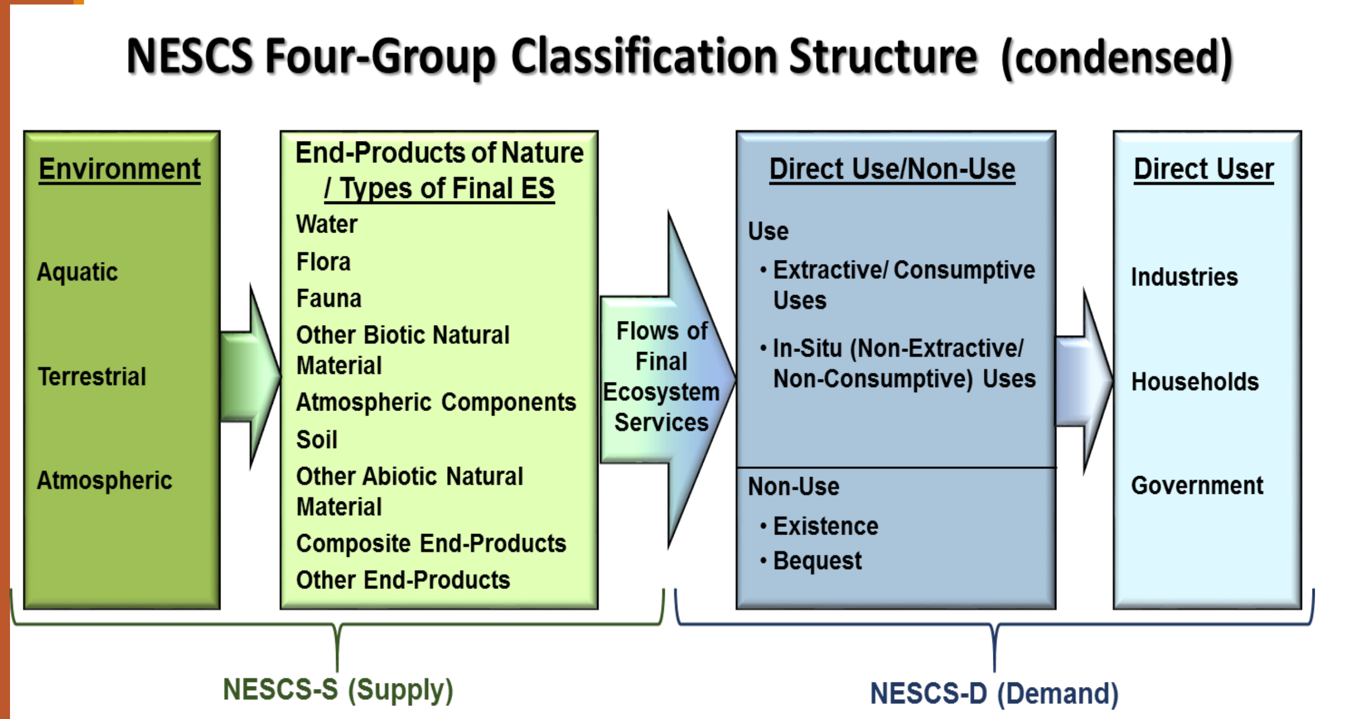
FEGS

BY
Dixon H. Landers and Amanda M. Nahlik

Dixon Landers and Amanda Nahlik 2013. EPA report.



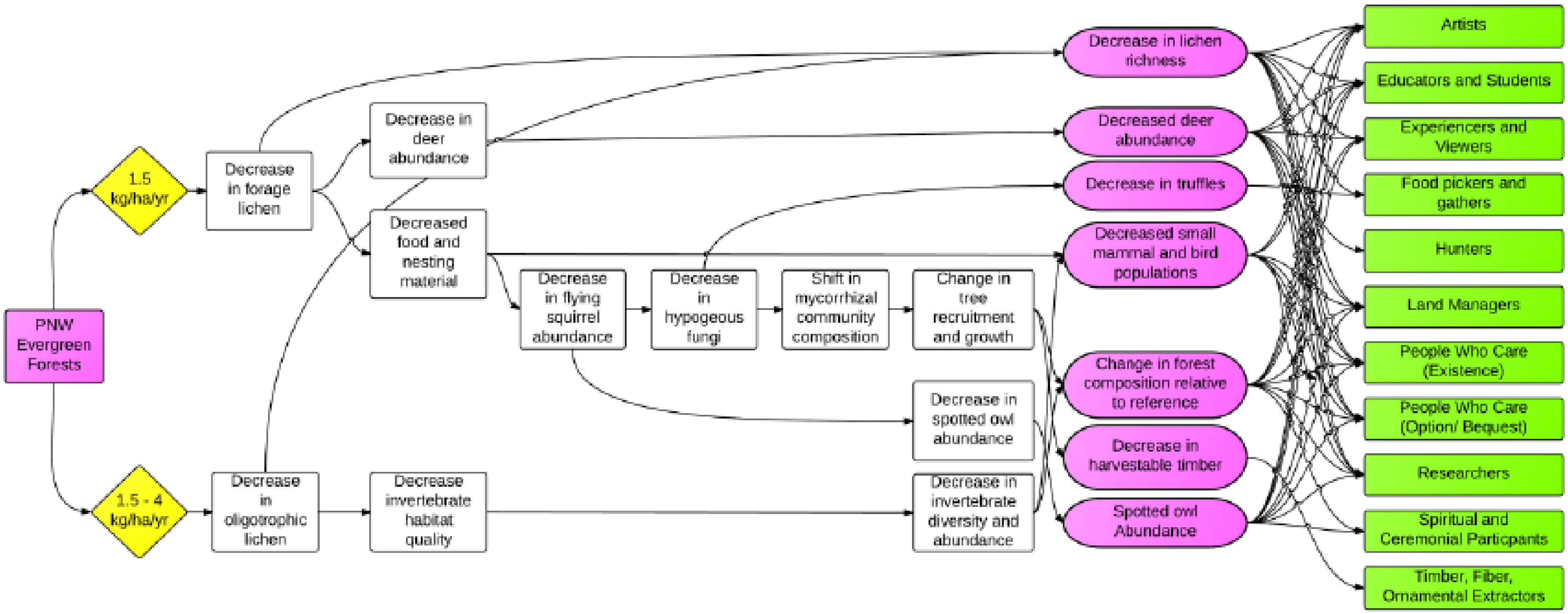




United States Environmental Protection Agency. 2015. *National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application*. EPA-800-R-15-002. United States Environmental Protection Agency, Washington, DC.

Who - ENDPOINTS (Beneficiaries)

Example from NPS and EPA on the effects of air pollutant levels. Used FEGS to identify beneficiaries. Does not include direct social effects.



Human Well Being Endpoints

Not a Brave New World

Synthesize and Simplify

Human Wellbeing World

Frameworks

Social Return on Investment

WB Attacking Poverty Framework

Capitals Framework/Wealth

⋮

Indicators

Unsatisfied Basic Needs

Human Development Index

Green GDP

Inclusive Wealth Index

⋮

Methods

WB Living Standards Measurement Survey

USAID Demographic and Health Survey

IFPRI Harvest Choice Surveys

IIED Monitoring PES

CIFOR Livelihood Impacts of REDD+

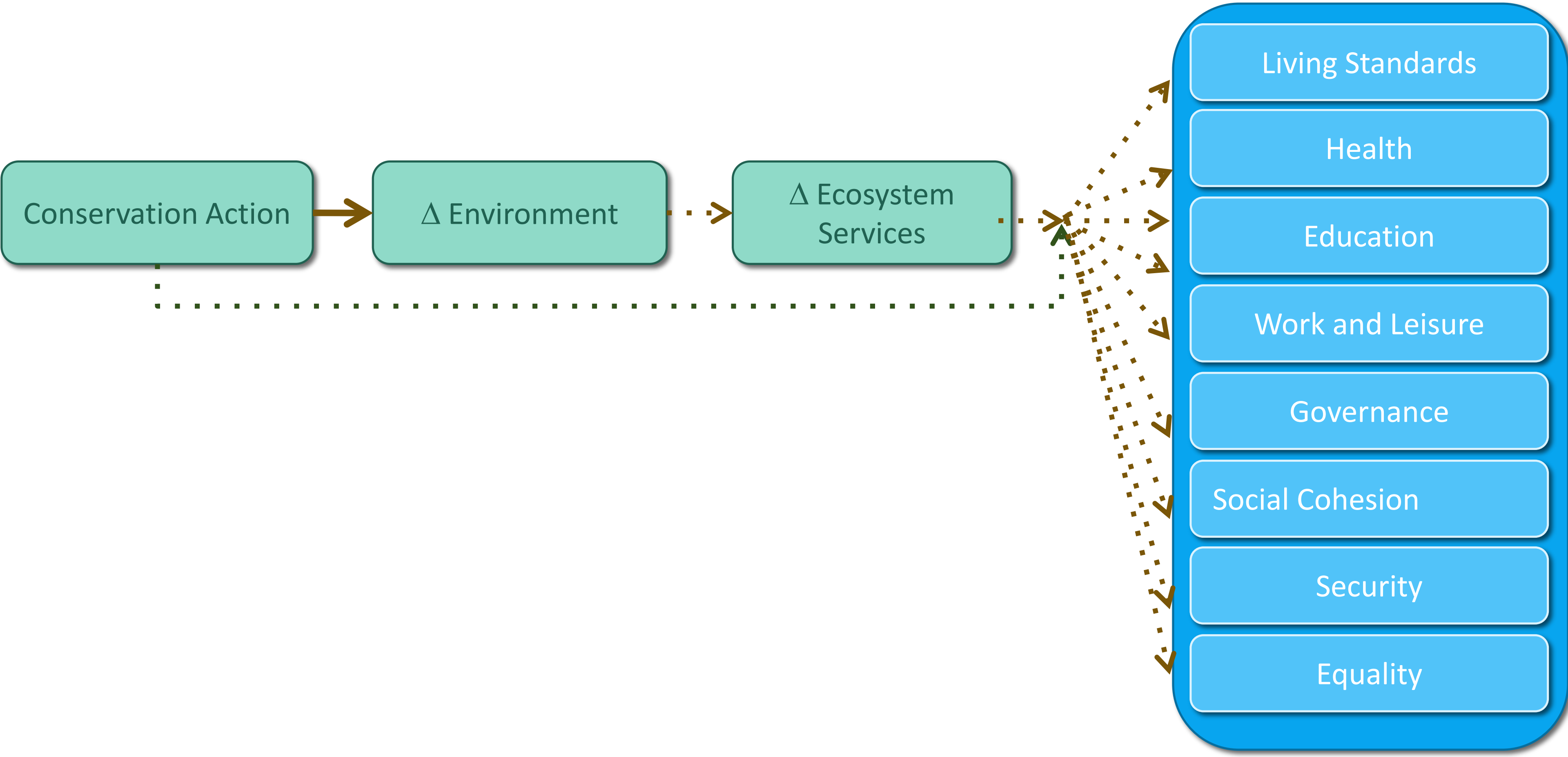
WCS Basic Necessities Survey

WWF Marine Livelihoods

Vital Signs

⋮

Human Well Being – What ENDPOINTS



Human Well Being Focal Areas and Components

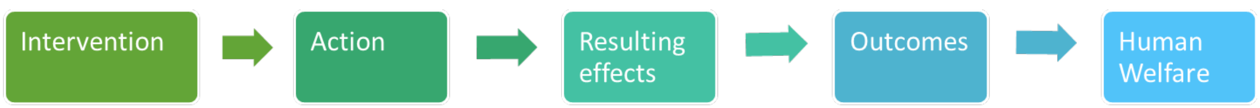
Living Standards	
Components	Sample Indicators
Income Wealth Water Housing Material Goods	- Household income from specific activity (e.g. fishing) - Population owning a bike (or other) - Urban people with access to clean water - Number of rooms in household - People with access to ecosystem good (e.g. timber, charcoal) - People below poverty line

Human Well Being Focal Areas and Components

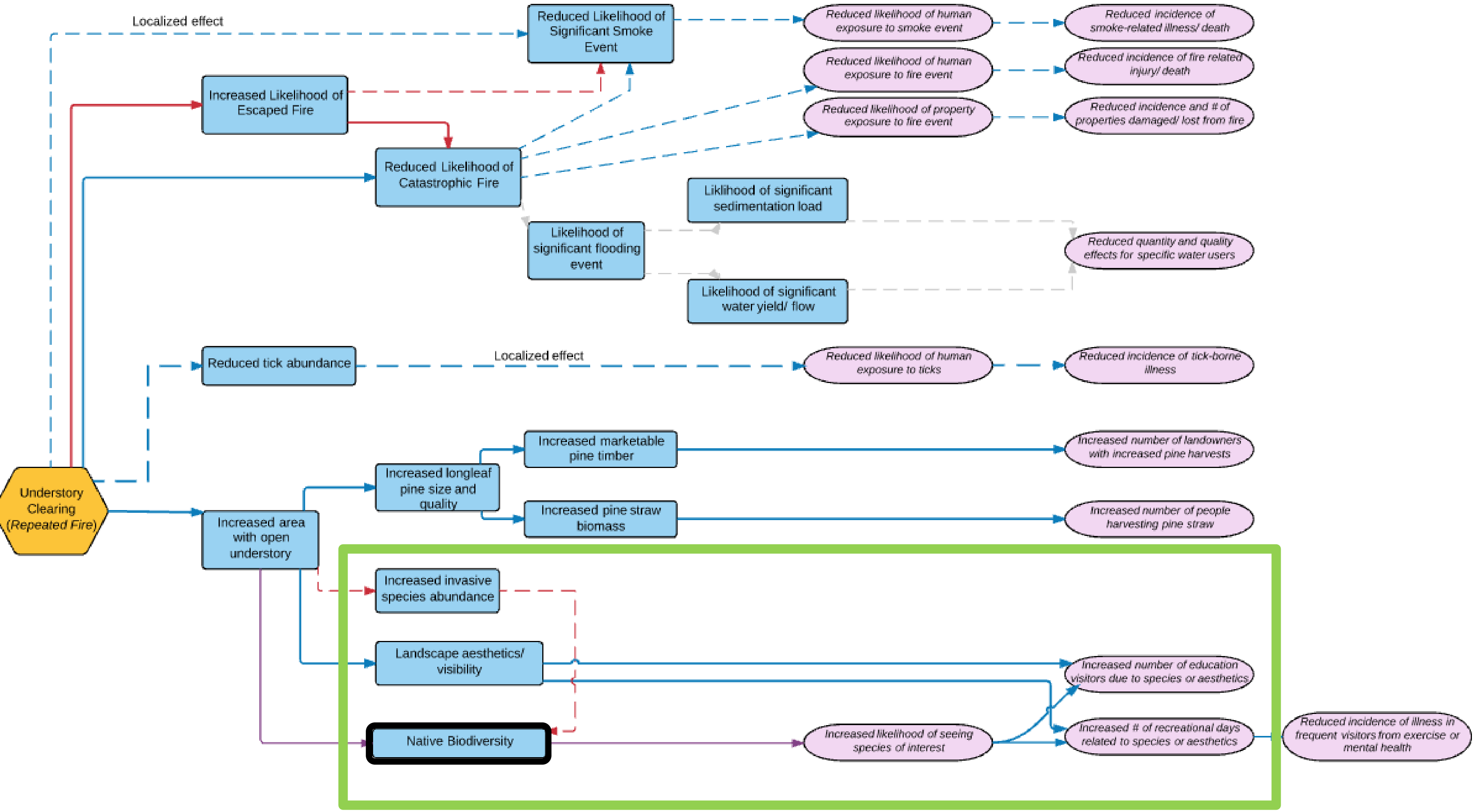
Health	
Components	**Sample Indicators**
Life expectancy Maternal health Child health Nutrition Water borne disease Vector borne disease Respiratory health Mental health	- People with access to health services - Child malnutrition rate - Malaria exposure risk - Hospital admissions with specific symptoms - % protein from wild food sources - Rate of medicinal plant use - Performance on cognitive tests

Consider what type of diagram/model you want to build?

- What is the purpose of model/diagram
  - Communication,
  - Identifying ecosystem services indicators,
  - Identifying ecosystem services of interest important in a decision context,
  - Identifying what is known and key research gaps,
  - Quantifying ecosystem services,
  - Informing a decision with trade-offs
- Do you need the whole chain or part of chain?

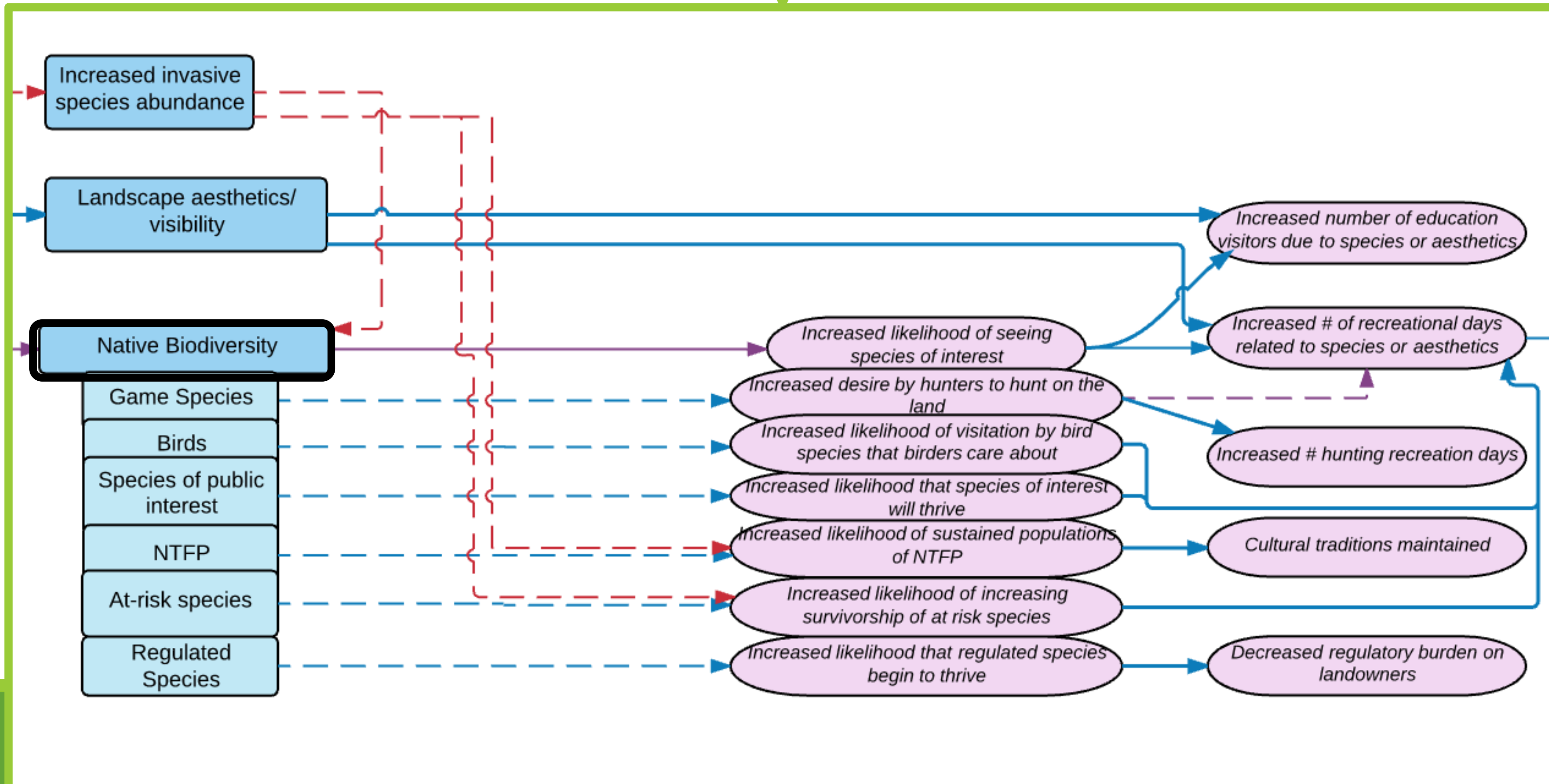


- Should the focus be long term effects, or short term, or do you need both?
- Does it need to capture local or large scale effects or both?
- What level of detail is needed? (High level model or exploded detail?)



"Exploding" biodiversity model (un-exploded)

Exploded model



Causal Chain/Logic Model Principles

Principle	Fire Example
Define a current challenge and decision context relative to environmental conditions and specific economic or social challenges to specific groups.	Frequent catastrophic fire in Western US threaten species, houses and lives. The USFS has to decide if thinning is a good strategy to reduce catastrophic fire and associated risks for nature and people.
Define a set of directional and quantifiable environmental, social and/or economic goals. -Social or economic goals should be specific to one beneficiary group. -Ecological goals should be specific to one process or element	Free threatened species from catastrophic fire risk. Reduce local resident's property loss from catastrophic fire by 50%. Reduce local resident and firefighter mortality from catastrophic fire by 80%.
Identify a focal intervention (single alternative) -include additional interventions if a goal is dependent on its interaction with the focal intervention -if combining multiple interventions, follow same principles for connecting logic chains between interventions	Thinning of small trees
Fill in the logical, expected changes between the intervention and the goals. -create boxes that represent one specific characteristic or property. Use nouns. -create directional arrows that represent single mechanistic or behavior relationships between two boxes. -stop chains at first human well-being change unless extending further is essential to the decision context.	Box: frequency of catastrophic fire near people Box: exposure to fire Box: mortality in fire prone areas Box: Density of large individual fire-tolerant trees Box: Area of fire-resistant habitat for threatened species

Causal Chain/Logic Model Principles

Principle	Fire Example
Write down assumptions for each arrow. Include assumptions that -describe the mechanism or behavioral relationship -relate to the magnitude of the effect - Consider if there are significant confounding, mediating, or moderating effects	Box1: Reduced exposure to smoke—Box 2: Less morbidity Assumptions: -Being exposed to less smoke lowers illness (morbidity) -Smoke exposure is a relatively large risk factor for local morbidity -There is not another disease risk factor commonly co-occurring with smoke.
Review the chain and consider -any additional positive or negative outcomes from the intervention or expected changes. -major additional drivers that alter relationships and include those as assumptions or new boxes and arrows.	
Consider any possible feedbacks and if they are essential to the decision context, include as additional links in chain or capture as assumptions.	Lower property damage from fire could lead to more people moving in to the area. This could reduce the strength of the effect of reduced catastrophic fires on property damage. If there is more property to damage, there may be the same level of property damage even if fires are less frequent. Add an assumption that fewer catastrophic fires lead to less property damage if local residential building density remains constant or declines.
Review the chain and remove any linkages that are not essential to the decision context.	

Testing your model/diagram: Ask these questions

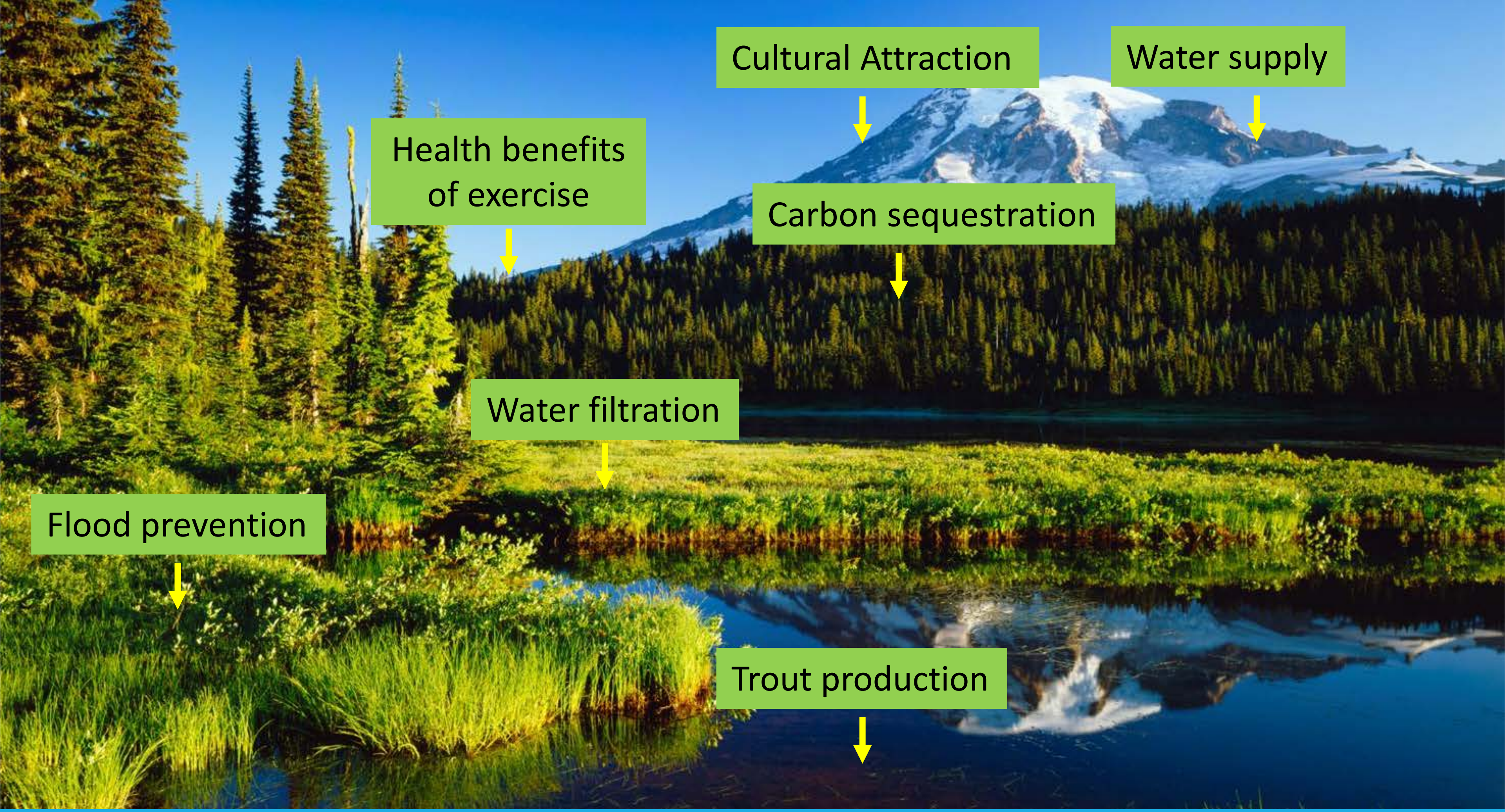
1) Does it capture outcomes relevant to anyone significantly affected by the intervention or action?

2) If you changed the intervention/action (to an alternative or baseline) would the change cascade as it should – does it logically change the other nodes and cascades in the model? (will help catch errors or missing boxes and arrows).

3) Are the features/proprieties/indicators in the boxes a) observable, b) controllable, and c) predictable?

4) Are the arrows placed where there are conditional dependencies between features? (There should be no arrows where features are conditionally independent)

5) Are the endpoints of the chains BRIs? Are they the outcome that people value? Do they clearly link ecological changes to beneficiaries? or are they ecological endpoints or values or well being measures?



Causal Chains and Conceptual Diagrams EXERCISE

National Ecosystem Services Partnership

Case Studies

Klamath Basin

Farm Bill Incentives

FARM BILL

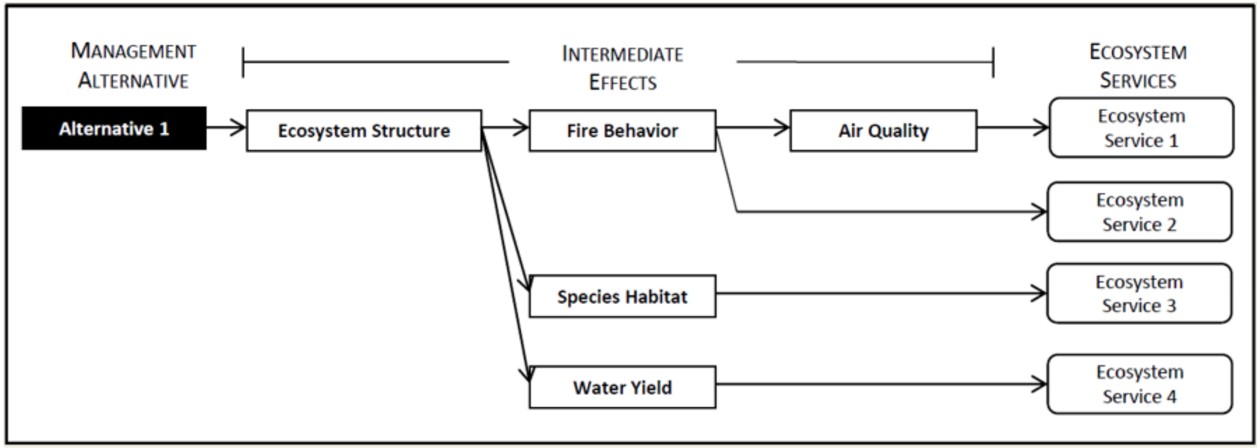
Laguna Atascosa NWR

Dam Removal

Pollinator Habitat Creation

Prescribed Fire

Create a Conceptual Model Diagram

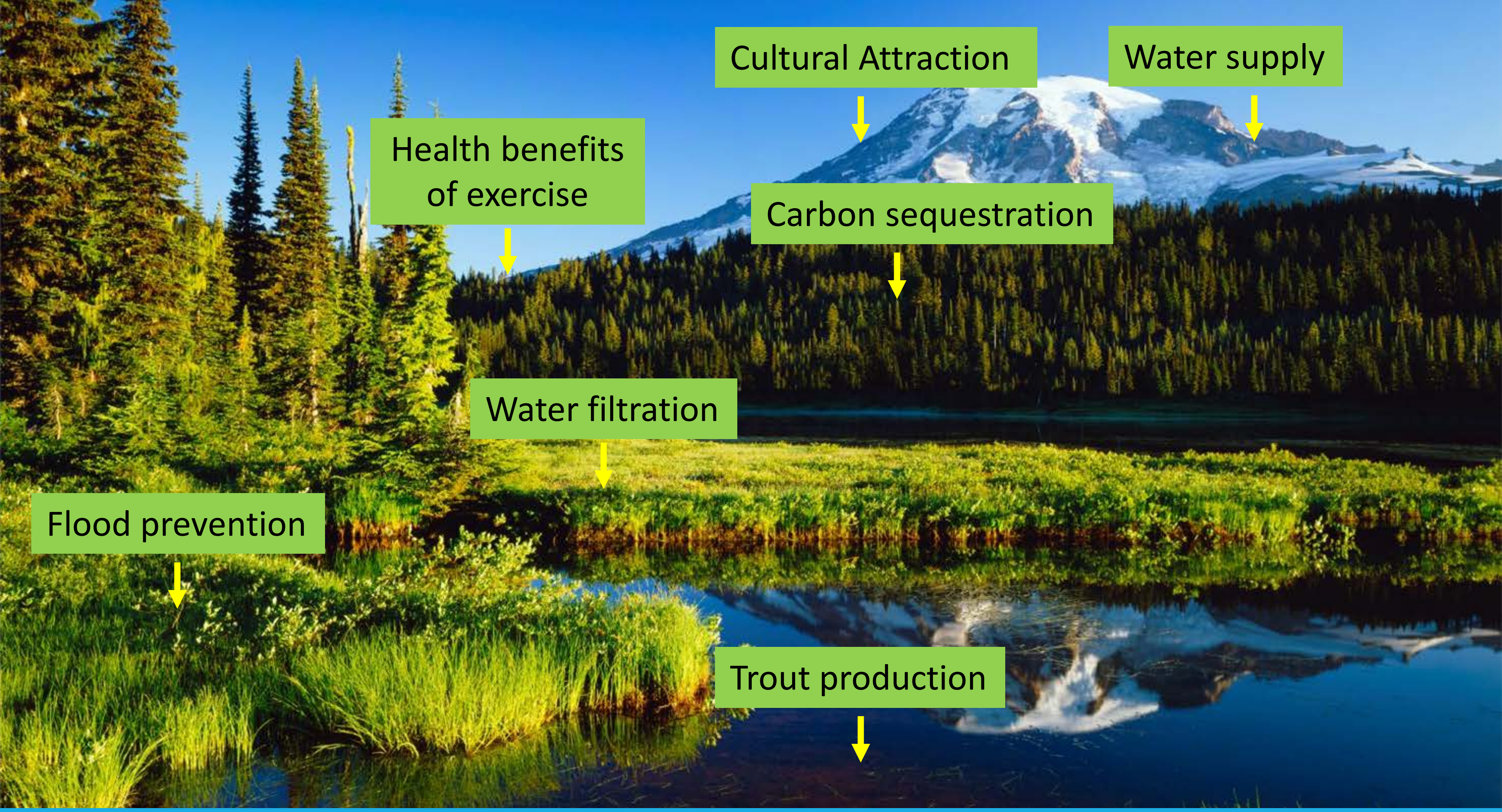


- Use the information provided in your packet to learn about your case study
- Talk with your group about the stakeholders and ecosystem services of importance
- Follow the instructions in the packet to develop a conceptual model diagram

Goal: Think about and document the impacts that a management action or policy intervention can have on a wide variety of ecosystem services

❖ Map the ecological, biophysical, and social outcomes of a management intervention

Time: 1 hour



Ecological Production Functions

National Ecosystem Services Partnership

What are Ecological Production Functions?

FREQUENTLY ASKED QUESTIONS

- What are ecological production functions?

Ecological production functions are relationships that can be measured or modeled and that estimate the effects of changes in the structure, function, and dynamics of an ecosystem on outputs that are directly relevant to people. They can take many forms, from conceptual relationships established through expert opinion to complex simulation models. However, they are often a series of statistical relationships connecting ecosystem condition to outputs.

What are Ecological Production Functions?

Ecosystem service valuation requires quantifying causal links from (1) human actions to (2) ecosystem changes to (3) changes in ecosystem services (BRIs) to (4) changes in social benefits (economic values).

Causal chains *identify* these linkages conceptually, but do not *quantify* them.

Ecological production functions (EPFs) provide quantitative linkages from (1) to (3).

EPFs are primarily *biophysical* in nature, although some may include components (or assumptions) related to interacting human behavior.

What are Ecological Production Functions?

Most types of analysis require information on the "deltas," or *changes* in the provision of ecosystem services caused by changes in human actions or ecosystem conditions).

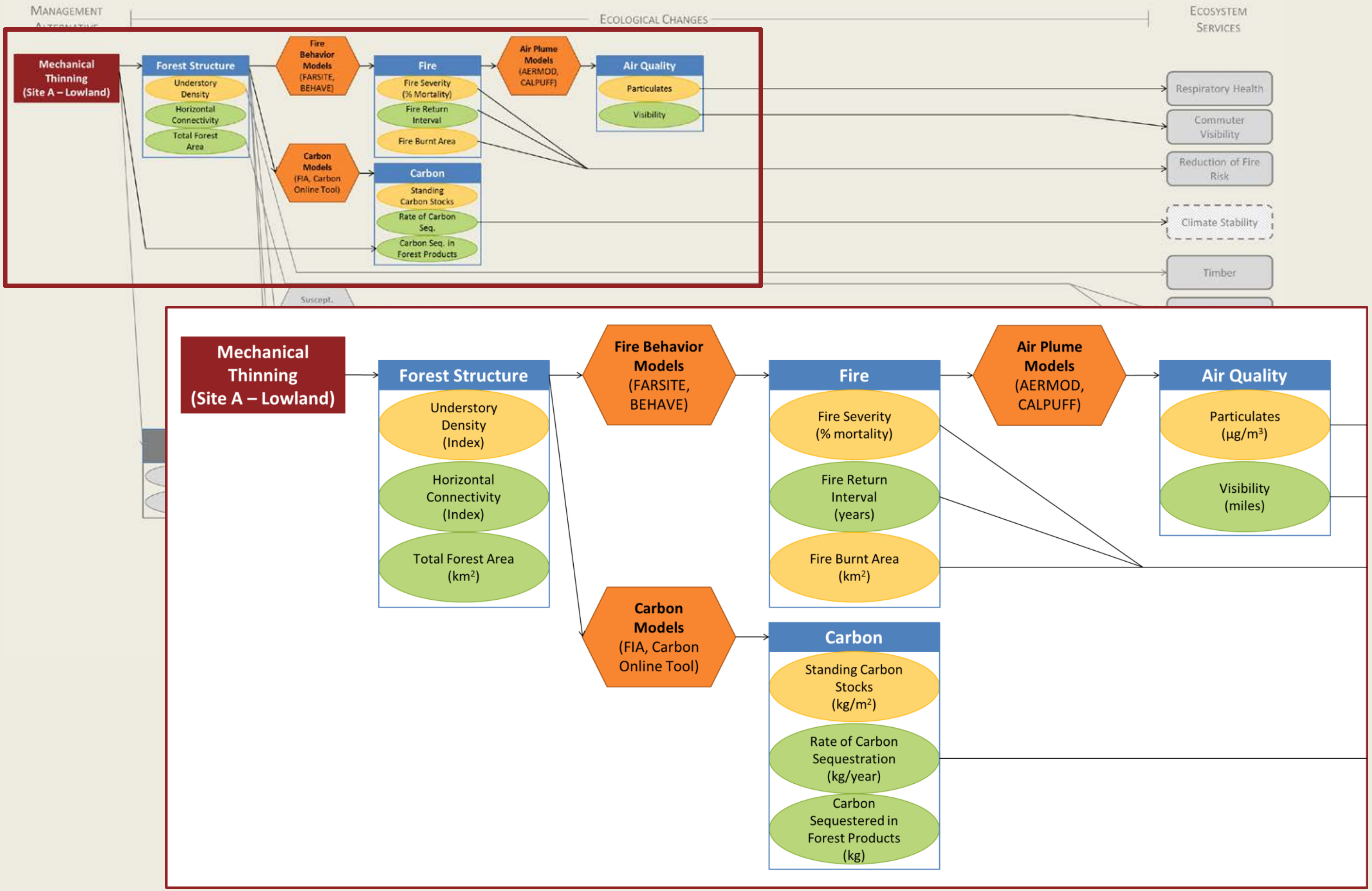
These can be changes in *stocks* or *flows*, depending on the definition of the BRI (and source of social benefit).

It is not enough to know the current status of an ecosystem or stock (or quantity) of an ecosystem service.

- Monitoring data, observation system data, or GIS data layers alone are insufficient.
- Models of some type are required (either implicit or explicit).

Development of EPFs in various contexts can be among the most challenging issues limiting the application of ecosystem services assessment and valuation.

Qualitative versus Quantitative Diagrams



Sources and Types of EPFs

There is always some degree of variation and/or uncertainty (e.g., statistical, modeling, etc.) involved in EPFs.

Some methods used to estimate EPFs generate forecasts with greater accuracy (and certainty).

It is important to consider both *bias* and *dispersion* in estimates.

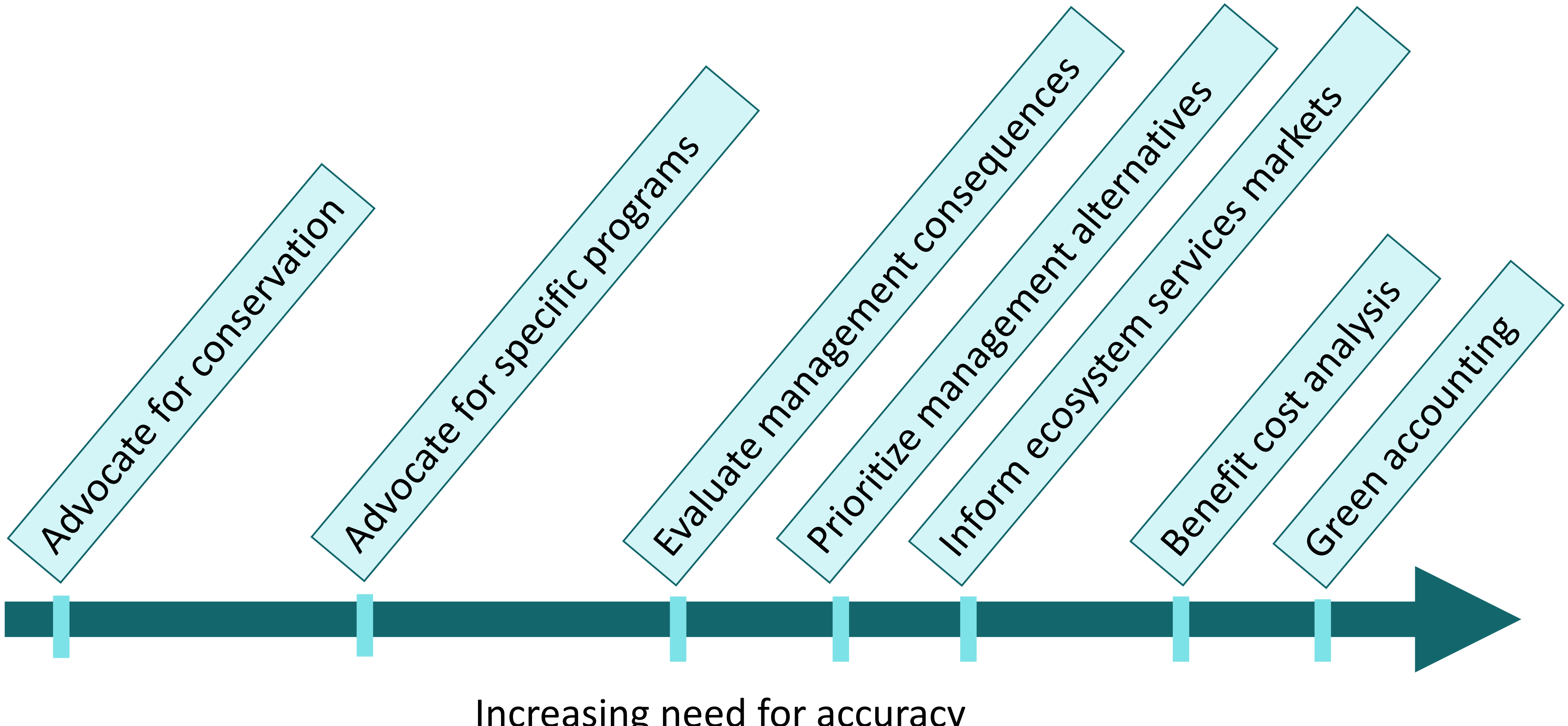
More accurate methods for generating EPFs generally require extensive data collection and modeling for the sites in question.

Less costly methods have lower requirements for data and modeling, but generally sacrifice accuracy.

Coordination with natural scientists or engineers is recommended, *from the beginning of the process*.

Degree of Accuracy Required

The need for accuracy depends on the purpose of the assessment or valuation.



Sources of More Accurate EPFs

Controlled, site-specific experiments to quantify relationships (via statistical modeling).

Statistical modeling of non-experimental observations or quasi-experiments (cross-sectional or time-series data).

Site-specific simulation models.

All of these approaches are more accurate when data are collected from the local site rather than elsewhere.

Approaches such as these often require extensive data collection and work by natural scientists, but can (if used correctly) provide relatively accurate EPFs

Sources of EPFs with Varying Accuracy

Pre-developed simulation models that characterize biophysical system dynamics, calibrated to local conditions. A few examples include:

- Sea Level Affecting Marshes Model (SLAMM)
- Hydrologic and Water Quality System Model (HAWQS)
- Framework for Aquatic Modeling of the Earth System (FrAMES)
- Individual, locally calibrated components of InVEST
- Models of fire behavior in forests (FARSITE)
- The Atlantis Ecosystem Model for marine systems.

The accuracy and calibration of such models varies.

Models should ideally be *validated* for the local system.

Sources of Less Accurate EPFs

Approximate relationships taken from the scientific literature. Illustrative examples include:

- Change in annual carbon sequestration per additional acre of an "average" ecosystem type
- Changes in water filtration or clarity associated with changes in oyster or mussel biomass
- Net nitrogen export or retention by different types of land cover (e.g., lawns, wetlands).

Expert opinion or Delphi modeling.

Scenarios or assumed relationships.

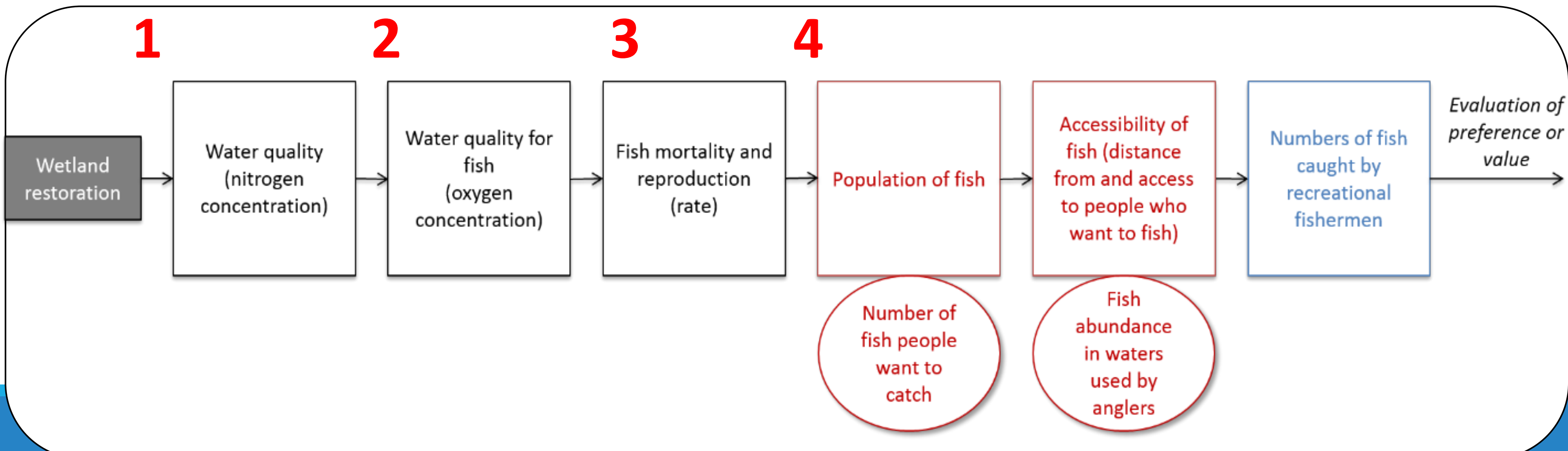
These are among the most commonly used (and least expensive) sources of EPFs, but are often the least accurate.

Linking EPFs

Ecosystem service assessments generally require the use of *multiple, linked EPFs*.

Simplified example for wetland restoration and recreational fishing involves at least 4 EPFs

This is only one pathway through which wetlands affect fish.



Linking EPFs

Developing linkages between EPFs requires variables and units that *can be reconciled across models*.

EPF development is often hindered because the models cannot successfully "talk to each other."

Assumptions are required when variables do not match exactly—this introduces error.

EPFs can also be required to account for multiple simultaneous causal pathways.

- Example—dam removal affects salmonid populations indirectly via effects on (a) sedimentation, (b) upstream habitat quality, and (c) changes in water quality due to changes in river flow.

Linking EPFs

Another common problem is "missing links."

- Example, an ecological model links changes in riparian land vegetation (restoration) to changes in catchable fish abundance.
- A recreation demand model provides a value per fish caught.
- What is the relationship between fish abundance and fish catch?
- This relationship is site- and species-specific, and is often assumed due to lack of data to estimate models.

Take home message—development of all EPFs for a project should be coordinated from the beginning to ensure that they can be linked at the end.

A common mistake is to develop EPFs independently.

Example EPFs: Beach Nourishment and Flood Protection Along Delaware Bay

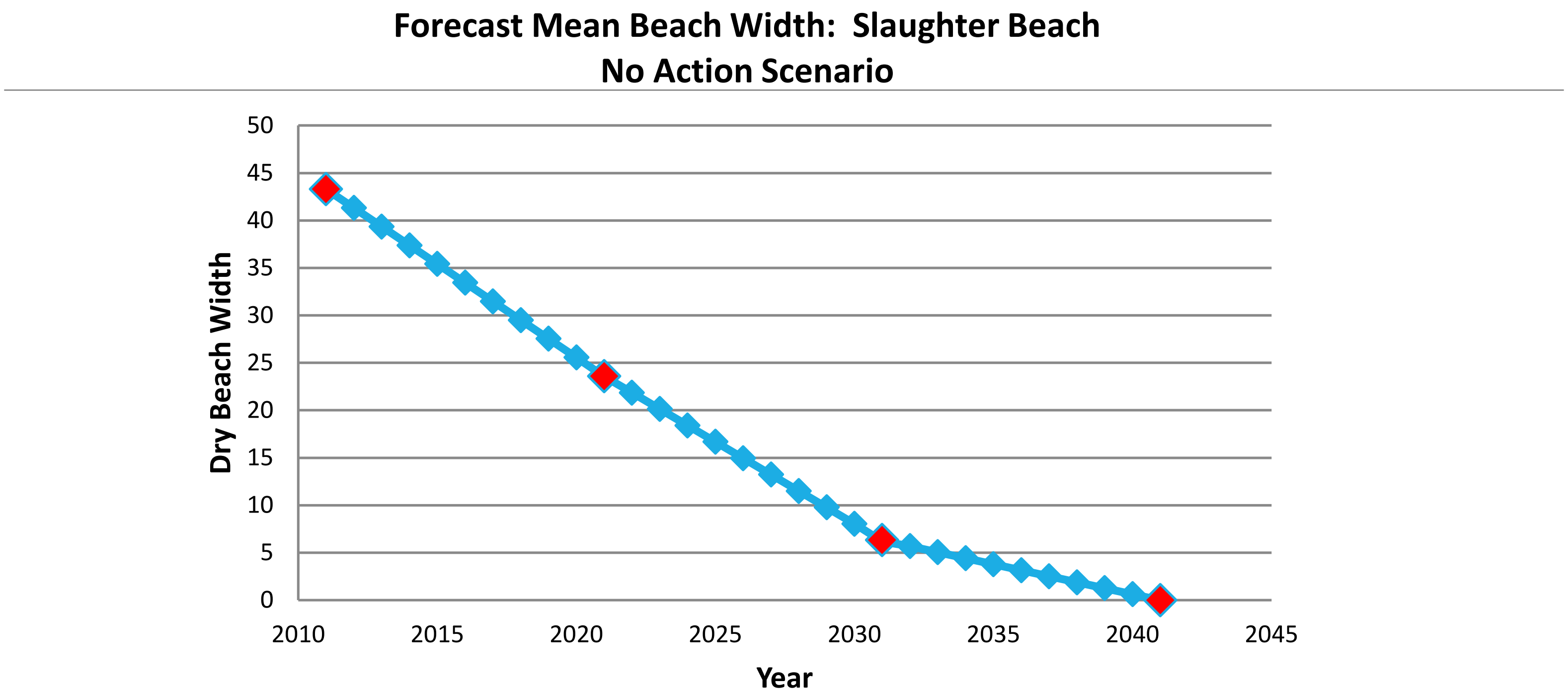
Goal of the project—evaluate benefits and costs of different management alternatives for seven Delaware Bay beaches.

Included various ecosystem service values, including flood protection services of the bay beaches.

The EPF component of the model linked *management actions* to *projected beach widths* to *projected housing loss* due to flooding.

Economic values were estimated for housing losses.

Example EPFs: Beach Nourishment and Flood Protection Along Delaware Bay

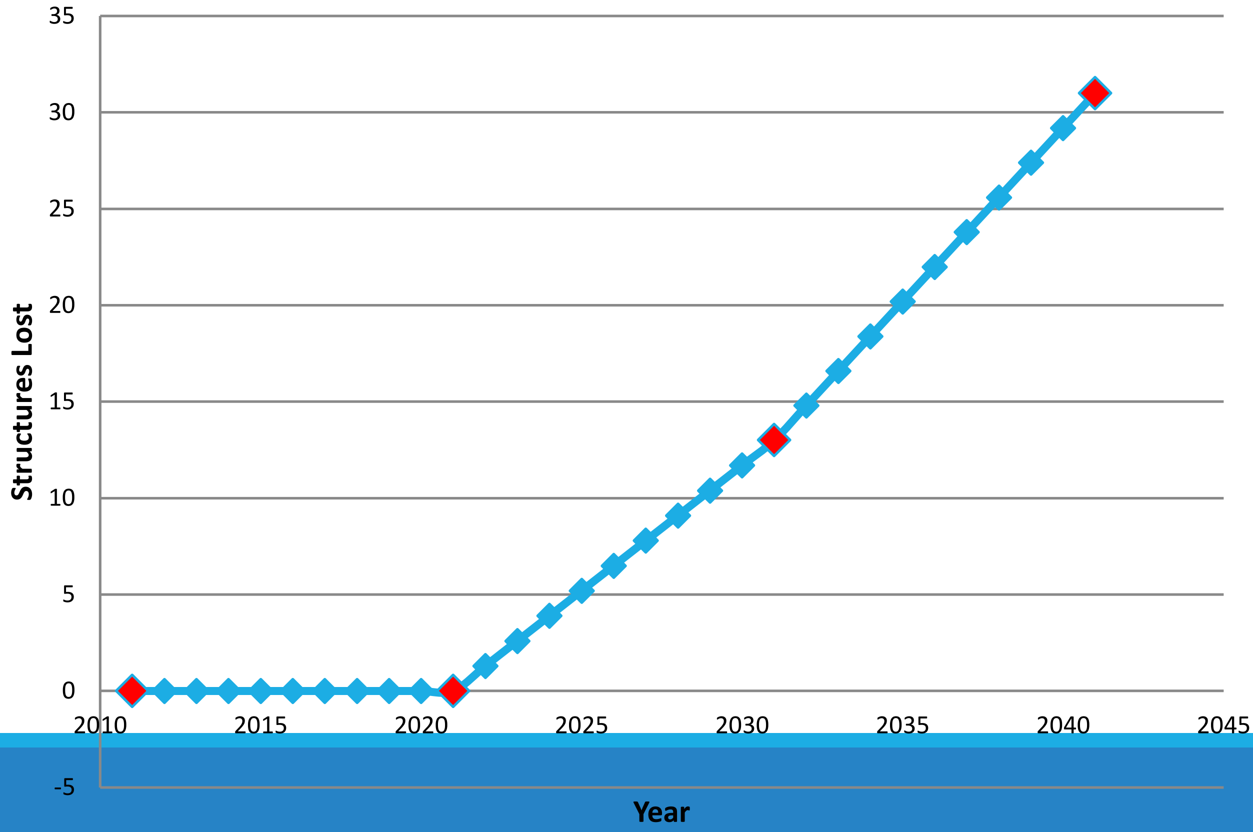


- Mean dry beach widths are forecast for each beach, during each year of the analysis, under each scenario.
- These forecasts are based on beach-specific retreat data from past years combined with sea-level/geomorphology forecasts and scenarios.
- Red points are modeled with interpolations in between.
- Widths at any year can be compared across scenarios to generate the "deltas."

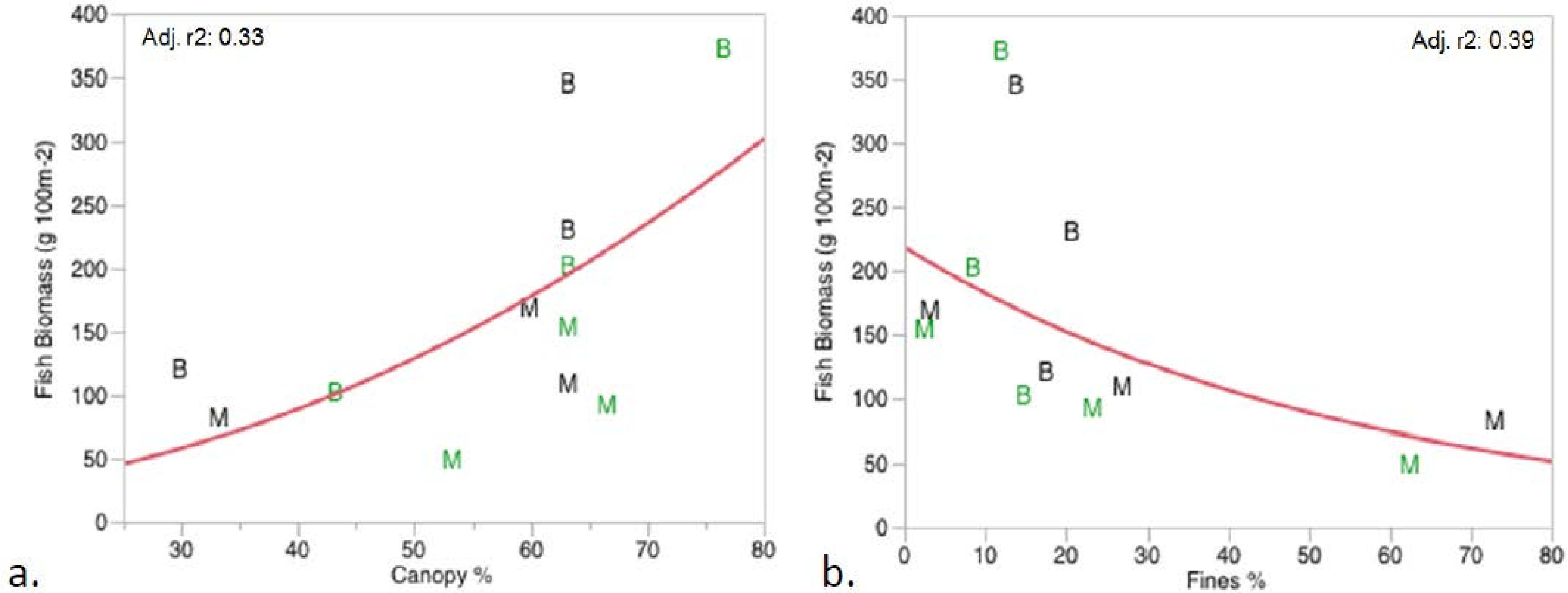
Example EPFs: Beach Nourishment and Flood Protection Along Delaware Bay

- Beach width forecasts are used to project housing structure losses for each year, for all scenarios (coastal geomorphology / engineering).

Total Structures Lost: Kitts Hummock Scenario 4



Using Observed Biophysical Correlations: Example from South Coastal Maine



In the Merriland River (M) and Branch Brook (B) for open (black font) and forested (green font) sites, fish biomass is significantly positively correlated with percent canopy cover (a) and significantly and negatively correlated with the percentage of fine sediments (b).

As an *approximate* linear relationship, an average 1% increase in tree canopy cover is associated with a 2.47% increase in fish biomass.

Types and Sources of EPFs Vary

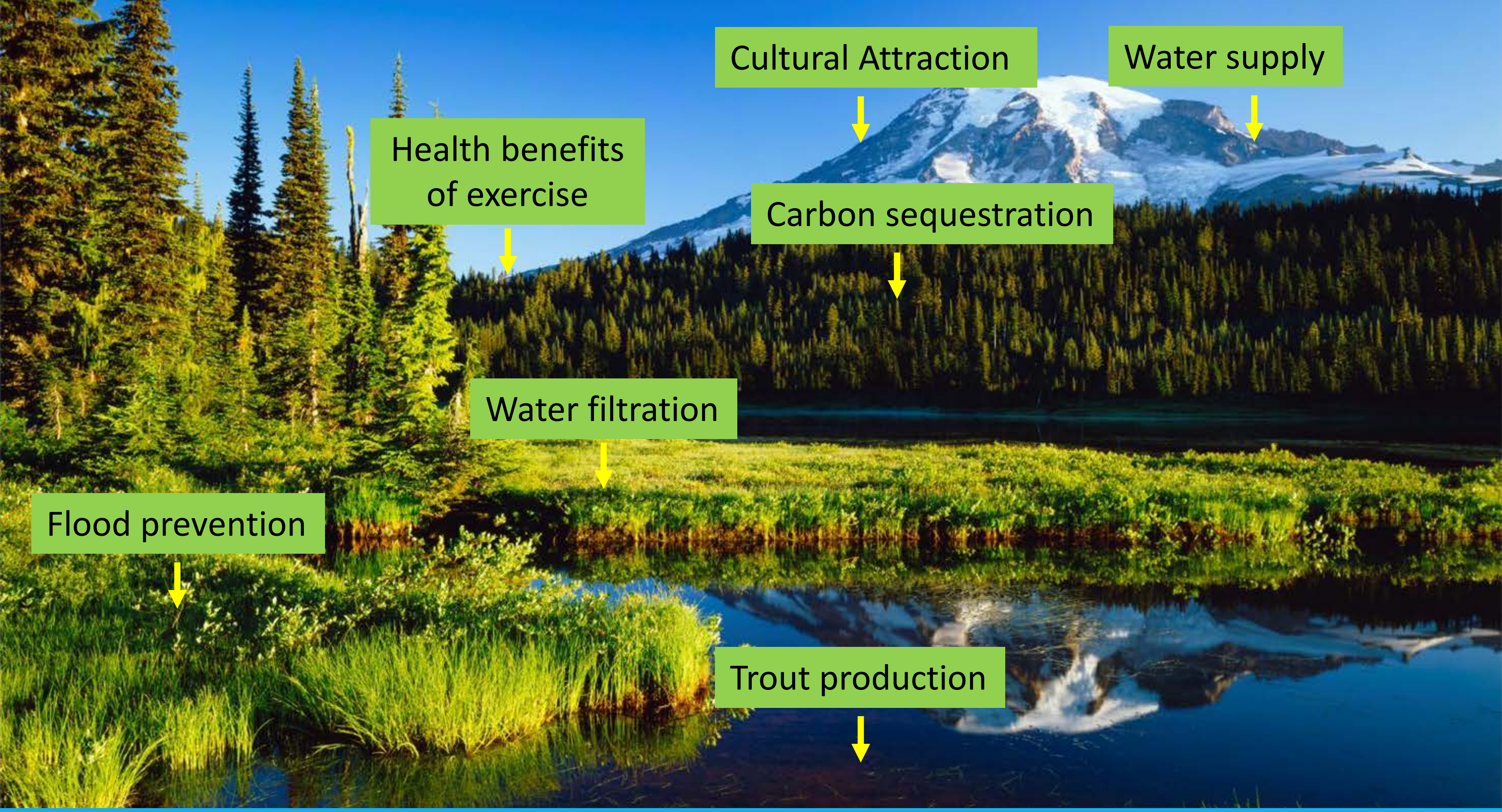
The types and sources of EPFs will vary depending on project needs, data availability, expertise available and other factors.

An ongoing challenge is that the desire to conduct ecosystem services analysis often outstrips the capacity to provide high quality EPFs.

Where Can I Get Data and Models?

NESP Resource on data and models

- Analysts often want to conduct ecosystem services analysis but do not have the time/money to develop new site-specific EPFs.
- Data and models to develop EPFs are increasingly available online and in published documents.
- There is a new NESP working paper on EPFs
- Data and models for the US for many of the major ecosystem services
- Also available as links on NESP website
- Will be released as final report in 2018 and integrated into new USGS web based tool on ecosystem services. (Sustaining Environmental Capital Initiative)



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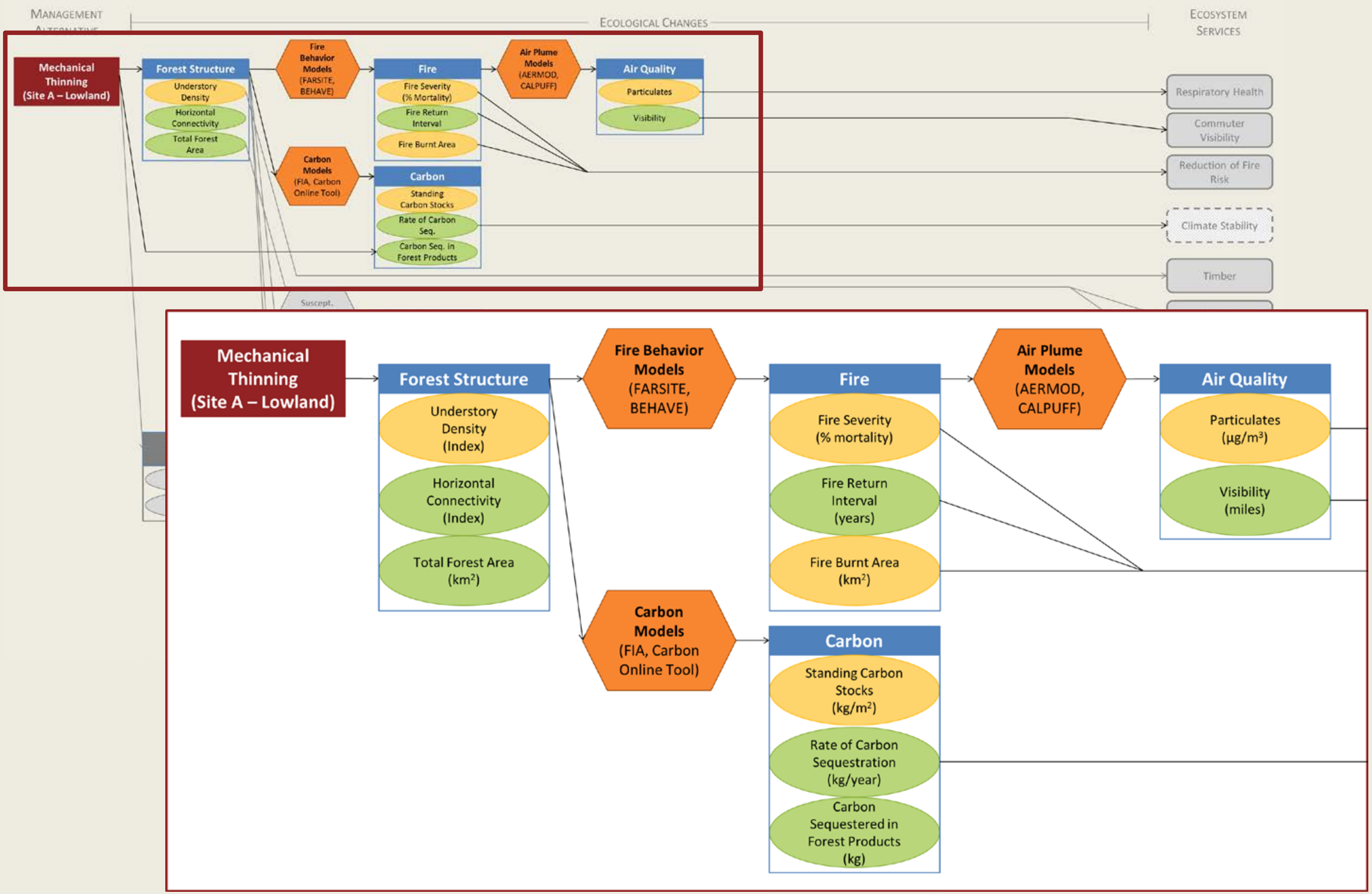
Qualitative versus Quantitative Diagrams



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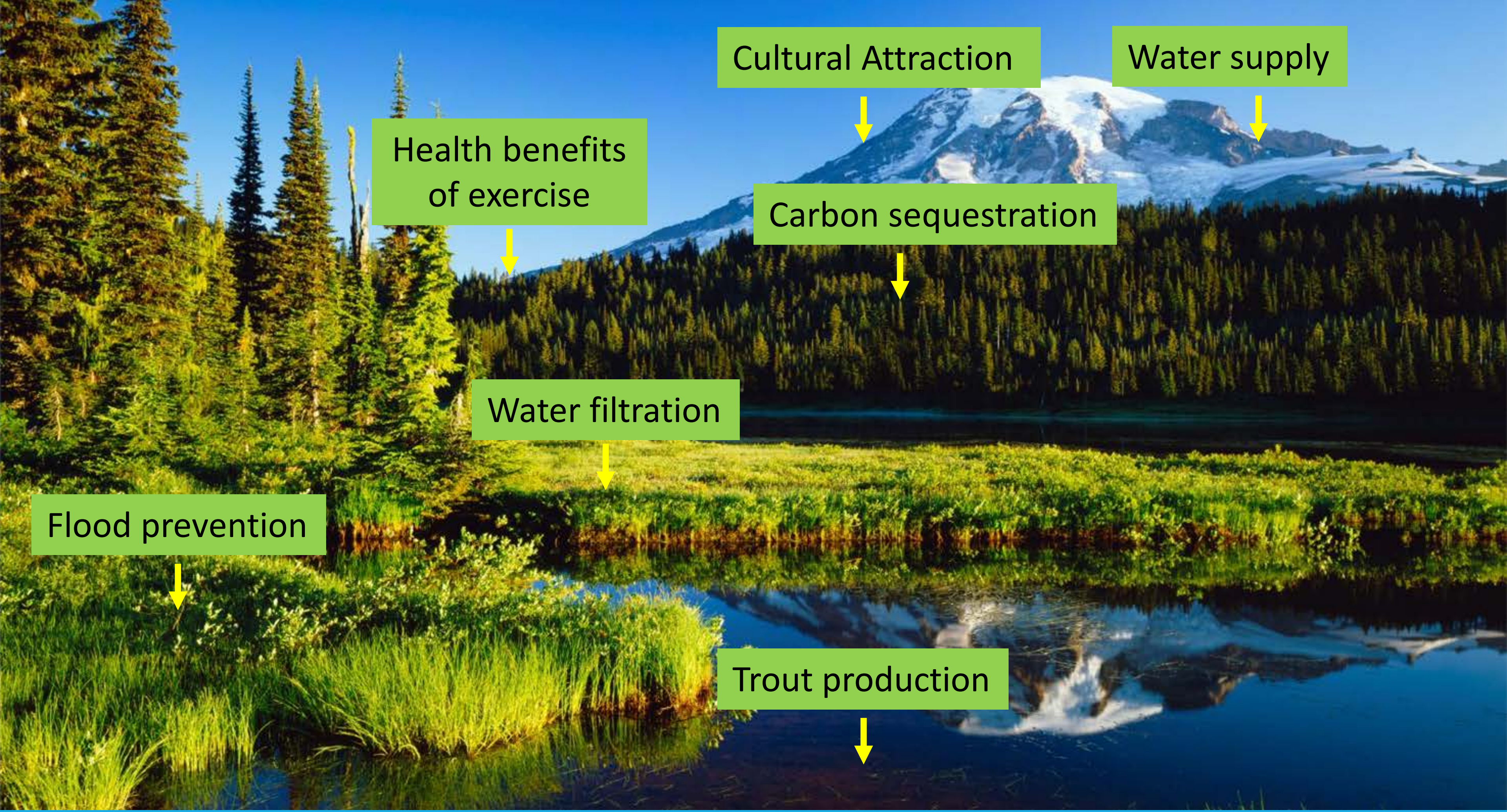

Quantifying BRIs, and Social Context, and Information on Existing Data Sources

National Ecosystem Services Partnership

Measuring BRIs Using Ecological & Social Context

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Solomons, MD

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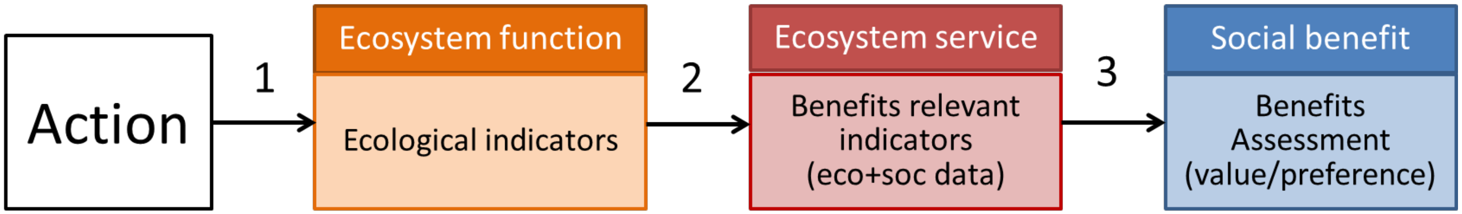
Outline

1. Review BRI definition
2. How end uses of BRIs inform their development
3. Creating & measuring BRIs
4. Examples and methods for overcoming data gaps
5. Aggregation and other analytic considerations
6. Sources of additional information
7. Group exercise – Developing BRIs

What are Benefit Relevant Indicators (BRIs)



- Measurable indicators that capture the connection between ecosystems and people
- The point of hand off between ecologists and economists – that combine ecological and social information
- A complement or stepping stone to valuation or an alternative

BRIs identify conditions under which an ecological change is likely to be valued

Ecosystem Service Opportunities

Biophysical changes

- Δ wave height
- Δ water quality
- Δ habitat
- …

BRIs →

Human Well-Being Outcomes

Health & Safety

- Home protection
- Food production
- Water supply
- …

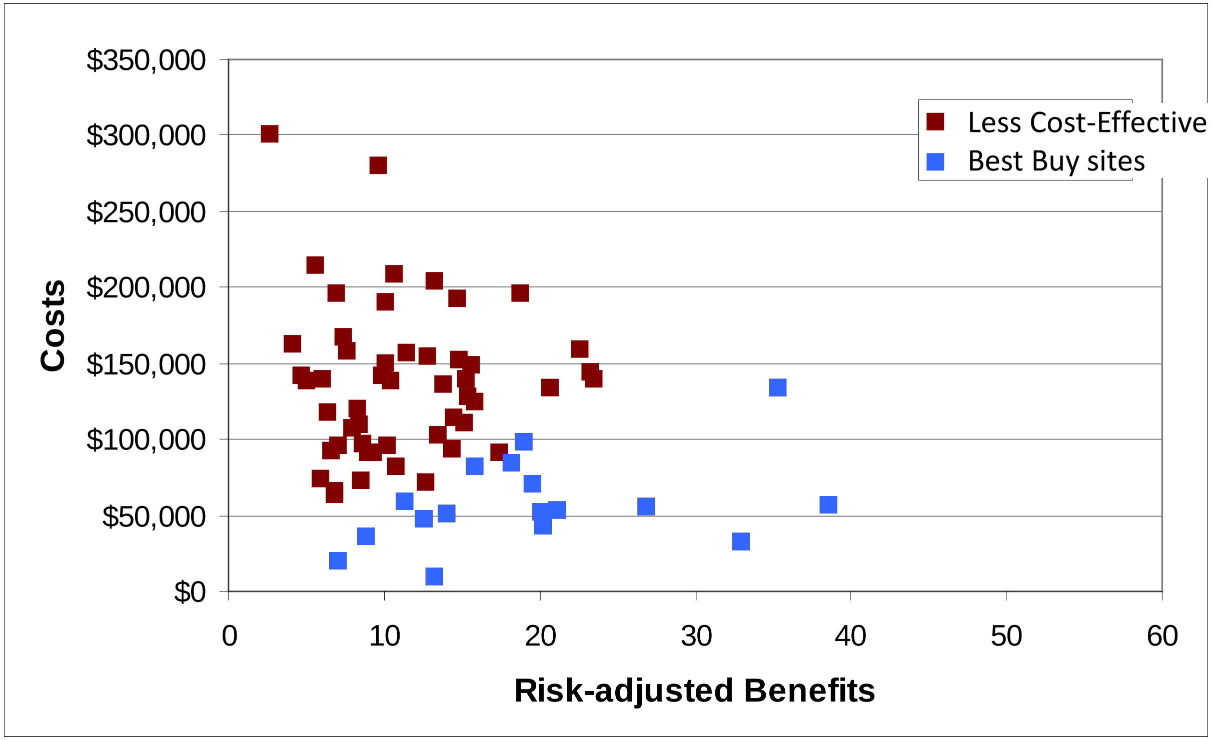
Fulfillment

- Recreation
- Satisfaction of environmental stewardship
- …

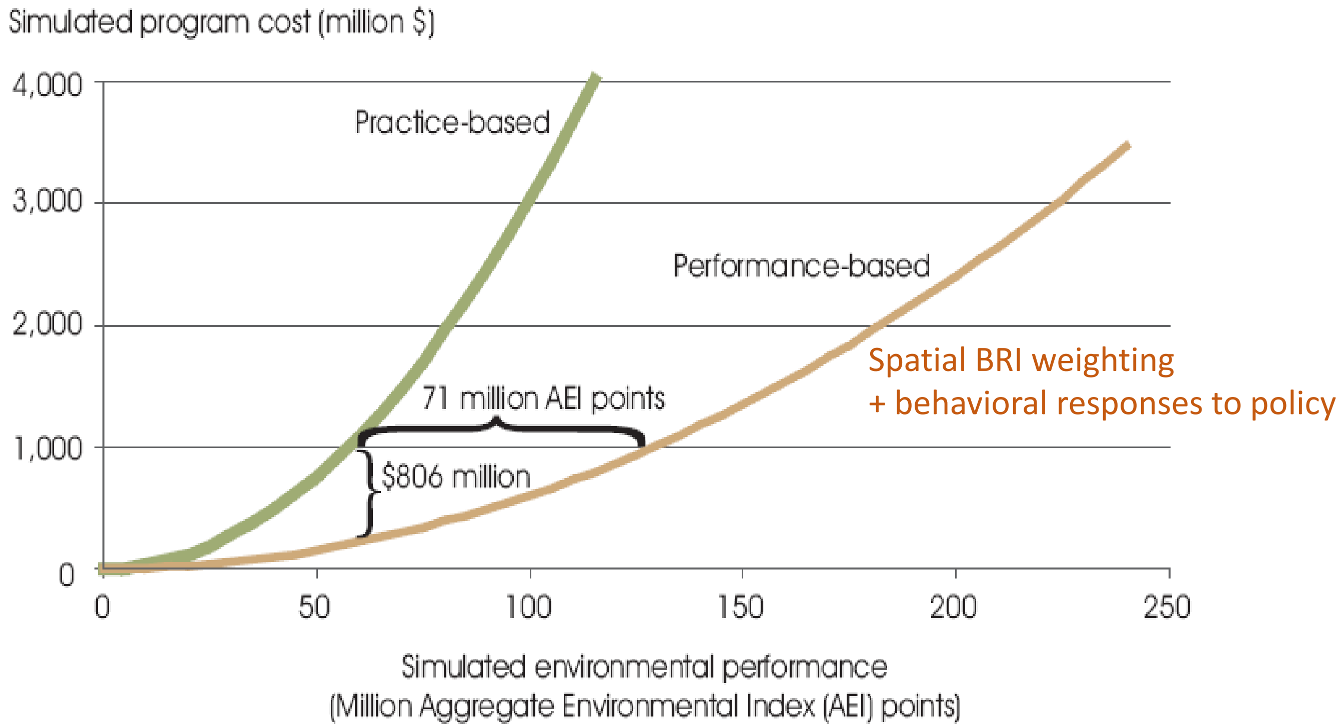
How are BRIs Used?

1. Quantitative Communication
   - Summarize impacts in quantitative units
   - *Tons CO2e sequestered* ↔ *Number of homes protected*
2. Cost Effectiveness Analysis
   - Uses a single metric or index to compare performance
   - *2 lives saved / $1 spent*
3. Multi Criteria Decision Analysis
   - Preference-weighted and normalized benefits
   - *20 points of recreation benefits* (relative units)

Cost-Effectiveness Analysis
BRI Goal: Generate performance metric for comparing alternatives

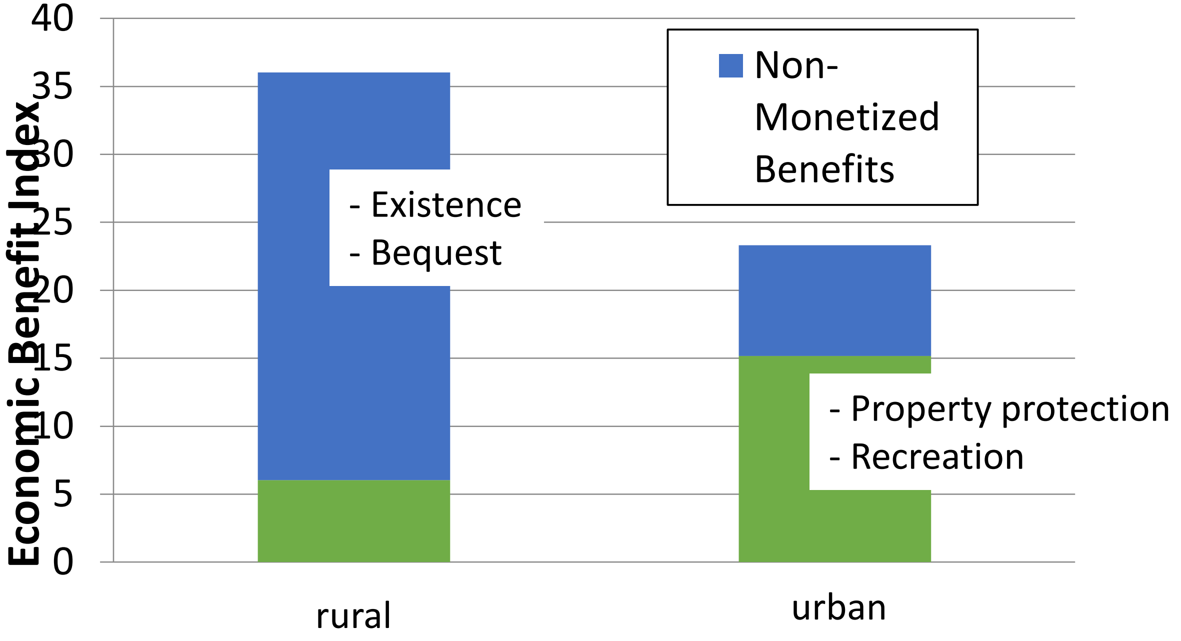


BRI goal: Enhance cost-effectiveness of decisions



Weinberg and Claassen, March 2006 USDA ERS Economic Brief

BRI goal: Provide inclusive view of benefits



Creating BRIs that match end uses

1. Complement
2. Stepping stone
3. Alternative

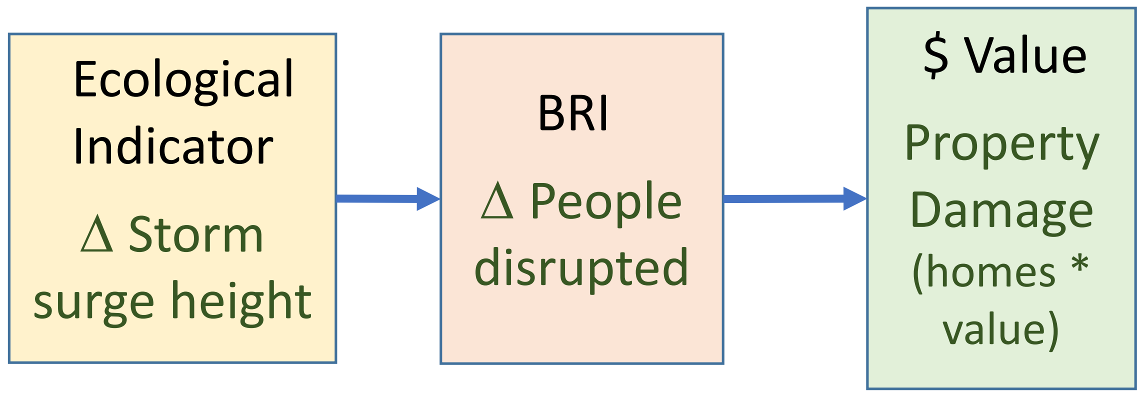
Example of a complement to valuation

Identify equity concerns

Complement

Stepping Stone

Alternative



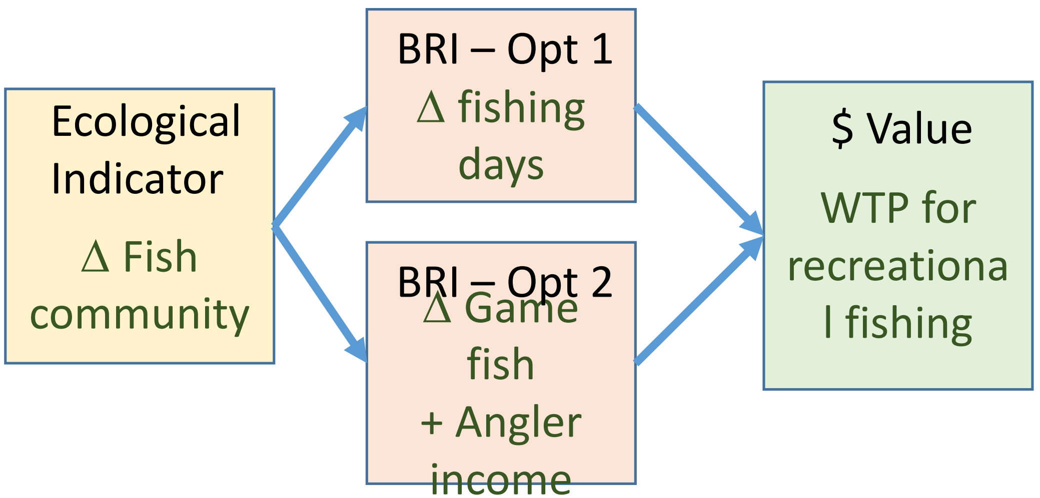
Example of a stepping stone to valuation

Match to benefit transfer variable

Complement

Stepping Stone

Alternative



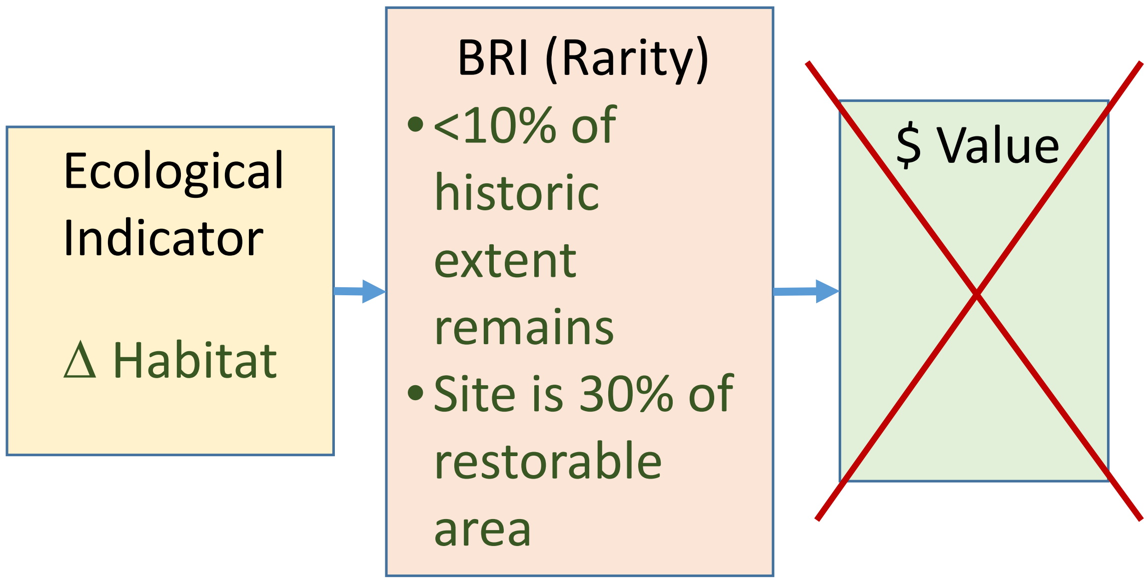
Example of a replacement for valuation

Express relative importance of something that will not be monetized

Complement

Stepping Stone

Alternative



Social and Economic Context for BRIs

What elements make a good BRI?

- Metrics come as close as possible to something that people would be willing to pay for
- Represents magnitude of use or intensity of concern
- Reveals meaningful tradeoffs

Elements of BRIs

1. Quality is sufficient for users
   - Charismatic birds are present
2. Complements - Capital and labor available
   - Piers and boardwalks provide access
3. Demand - Users or beneficiaries present / possible
   - Potential birders living in driving distance
4. Reliability of the future stream of services
   - Surrounding landscape is protected from development
5. Scarcity and substitutability
   - Few alternative birding sites or other sites are congested

Examples + data realities

Use of site quality

Action

Δ Manure management

→

Ecological Indicator

Δ Index of biotic integrity

→

BRI

Δ Aquatic system health or resilience

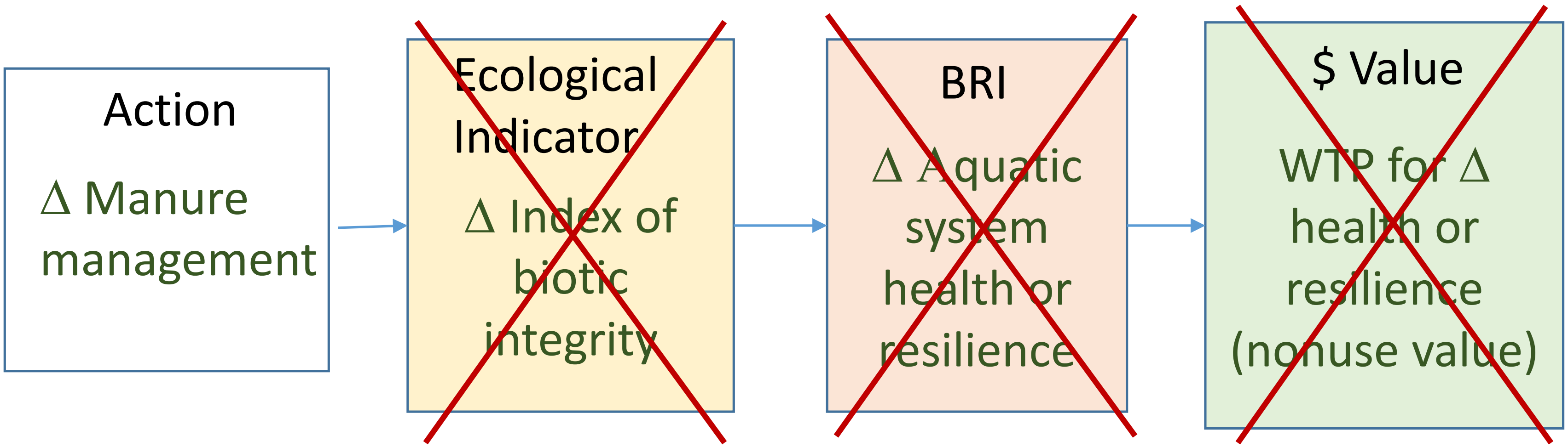
→

$ Value

WTP for Δ health or resilience (nonuse value)

Examples + data realities

Use of site quality



Examples + data realities

Use of site quality

Action

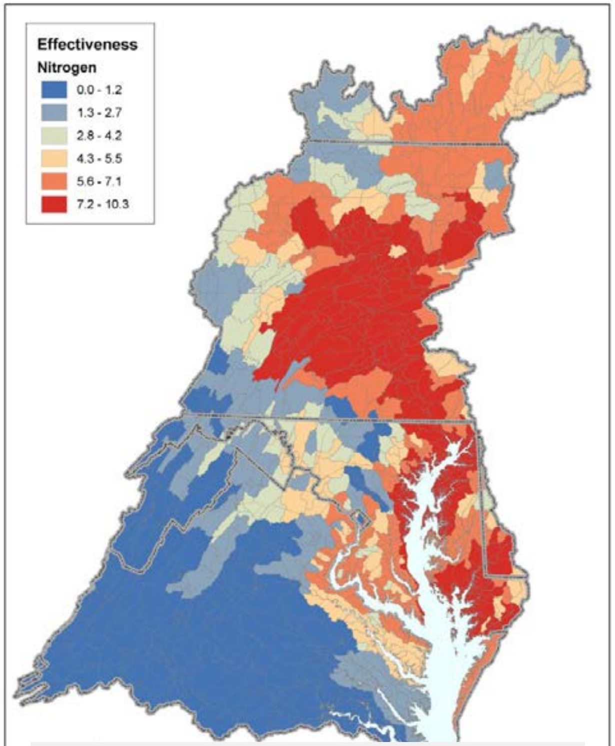
Δ Manure management

~~**Ecological Indicator**~~

~~Δ Index of biotic integrity~~

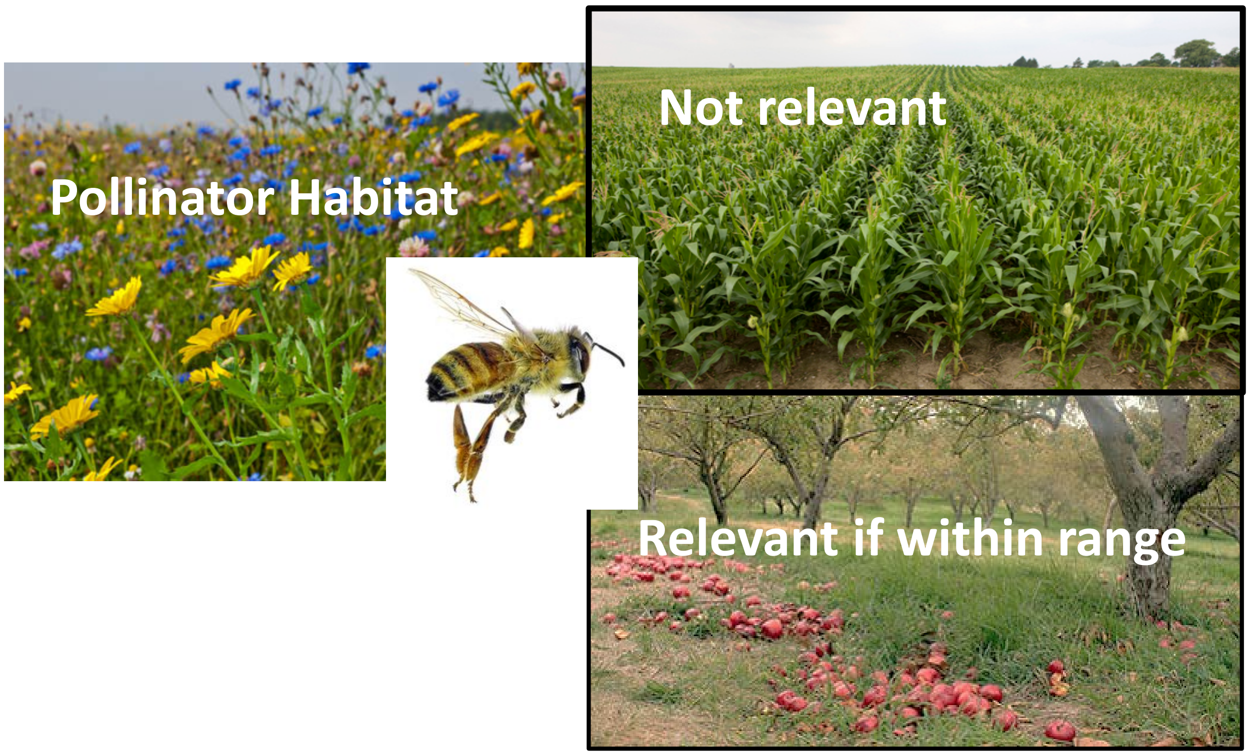
BRI

Δ Nutrient runoff weighted by effect on aquatic invertebrates



US EPA Chesapeake Bay Program

Benefit Relevant Indicator
Complementary Inputs
Co-location of labor and capital

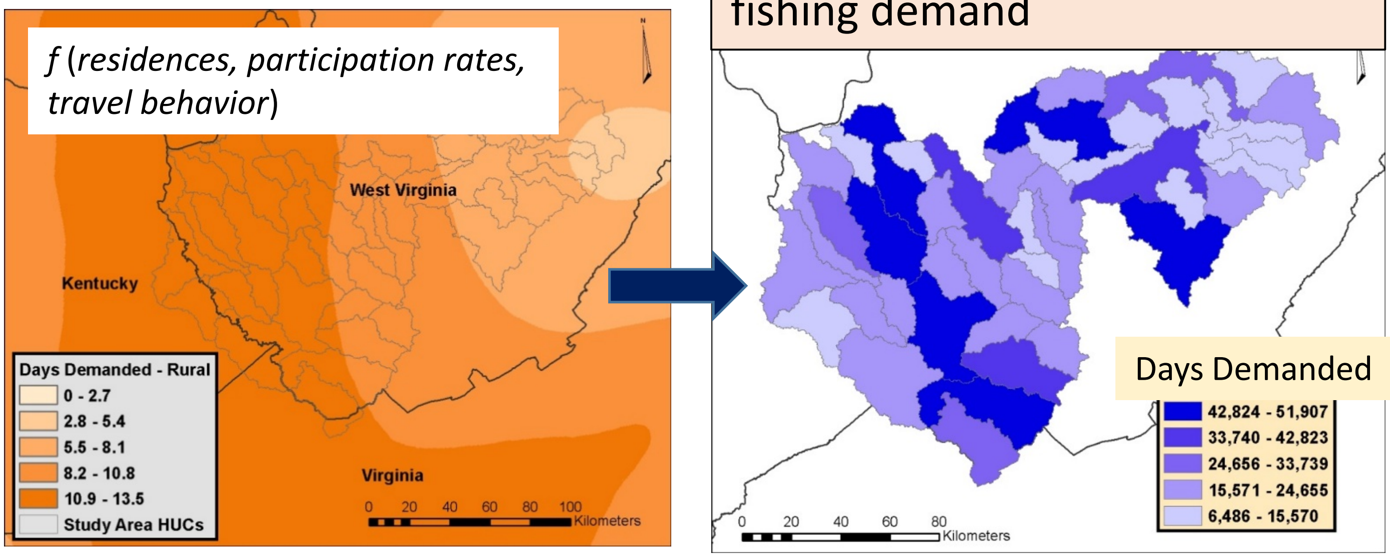


Food Provision
BRI: Area of pollinator-dependent crops within flying distance of pollinator habitat

Benefit Relevant Indicator
Demand

Recreational Fishing

BRI: Increased game fish density in areas of high freshwater fishing demand



Mazzotta, Wainger et al. 2015 *Ecological Economics*

Benefit Relevant Indicator
Scarcity (use value)

Action
Δ Restore streams

→

Ecological Indicator
Δ Groundwater recharge

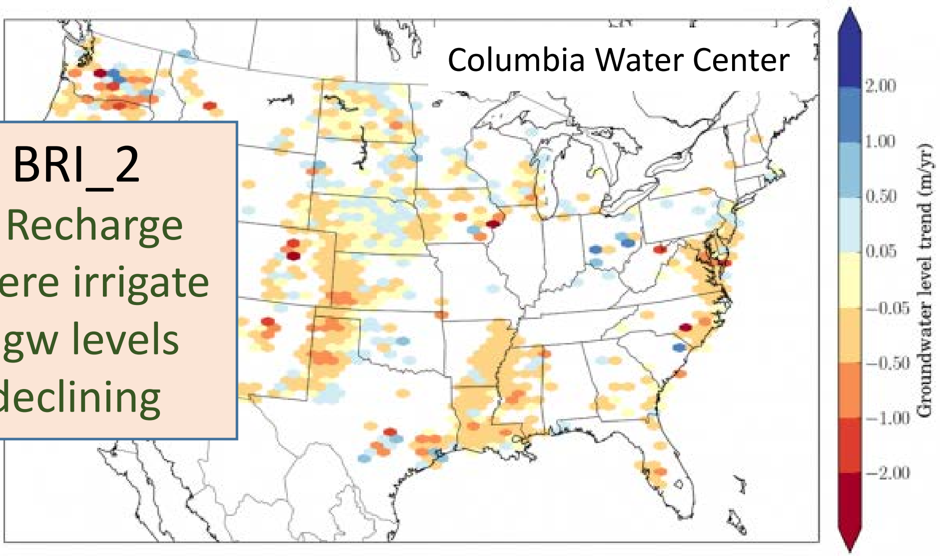
→

BRI_1
Δ Recharge where irrigation used

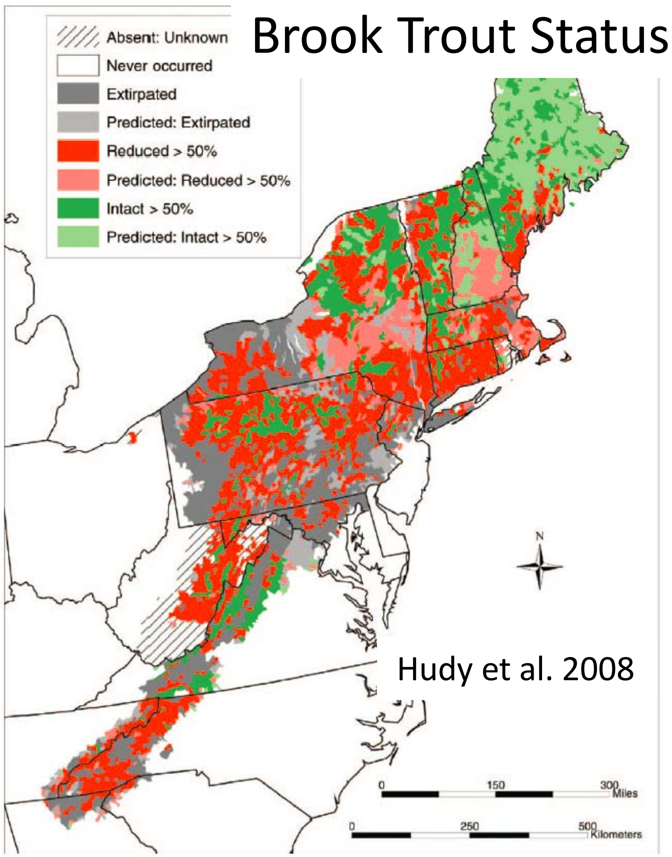
→

BRI_2
Δ Recharge where irrigate + gw levels declining

Groundwater Level Trend



Benefit Relevant Indicator
Scarcity (Non-Use)



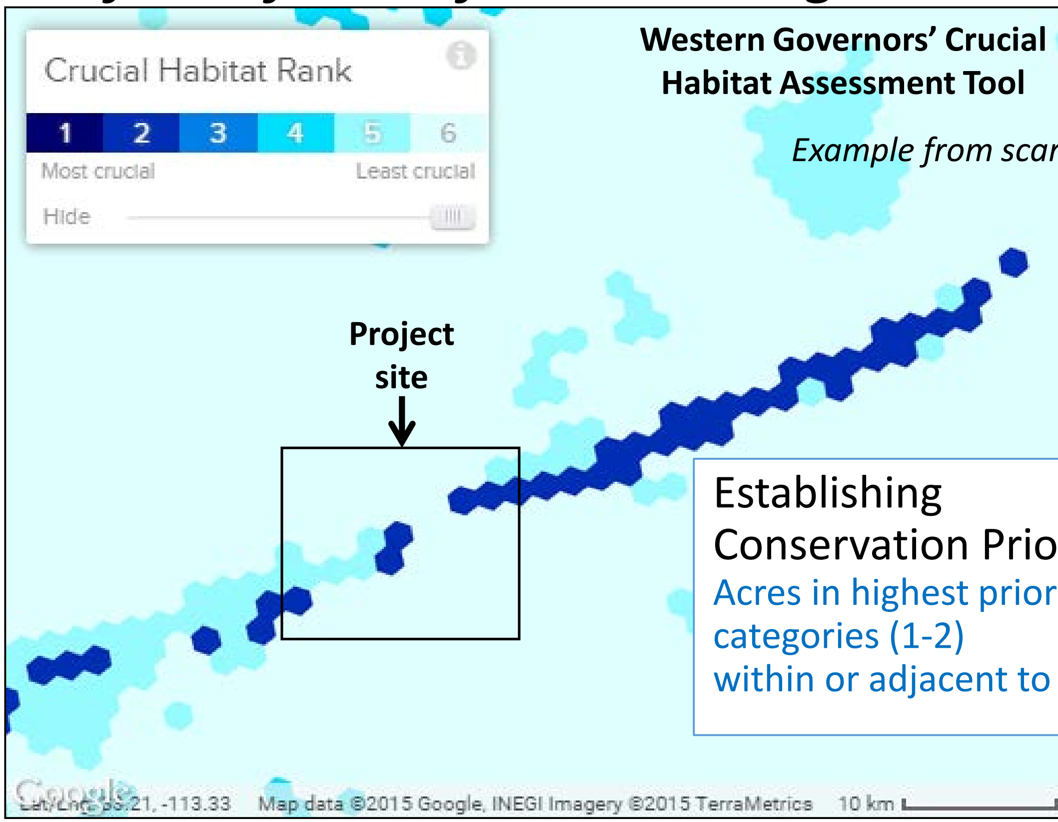
Non-use Value for Species of Concern

BRI: Δ stream miles suitable for reproduction of trout species of conservation concern

Δ Riparian buffers → Δ Sediment runoff + water temp → Δ Habitat quality for reproduction

The current vs future information gap

Future benefits inferred from existing conditions



Example from scarcity indicators

Establishing Conservation Priorities

Acres in highest priority categories (1-2) within or adjacent to project

Underpinnings of BRIs

- Scarcity, Substitutability, Irreplaceability

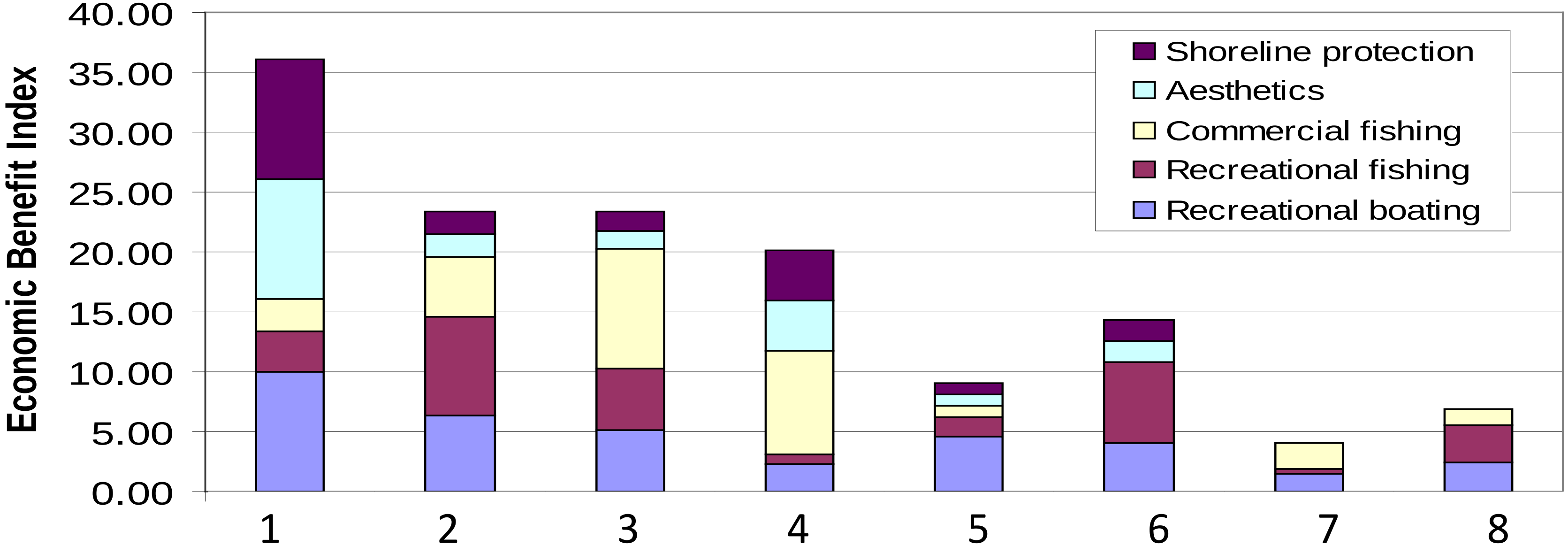
Underlies metric choices

In general, the scarcer a service is, the more an increase in its quantity is likely to be valued, all else equal

- Manage data gaps

Express importance to people to the extent supported by data and understanding

Aggregating Indicators
Do they capture relative importance of changes?



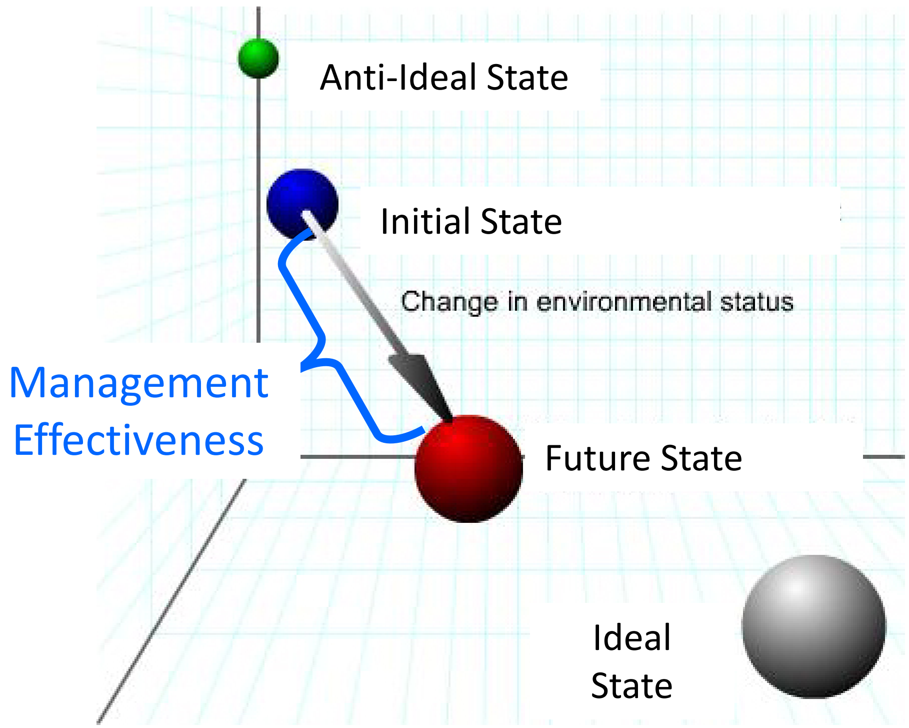
Aggregating indicators
Outside of MCDA

- Use expert judgment and/or statistical properties of data to compare and/or combine variables
- Fill gaps when empirical relationships between variables and outcomes are unknown
- Must be used cautiously to avoid creating bias or unintended consequences

Common aggregation approaches

- Normalization
- Standardization
- Simple weighting
  (user or expert judgement rates intensity of concern)
- Multivariate statistical approaches
  (e.g., evaluate “distance” to a user-specified ideal)

Multivariate distance metrics



Pros and cons of multi-metric aggregation

Pros

- Simplifies results
- Reveals synergies and tradeoffs
- Some methods reduce double counting and/or biases (but not eliminate)

Cons

- Methods embed many unexplored assumptions
  - Often ignore thresholds or other non-linearities in benefits
- Some methods double-count benefits
  = opportunity to game stakeholder processes
- Simple mathematical choices can unintentionally bias results
  - E.g., A single high or low outlier values can make moderate changes appear unimportant when normalizing

Source of further information

Locantore et al. 2009

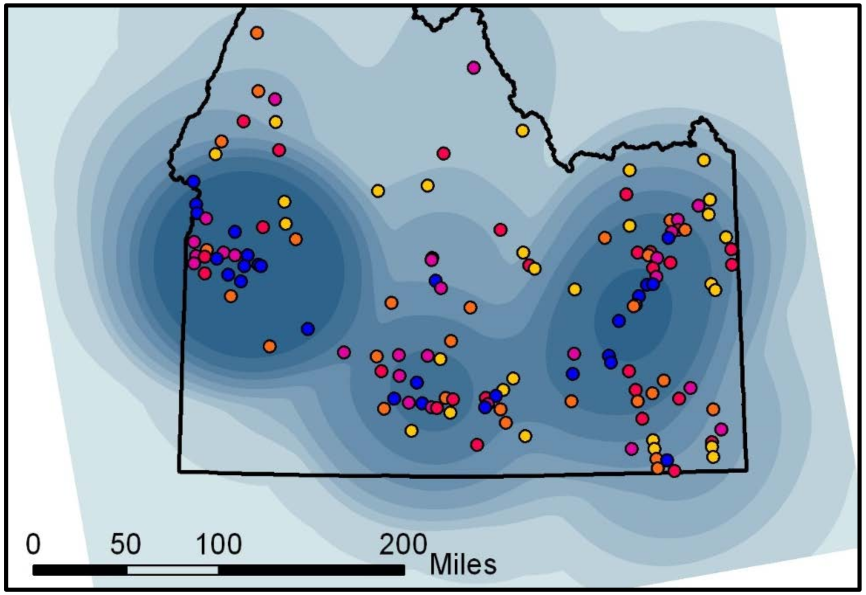
EPA Regional Vulnerability Assessment Program

Category	Method	Description	Reference
Basic	Best/Worst Quintile	Count the number of variables in the best/worst quintile.	Jones et al., 1997
	Sum	Add the normalized values of all variables.	
Distance-based	PCA Distance	Transform variables to adjust for correlations, then calculate Euclidean distance from a reference.	
	State Space	Adjusts for correlations by calculating the Mahalanobis distance from a reference.	Johnson, 1988; Mahalanobis, 1936
	Criticality	Calculates fuzzy distance to a hypothetical "natural" state.	Dubois, 1979; Gatto and Renaldi, 1987; Tran and Duckstein, 2002
	Analytical Hierarchy Process (AHP)	Multi-criteria tool that uses decision-maker preferences in the calculations.	Saaty, 1980
Grouping	Cluster Analysis	Uses a robust partitioning method to group watersheds.	Wickham et al., 1999
	Self-organizing Maps (SOM)	Uses neural networks to group watersheds.	Kohonen, 2001; Tran et al., 2003
Overlay	Stressor-Resource Overlay	Composite coloring, counts high-stress variable values and high-resource variable values.	Landis and Wiegers, 1997; Jackson et al., 2004
	Overlap	Comparison of two regional maps to highlight differences.	
Matrix	Stressor-Resource Matrix	Computes scores based on correlation values to rate stressors and resources.	Gentile, et al., 1999; Harris et al., 1994; Parkhurst et al., 1997
	Univariate Regression	Computes scores based on regressions of stressors on individual resources.	

Other Analytic Details

Spatial extent considerations (servicesheds)

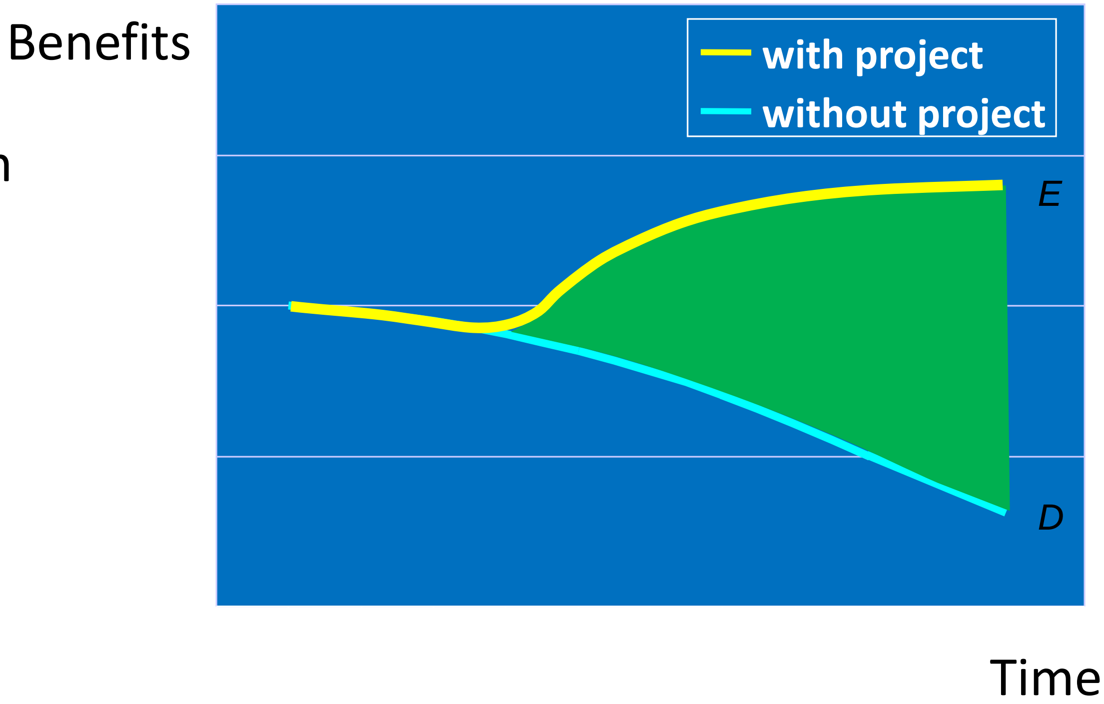
- Does service value decline with distance?
- What is the appropriate range of beneficiaries?
  - Species ranges (e.g., pollinators)
  - Networks & social conditions (e.g., downstream, likely driving distance)
  - Proximity-independent (e.g., climate risk mitigation)



Other Analytic Details

Temporal Analysis Issues

- Benefits are often measured as a stream of services through time
- Benefits may depend on future (unmeasured) conditions
- Not obvious how to discount future BRIs



BRIs fulfill two important needs for ecosystem services assessments

1. Enable lay audiences to clearly connect ecological outcomes to their own well-being
2. Improve analysis of tradeoffs by representing benefits that are not possible or feasible to monetize

Resources

Descriptions of Methods

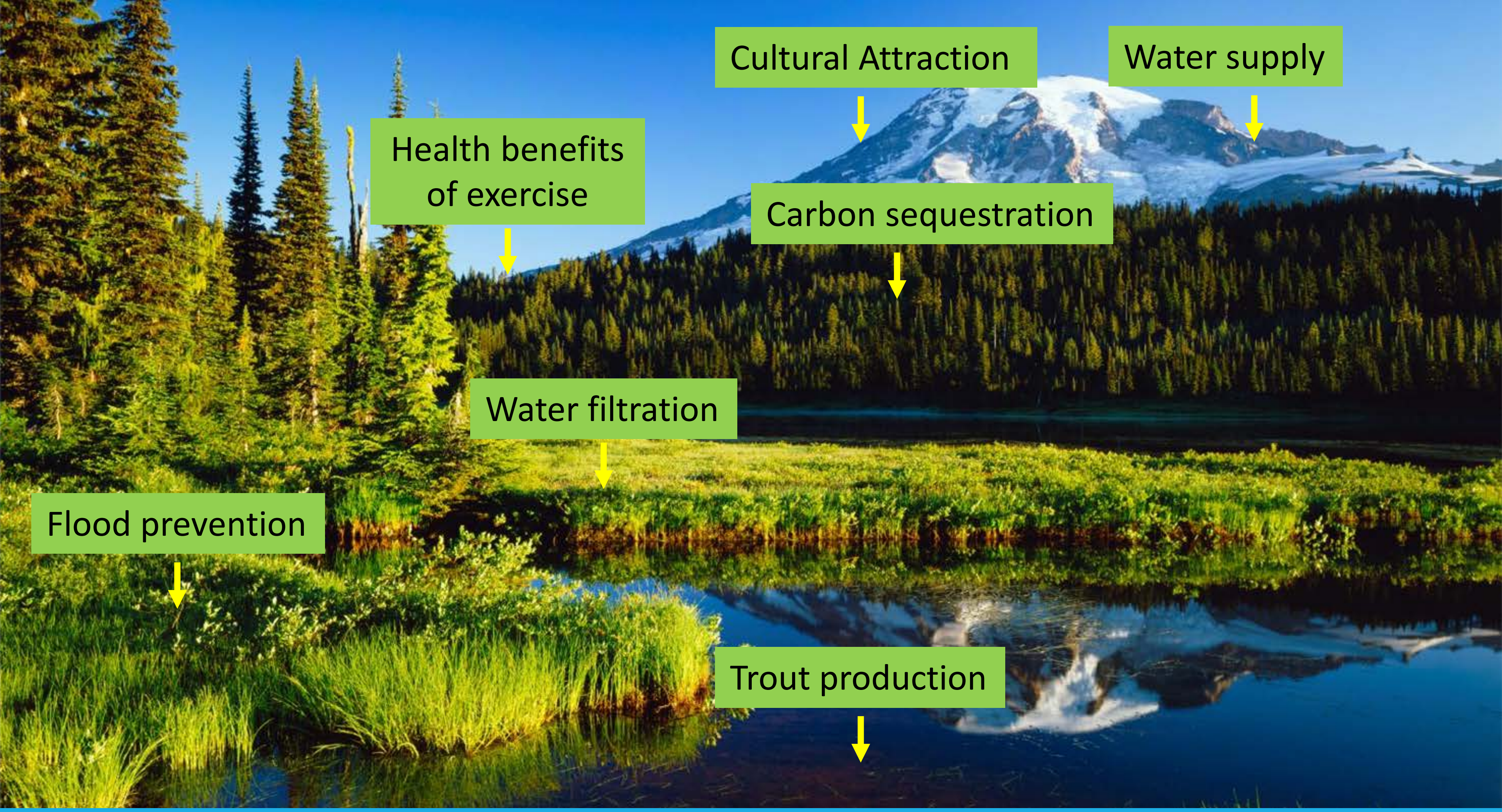
- NESP guidebook; Quantifying BRIs: https://nespguidebook.com/assessment-framework/quantifying-social-and-economic-context-in-bris/
- Wainger LA, Boyd JW. 2009. Valuing ecosystem services. Pages 92–111 in K. McLeod and H. Leslie, editors. Ecosystem-Based Management for the Oceans. Island Press, Washington, DC.
- Wainger et al. (in press). A proposed ecosystem services analysis framework for the US Army Corps of Engineers. ERDC/EL TR-xx-xxx. Vicksburg, MS: U.S. Army Engineer Research and Development Center

Some example implementations of BRIs

- Mazzotta, M.J., Bousquin, C. Ojo, K. Hychka, C. Druschke, W. Berry, and Rick Mckinney. 2016. Assessing the Benefits of Wetland Restoration: A Rapid Benefit Indicators Approach for Decision Makers. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-16/084.
- Wainger LA, King DM, Mack RN, Price EW, Maslin T. 2010. Can the concept of ecosystem services be practically applied to improve natural resource management decisions? Ecological Economics 69:978–987.
- Boyd J, Wainger LA. 2002. Landscape Indicators of Ecosystem Service Benefits. American Journal of Agricultural Economics 84:1371–1378.
- Wainger LA, King DM, Salzman J, Boyd J. 2001. Wetland value indicators for scoring mitigation trades. Stanford Environmental Law Journal 20:413–478.

Technical resources

- *Metric Aggregation:* Locantore, N., L. T. Tran, R. V. O'Neill, P. W. Mickinnis, E. R. Smith, M. O'Connell. 2004. An overview of data integration methods for regional assessment. Environmental Monitoring and Assessment. 94. 249-261.
- *Demand Assessment:* Mazzotta M, Wainger L, Sifleet S, Petty JT, Rashleigh B. 2015. Benefit transfer with limited data: An application to recreational fishing losses from surface mining. Ecological Economics 119:384–398.
- *Scarcity data sources and metric aggregation:* Wainger, L., K. Gazenski, E. Murray. (in review). Using scarcity and reliability data to value ecosystem services: assessment of currently available resources and metric aggregation methods. USACE ERDC Technical Report; some info at waingerlab.cbl.umces.edu/ecoscarcity (and Gazenski et al. **poster at ACES 2016**)



Developing Benefit Relevant Indicators EXERCISE

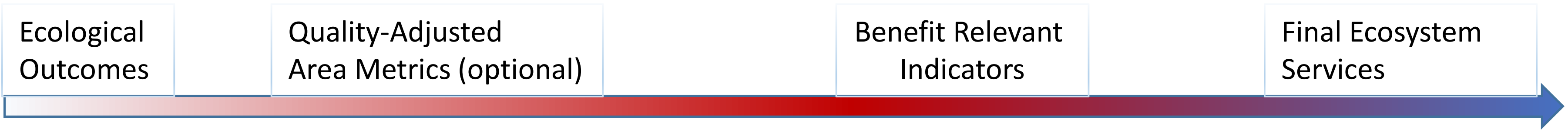
National Ecosystem Services Partnership

Developing Benefit Relevant Indicators

EXERCISE

BRI Exercise Steps

1. Select a conceptual model
2. Develop BRIs that incorporate at least one of these elements
   - Quality is sufficient
   - Complements - Capital and labor co-located / available
   - Demand - Users or beneficiaries present / possible
   - Reliability of the future stream of services
   - Scarcity and substitutability
3. Produce flow chart summarizing BRIs and connections



<u>Factors to consider</u>

- Qualities relevant to beneficiaries
- Complements - Capital and labor
- Demand - Users or beneficiaries
- Reliability
- Scarcity and substitutability

<u>BRIs (people implicit)</u>

Weight extent of biophysical change by a quality that is relevant to beneficiaries

Examples:

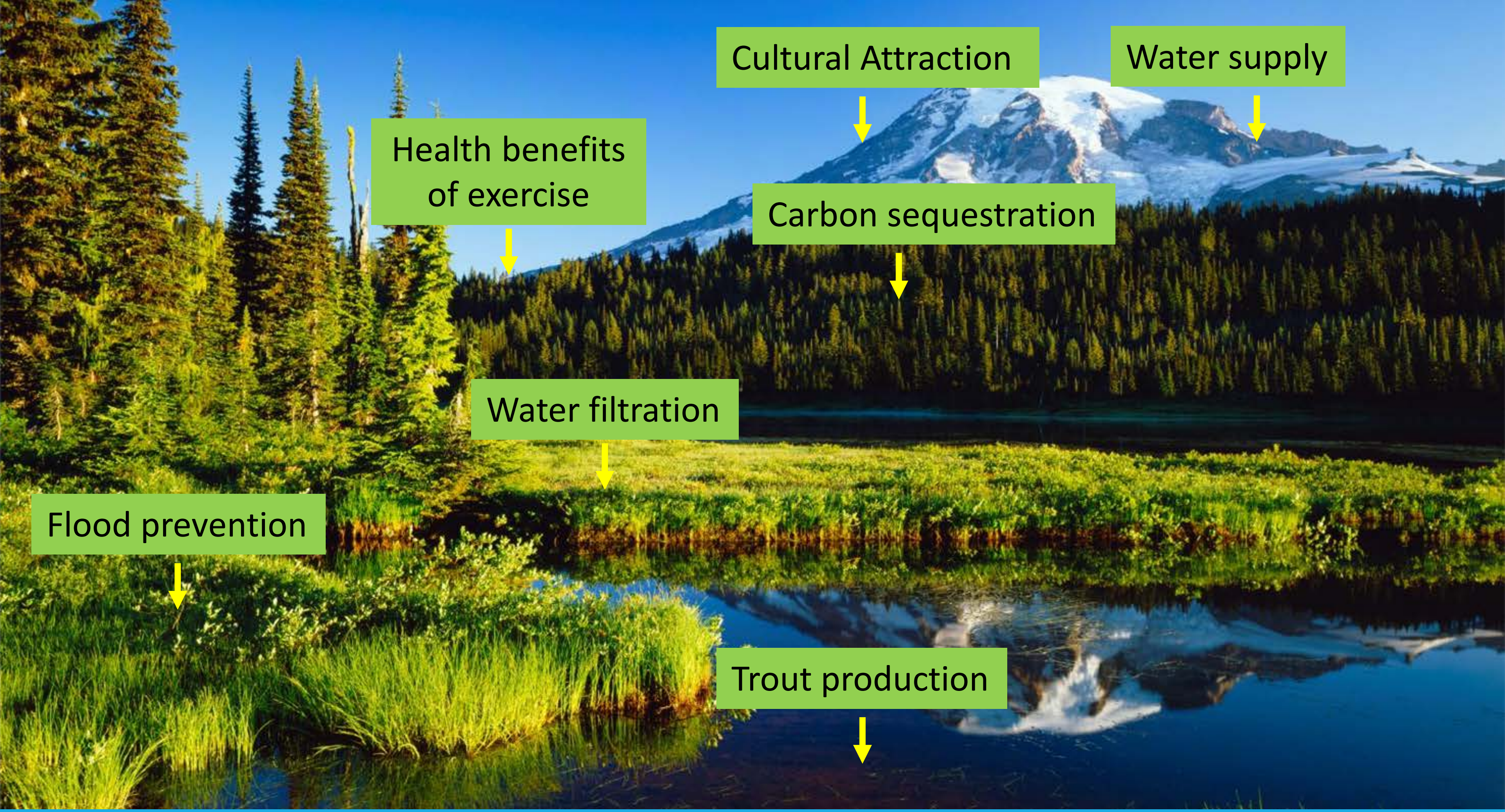
- Area with stable groundwater levels (water supply)
- Number of rare species with enhanced population viability (non-use value of aquatic ecosystem)

<u>BRIs (people explicit)</u>

Weight a biophysical change by the number of affected people or the intensity of concern

Examples:

- Number of private well users with stable groundwater supply



Benefits Assessment – Valuation methods

National Ecosystem Services Partnership

Ecosystem Service Values

- Ecosystem services may be defined as the aspects, flows or conditions of natural systems that benefit society.
  - “the flows from an ecosystem that are of relatively immediate benefit to humans and occur naturally” (Brown et al. 2007).
- The goal is a formal link between changes in ecosystems and changes in human well-being.
- Ecosystem service values are not limited to market values. Money does not have to be exchanged for a value to exist. Many services provide non-market values.
  - Values for things that are not directly bought and sold in markets, e.g., changes in recreational fishing, clean air and water, pollination, natural flood control.

Ecosystem Service Values

- Economic values provide a consistent means to quantify and compare changes to ecosystem services, in terms of their value to people.
- Economic values quantify changes in well-being in consistent and directly comparable units.
- Although the methods of measuring values can differ, the theory underlying value estimation is the same as that applied to market goods. The same rules apply.

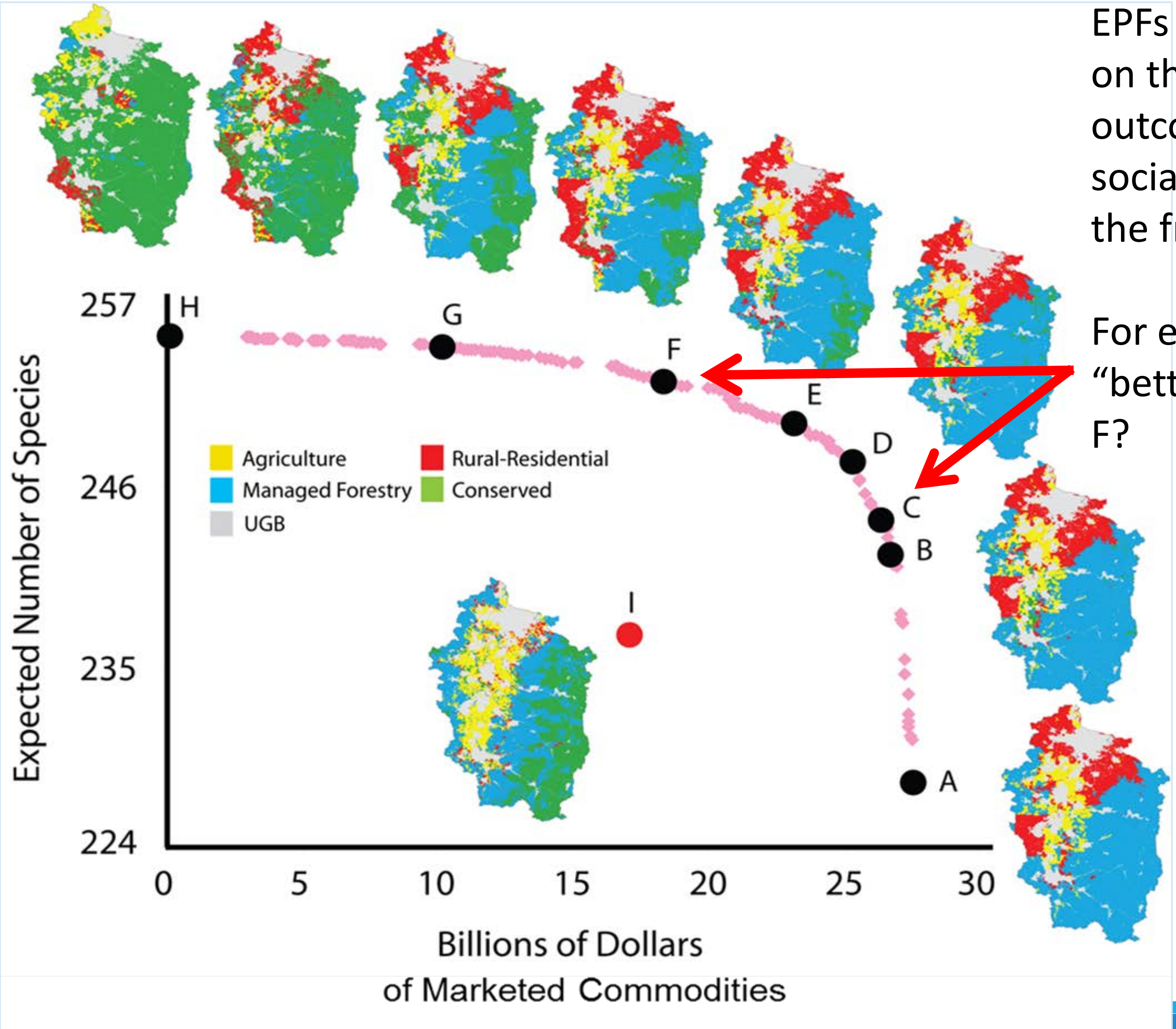
Why is Economic Valuation Useful?

- Economic valuation (like all valuation) is reductionist—it conveys value using a set of monetary metrics.
- It is designed to be one of the tools used to inform decisions, not the only tool.
- Unlike other ways of characterizing value, *correctly estimated* economic values are:
  - Quantified in units with clear meaning (e.g., dollars)
  - Of consistent interpretation across projects and methods.
  - Comparable to project costs quantified in monetary units.
  - Directly comparable across individuals, regions, services, etc.

When is Economic Value Required?

- BRIs measure *what is valued*, but do not measure *values*. When is valuation (or preference evaluation) required?
- Preference evaluation (including monetary or non-monetary valuation) is informative whenever *tradeoffs must be evaluated*. Examples include when:
  - Service provision varies substantially across different human populations, i.e., there are *tradeoffs across groups*; or
  - Ecosystem service changes vary in direction or magnitude across services, i.e., there are *tradeoffs across services*.
  - The *costs of actions that affect ecosystem services must be compared to the benefits* of these actions.
  - More is not monotonically better (e.g., deer populations).

Tradeoffs and Values



EPFs provide information on the frontier of possible outcomes, but not on the socially optimal point on the frontier.

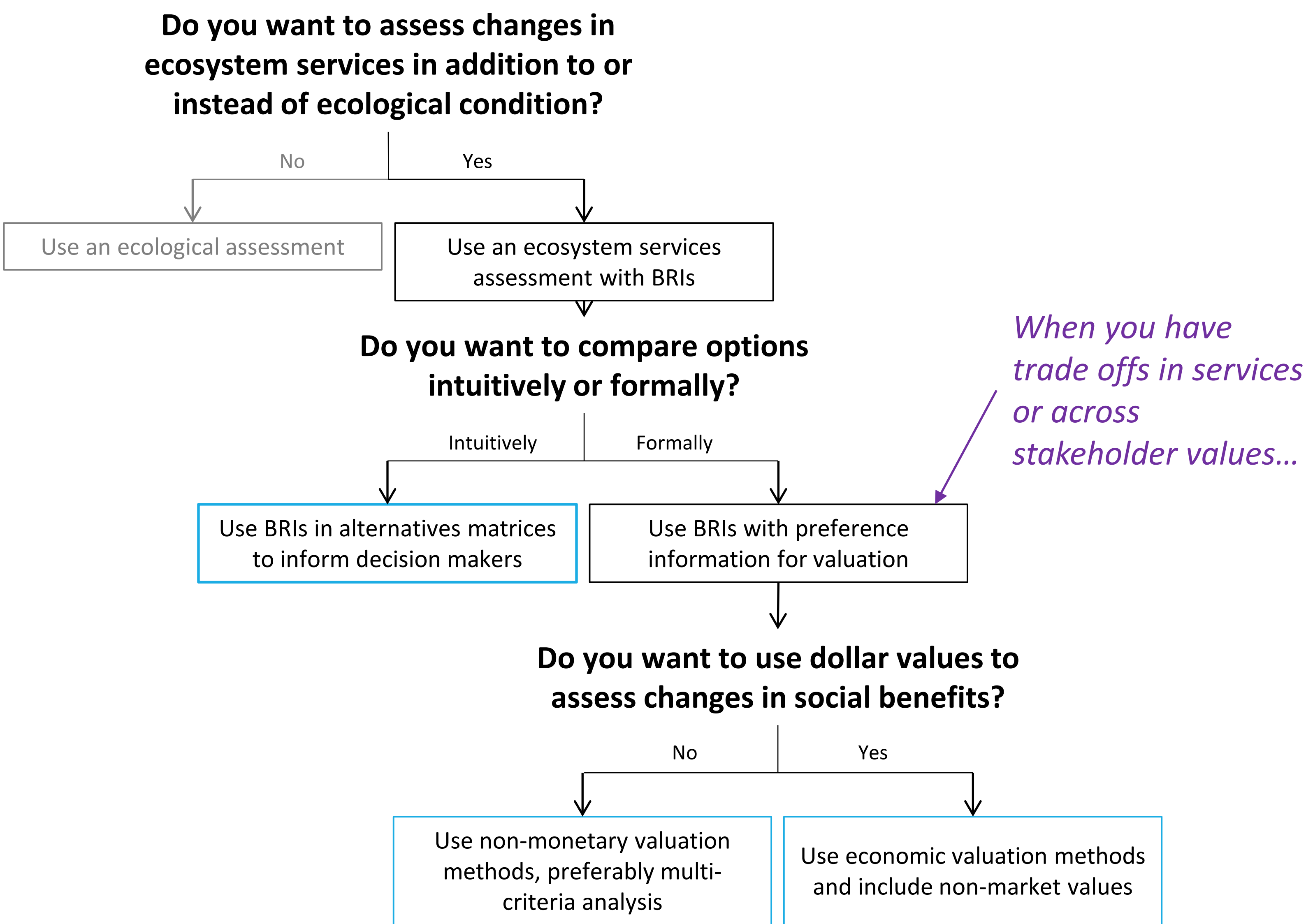
For example, which is "better," point C or point F?

The answer depends on relative social value.

Source: S. Polasky, et al. "Where to Put Things? Spatial Land Management to Sustain Biodiversity and Economic Returns," Biological Conservation 141(6) (2008):1505–1524

NESP

Decision Tree for Methods



Types of Preference Evaluation

- There are two main quantitative approaches to preference evaluation
  - Monetary (or economic) valuation
  - Non-monetary multi-criteria analytical methods
- This presentation focuses on *economic valuation*
  - Commonly applied and often required by government agencies (due to executive orders or statutes)
  - Directly comparable across sites and projects
  - May be used for benefit transfer

Key Concepts of Economic Value

- For something to have value (and hence be an ecosystem service or BRI), it must be valued either directly or indirectly by humans, because it enhances quality of life.
- Example: Existence values (nonuse) are a type of economic value. “Intrinsic” values are not.
- Values are measured (implicitly or explicitly) in terms of *tradeoffs*— what is the maximum one would be willing to give up in terms of
  - other goods/services (I’ll would be willing to give up my sandwich for a chocolate bar)
  - time (it takes an extra hour for me to travel to a better fishing site, but it’s worth it to me)
  - money (I’m willing to pay $50 a night more for the room with the ocean view)

Key Concepts of Economic Value

- Economic values are measured in terms of a marginal quantity of a good or service, from a known baseline.
  - NO: The total value of Narragansett Bay is $X.
  - YES: The value of a 5% increase in clam harvest in Narragansett Bay, from the current level, would be $Y.
- Example—it is possible, in principle, to estimate the economic value of additional fish "produced" by an additional X acres of coastal wetland in a specific area.
- It is *not* possible to estimate the economic value of all wetlands in the world, or the value of Long Island Sound.
  - These are not meaningful economic values.

Precursors to Economic Valuation

- Economic valuation requires:
  - A well-defined set of ecosystem services, generally measured as BRIs (what services generate the value?)
  - A well-defined baseline and set of changes (what are the ecosystem service changes to be valued?)
  - A well-defined set of beneficiaries in a specific set of areas (who receives the value?)
  - A well-defined set of values to be estimated (what type of values are to be measured?)
  - The use of valid and credible valuation methods (how are these values to be measured?)
- The first three of these requirements have already been discussed. Here we focus on the remaining two issues.

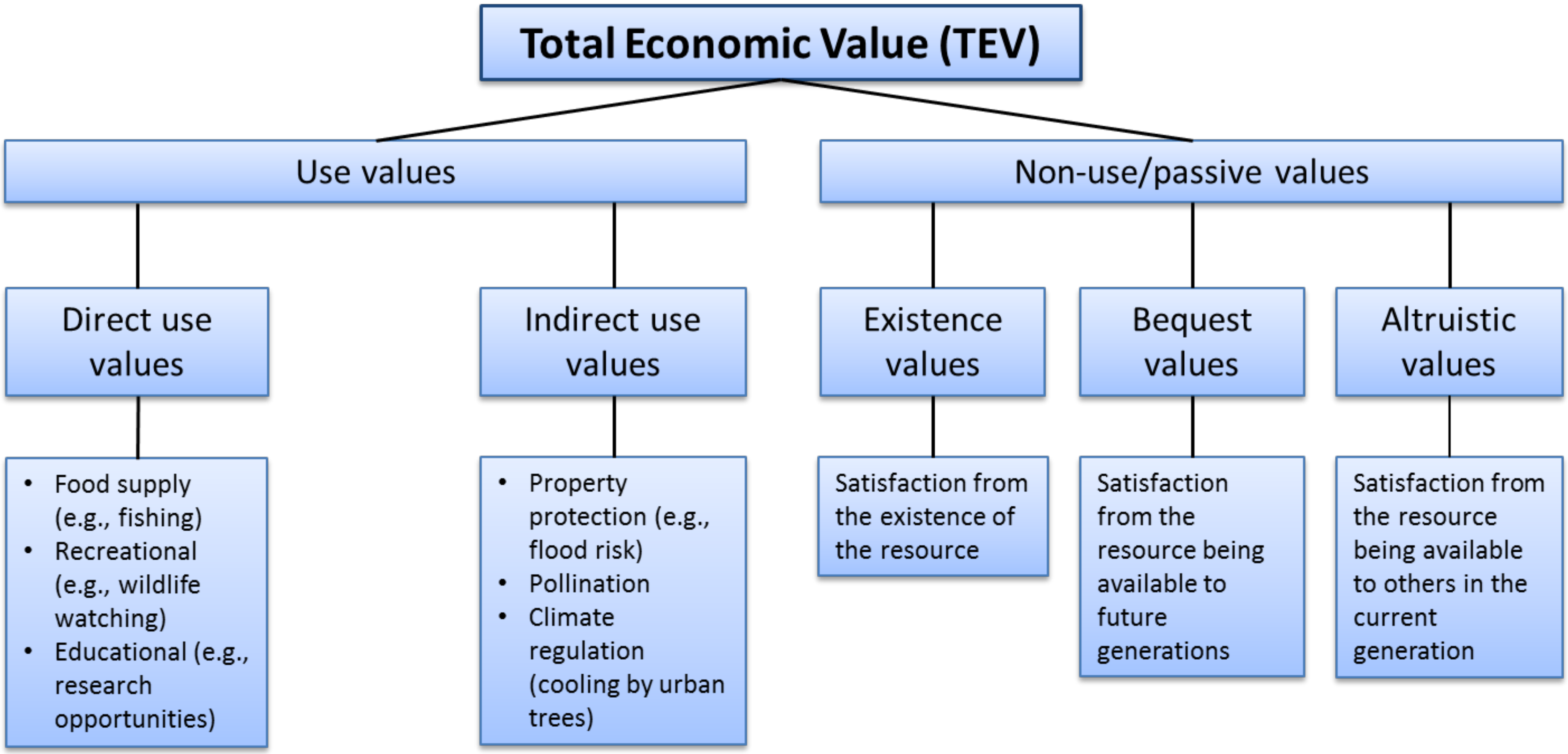
Beneficiaries

- Measures of ecosystem services depend on whose values are to be measured—the beneficiaries.
- One cannot define ecosystem services until one defines the relevant beneficiary groups. *If you have not defined the beneficiaries you are not doing ecosystem service valuation*.
- Changes in ecosystem features and functions often involve different benefits realized by multiple groups.
- It is often infeasible to measure all possible benefits to all possible groups. Choices must be made regarding the primary benefits to be measured, and to whom.
- "Whose values count" depends on a variety of factors, including legal/statutory restrictions and goals of the analysis.

How Economists Define Value

- Economists measure economic value in terms of willingness to pay (WTP), or sometimes willingness to accept (WTA).
- WTP is a theoretical concept that gives meaning to the monetary measure:
  - Defined as the maximum amount of money or some other good a person or group would be willing to give up in exchange for a good or service, rather than go without.
- When you measure economic value you are measuring (or approximating) WTP or WTA, whether you recognize it or not.
- Whether WTP or WTA is appropriate depends on various factors, including assumed property rights.
- WTP does not necessarily imply contingent valuation!

Different Types of Economic Value



Note: Source: NESP guidebook. Adapted from R.K.K. Turner, S.G. Georgiou, and B. Fisher, *Valuing Ecosystem Services: The Case of Multi-Functional Wetlands* (London: Earthscan, 2008).

Methods for Measuring Value

- Once the BRIs, beneficiaries and values (to be measured) are identified, one can determine the methods best suited to measuring these values.
- Different methods are applicable depending on whether these are market or non-market values.
- Methods for market valuation are often straightforward, based on analysis of market prices and quantities.
- Many ecosystem services generate large non-market values.
- Non-market valuation can be more challenging and require greater expertise.

Valuation Methods (Primary Study)

Table 1. Primary valuation methods applied to ecosystem services.

Valuation Method		Description	Examples of Ecosystem Services Valued
Market Valuation[a]	Market Analysis and Transactions	Derives value from household's or firm's inverse demand function based on observations of use	Fish, Timber, Water, Other raw goods
	Production Function	Derives value based on the contribution of an ecosystem to the production of marketed goods	Crop production (contributions from pollination, natural pest control). Fish production (contributions from wetlands, seagrass, coral)
Revealed Preference	Hedonic Price Method	Derives an implicit value for an ecosystem services from market prices of related goods	Aesthetics (from air and water quality, natural lands). Health benefits (from air quality)
	Recreation Demand Methods	Derives an implicit value of an on-site activity based on observed recreational travel behavior	Recreation value (contributions from: Water quality and quantity Fish and bird communities. Landscape configuration Air quality)

Source: NESPguidebook.com. Originally a**dapted from** Table 4.8 in **Turner,** Georgiou, and Fisher **(2008)**.

[a] Some typologies consider market valuation a type of revealed preference analysis.

[b] Most typologies group defensive and damage cost methods under revealed preference techniques.

Table 1. Primary valuation methods applied to ecosystem services.

Valuation Method		Description	Examples of Ecosystem Services Valued
Revealed Preference: Cost Avoided and Public Pricing[b]	Damage Costs Avoided	Value is inferred from the direct and indirect expenses incurred as a result of damage to the built environment or to people.	Flood protection (costs of rebuilding homes) Health and safety benefits (treatment costs)
	Averting Behavior / Defensive Expenditures	Value is inferred from costs and expenditures incurred in mitigating or avoiding damages	Health and safety benefits (e.g., cost of an installed air filtration system suggests a minimum willingness-to-pay to avoid discomfort or illness from polluted air)
	Replacement / Restoration Cost	Value is inferred from potential expenditures incurred from replacing or restoring an ecosystem services.	Drinking water quality (treatment costs avoided). Fire management
	Public Pricing	Public investment serves as a surrogate for market transactions (e.g., government money spent on purchasing easements).	Non-use values (species and ecosystem protection). Open space. Recreation
Stated Preference	Contingent Valuation (open-ended and discrete choice)	Creates a hypothetical market by asking survey respondents to state their willingness-to-pay or willingness-to-accept payment for an outcome (open-ended), or by asking them whether they would vote for or choose particular actions or policies with given outcomes and costs (discrete choice).	Non-use values (species and ecosystem protection), Recreation. Aesthetics
	Choice Modeling / Experiments	Creates a hypothetical market by asking survey respondents to choose among multi-attribute bundles of goods with associated costs and derives value using statistical models.	Non-use values (species and ecosystem protection). Recreation. Aesthetics

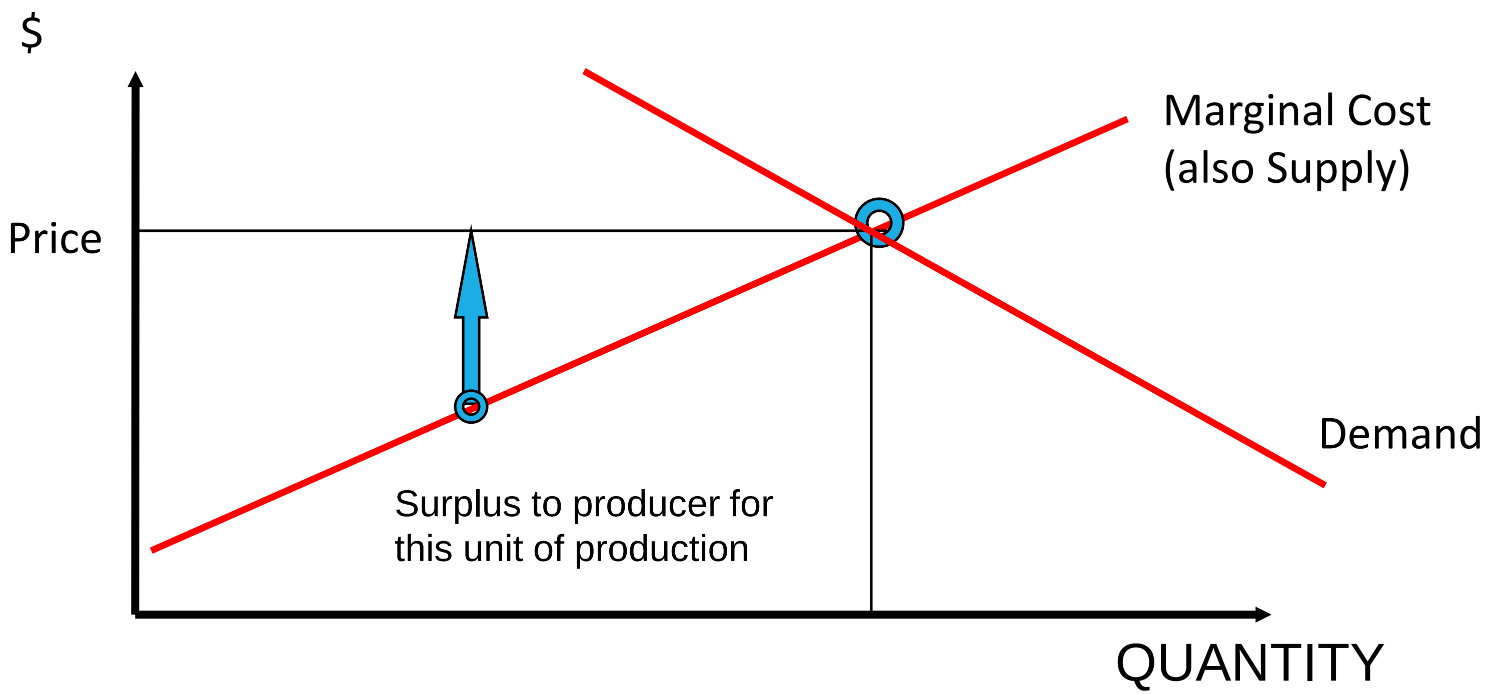
- Cost avoided and public pricing methods generate accurate measures of economic value only *under very narrow and restrictive circumstances (if at all)*.

Primary Valuation Studies

- Note that none of these methods measures jobs or "economic impacts" such as local economic activity.
  - These are not valid measures of economic value.
  - Natural disasters or warfare can generate lots of jobs and income, but do not enhance net social benefit.
  - Simply because something is measured in monetary terms does not mean it qualifies as an economic value.
- All valuation approaches require specialized expertise and data collection for the affected sites—spreadsheet tools are only rarely sufficient.
- Economists should be involved from the beginning of any ecosystem services assessment, to ensure that biophysical measures (BRIs) and EPFs are suitable to inform valuation.

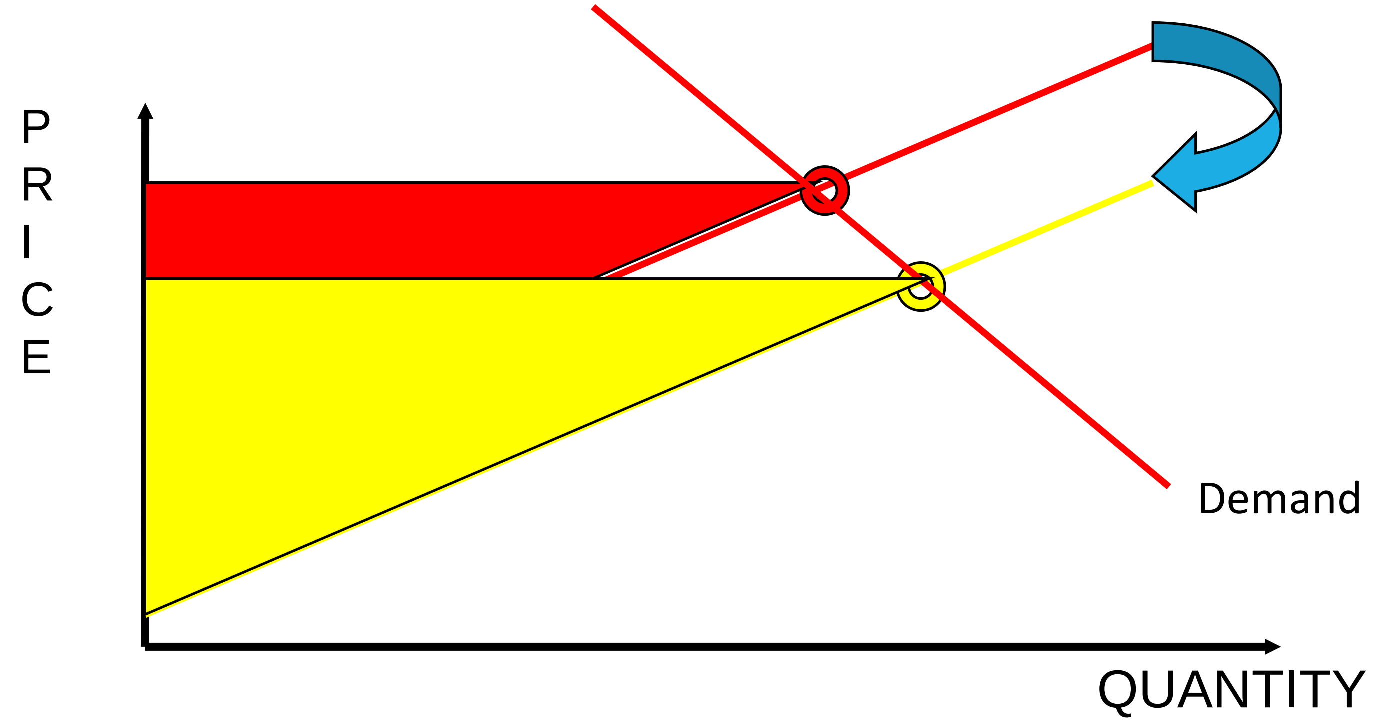
Example—Factor Inputs (Value to Producers)

Consider a market product produced with an ecosystem service as an input (e.g., shrimp). Producer value is the difference between revenue and cost for each unit sold.



Example—Factor Inputs (Value to Producers)

Habitat restoration increases shrimp abundance (EPF) and decreases the marginal cost of harvest (economic modeling). The difference between the red and yellow triangles is the value of the change.



A Simple Spreadsheet Example

- **Degraded Habitat**
  - Catch rate per day = 5,000 lbs.
  - Dockside Price = $0.70
  - Variable cost per pound = $0.50
  - Total days fished in season = 16
  - Total revenue = 16 x 5,000 x $0.70 = $56,000
  - Total variable costs = 16 x 5,000 x $0.50 = $40,000
  - Producer Surplus = $56,000 - $40,000 = $16,000

- **Improved Habitat**
  - Catch rate per day = 8,000 lbs.
  - Dockside Price = $0.70
  - Variable cost per pound = $0.40
  - Total days fished in season = 16
  - Total revenue = 16 x 8,000 x $0.70 = $89,600
  - Total variable costs = 16 x 8,000 x $0.40 = $51,200
  - Producer Surplus = $89,600 - $51,200 = $38,400

Change in Ecosystem Service Value to Shrimp Harvesters = $22,400 / yr.
Additional values may be realized by consumers if prices change.

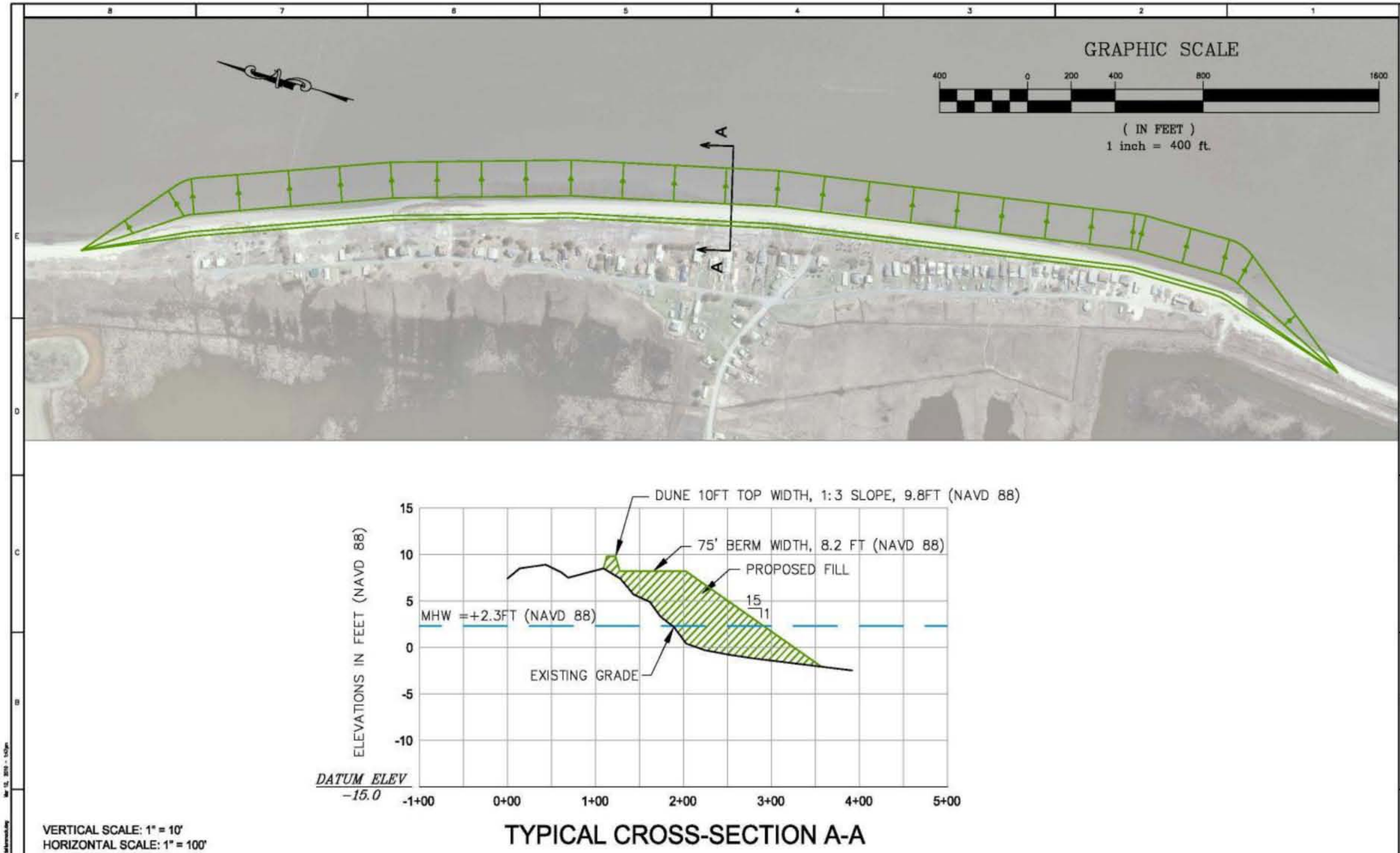
Non-Market Example: Recreational Services of Delaware Bay Beaches

- An example is drawn from a project conducted with the Delaware Department of Natural Resources and Environmental Control (DNREC).
- What is the recreational ecosystem service value gained or lost under different policies to protect Delaware Bay Beaches from erosion due to storms and sea level rise?
- Beaches are: (1) Pickering, (2) Kitts Hummock, (3) Bowers, (4) South Bowers, (5) Slaughter, (6) Primehook, and (7) Broadkill.
- Recreation demand models are used to estimate the value of these beaches under different management scenarios.

Scoping, Causal Chains and EPFs

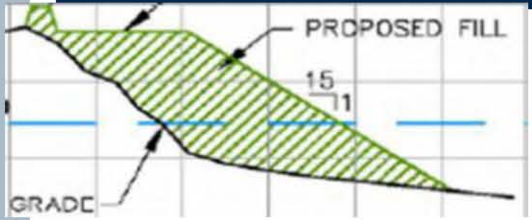
- Scoping and causal chain development was conducted in coordination with stakeholders, policymakers and scientists.
- This illustration shows valuation of recreational benefits.
- Engineering projections of beach width and housing loss were provided by Johnson, Mirmiran and Thompson (2012) for each beach, under four management scenarios for 2011-2040. These provided the basis for EPFs.
  - Scenario 1—Beach Nourishment
  - Scenario 2—Managed Retreat
  - Scenario 3—Basic Retreat
  - Scenario 4—Do Nothing

Beach Nourishment - Defined



PBSJ	CLIENT: DELAWARE DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENTAL CONTROL	PROJECT: KITTS HUMMOCK	TASK: 10 YEAR SCENARIO	FIGURE 7.18

Enhanced Retreat - Defined



Initially remove structure to allow a beach/dune width equal to the recommended beach nourishment templates for each community.

As additional erosion/shoreline migration occurs, additional structures are removed to maintain this beach width

Basic Retreat - Defined

Initially remove structures to allow a beach/dune width equal to the current widths in each community.

Where existing structures occupy the beach, initial removal occurs .

As additional erosion/shoreline migration occurs, additional structures removed to maintain this beach width.

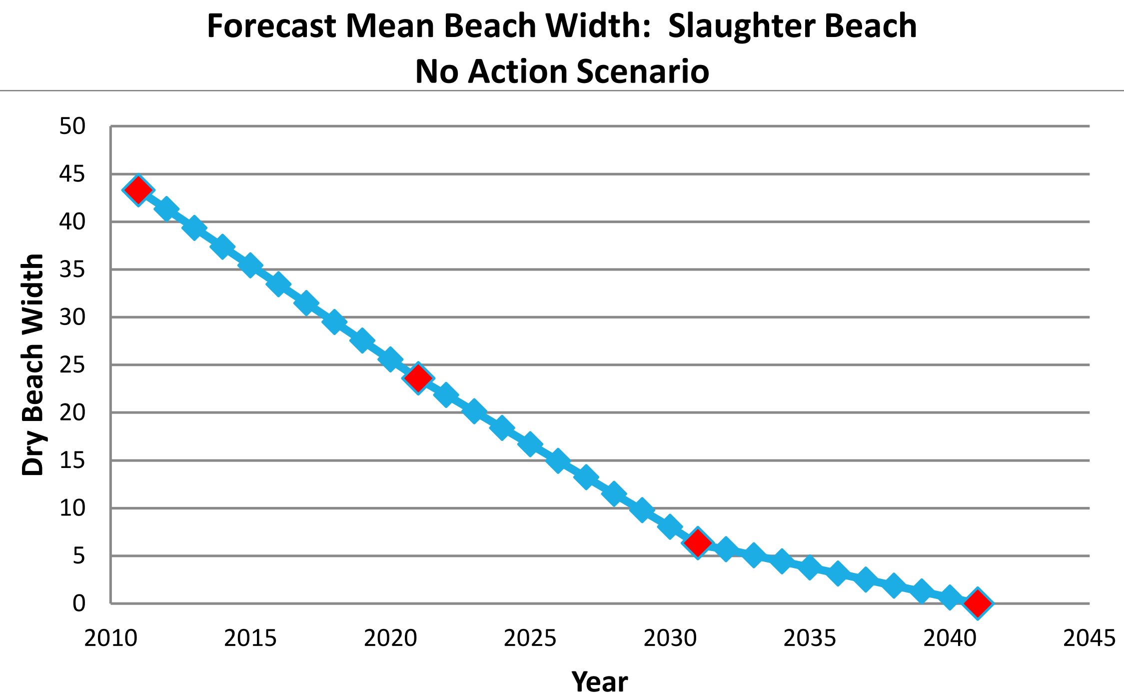
Do Nothing - Defined

This alternative involves no action on the part of state shoreline managers. No beach fill or beach enhancement will occur, historic shoreline migration will cause increasing damage to structures. Houses will be destroyed or removed. Flood insurance is available, and generally covers damage and removal.

Biophysical and Economic Tradeoffs

- Nourishment—recreational benefits increase due to width increases. But this is also the most costly policy.
- Strategic Retreat—Benefits increase due to width increases, but decrease due to large housing losses (forced landward retreat).
- Basic Retreat—Benefits increase due to width increases, but decrease due to modest housing losses (forced landward retreat).
- No Action—Benefits decrease due to width and housing losses. No natural retreat allowed.

EPFs: Projecting Beach Width



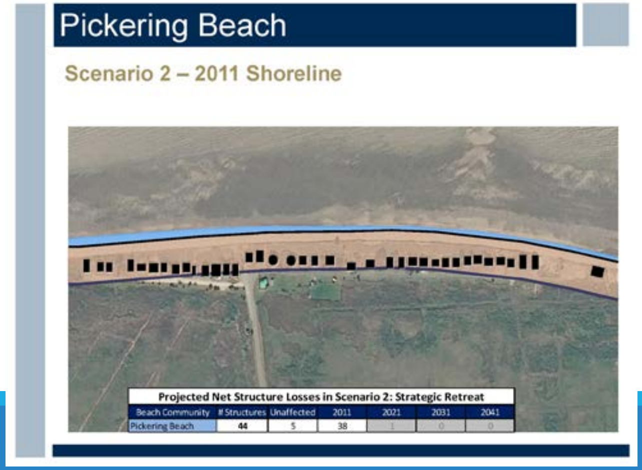
- Mean dry beach widths are forecast for each beach, during each year of the analysis, under each scenario.
- These forecasts are based on beach-specific retreat data from past years combined with sea-level/geomorphology forecasts and scenarios.
- Red points are modeled with interpolations in between.
- Widths at any year can be compared across scenarios to generate the “deltas.”

Estimating Recreational Values

- Recreation demand model estimates annual recreational benefits for each beach at: (1) zero width, (2) current average width, (3) 25% of current width, (4) 200% of current width (Parsons et al. 2013).
- Model is estimated based on observations and survey data from recreationists sampled at each site.
- Random effects Poisson regression predicts trips as a function of beach width, travel cost and other factors
- Tradeoffs between travel cost and trips used to estimate demand & consumer surplus (WTP) under different scenarios for action and beach width.

The Integrated Model

- Model predicts recreational value changes for all beaches, under each scenario, for all years between 2011 – 2041.
- Number of owner and overnight trips is assumed to decline in proportion to loss of standing houses, further reducing benefits.
- The sum of discounted benefits over all time periods (2011 to 2041) is defined as the net present value.
- All values are discounted at a 4% annual discount rate.



Change in Recreational Values Under Alternative Actions

Beach and Visitor Type	Beach Nourishment	Basic Retreat	Enhanced Retreat
Pickering (total)	$659,832	$306,567	$169,168
Kitts Hummock (total)	$625,966	$330,514	$278,198
Bowers (total)	$1,173,049	$579,326	$927,590
South Bowers (total)	$393,726	$82,450	$290,372
Slaughter (total)	$2,391,604	$1,583,761	$2,194,251
Prime Hook (total)	$1,092,704	$63,236	-$365,880
Broadkill (total)	$9,729,112	$7,837,672	$7,268,543
TOTAL ALL BEACHES	**$16,065,994**	**$10,783,525**	**$10,762,243**

Note. All estimates represent Present Value over 2011 to 2041, discounted at 4% and compared to No Action Scenario.

- The table shows changes in non-market recreational values provided by Bay beaches under different adaptation alternatives, compared to a default of No Action.
- Note that this does NOT reflect the costs of each option.

Benefit Transfer

- The use of primary research to estimate economic values is almost universally preferred when possible.
- This requires new data and models for the site(s) of interest.
- But, realities of the policy process often preclude the use of primary research to quantify ecosystem service values, leaving Benefit Transfer (BT) as the only option.
- BT uses economic value estimates from existing research (at a study site) to approximate the value of a similar but separate change elsewhere (the policy site).
- BT allows these values to be measured, but includes unavoidable errors.

Main Types of Benefit Transfer

- **Unit Value Transfer** (transfer a number or adjusted number)—Simple but risks large error if study and policy sites are not very similar.
- **Benefit Function Transfer** (transfer a function, usually from one study)—Allows adjustments for some differences between study and policy sites, but accuracy depends on site similarity.
- **Meta-Analysis** (transfer a function calculated from statistical analysis of many studies)—Most flexible approach and does not require site-to-site similarity, but can be sensitive to statistical methods and available studies.

Using Meta-Analysis for Benefit Transfer

Mean Predicted Marginal Value per Fish, by Region and Species							
Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
big game	$12.32	$6.19	$5.95	$13.57	$13.26		
small game	$6.38	$5.22	$5.19	$5.03	$4.95		$4.71
flatfish	$8.57	$5.24	$4.94	$4.93	$4.82		
other saltwater	$2.60	$2.62	$2.56	$2.50	$2.44		$2.54
salmon	$13.67					$11.66	$13.88
steelhead	$11.25					$12.57	$11.42
musky						$61.37	$64.71
walleye/pike						$3.61	$3.60
bass						$7.52	$7.92
panfish			$0.93	$0.93		$1.17	$0.93
rainbow trout						$7.38	$2.84
other trout						$8.29	$2.48
generic freshwater						$5.46	$1.96
generic saltwater	$2.73	$2.64	$2.85	$2.51	$3.22		$2.79

- Stapler and Johnston (2009) show how benefit transfers can account for value differences across service types (e.g., types of fish), based on meta-regression models estimated from many prior studies.

Benefit Transfer Errors

- Rosenberger (2015, Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners, Chapter 14) summarizes transfer errors in non-market valuation.

Benefit Transfer Method	Median Absolute Value Error	Mean Absolute Value Error (Std. Err.)	Range of Absolute Value Errors	Number of Studies (N)
Unit Value	45%	140% (10.6)	0-7496%	1792
Benefit Function	36%	65 (4.0)	0-929%	756

Benefit Transfer for Ecosystem Service Valuation

- Methods for ecosystem service benefit transfer are described by Johnston and Wainger (2015, Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners, Chapter 12).
- These methods are indispensable but often misused.
- Factors influencing the applicability of benefit transfer include:
  - (a) the time and resources available; (b) the availability of data for a primary study; (c) policy process constraints;(d) accuracy and other needs of the policy context; (e) the size of policy impacts relative to the cost of a primary study; (f) the availability of primary studies suitable for transfer.

Valuation Toolboxes and Systems

- There are an increasing number of pre-programmed valuation “toolboxes” and decision-support tools marketed for ecosystem services analysis.
- Some are fairly sophisticated, at least with regard to biophysical components (e.g., InVEST)
- However, caution should be exercised in the use of such tools, without knowledge of the underpinnings of the model.
- These tools often use simplistic benefit transfers that fail to account for many factors that may cause values to change over areas, even for a given ecological change.

Some Values Decline with Distance

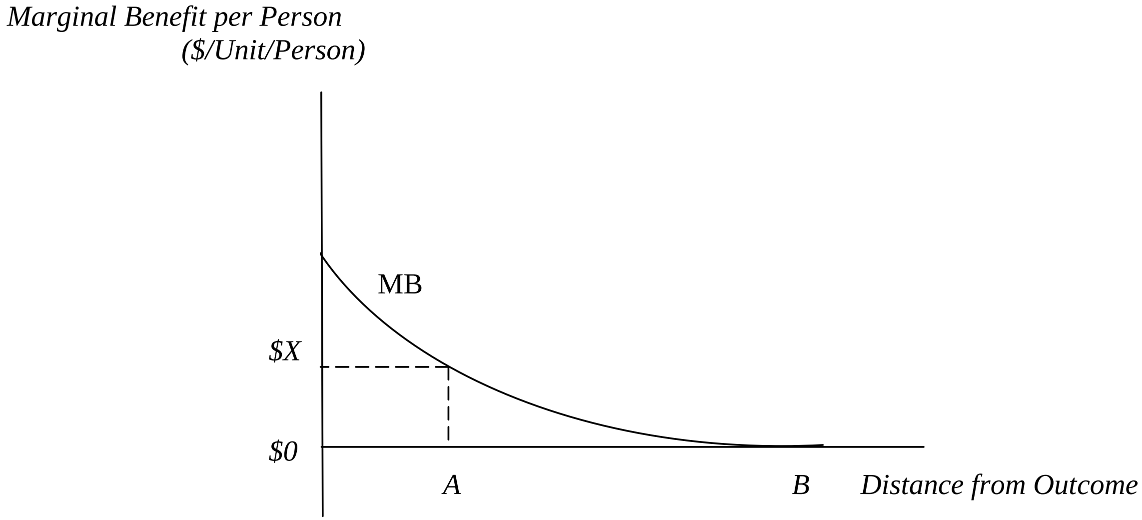
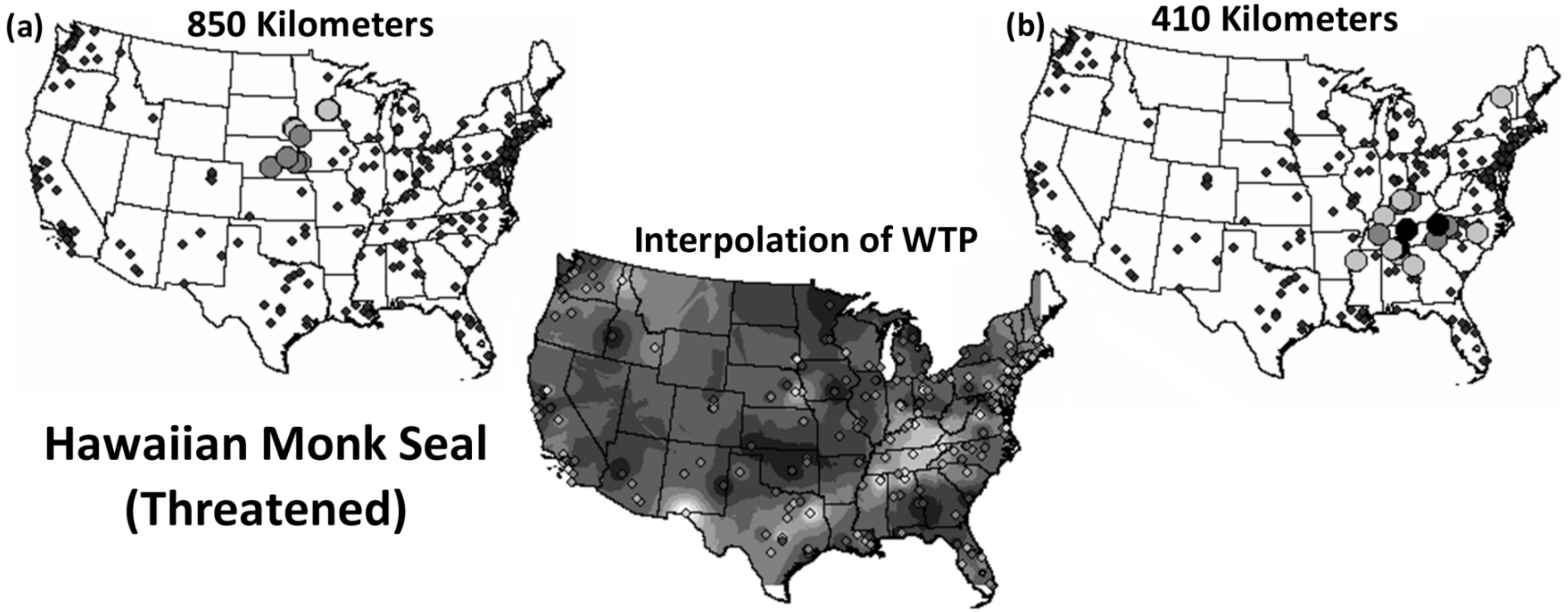
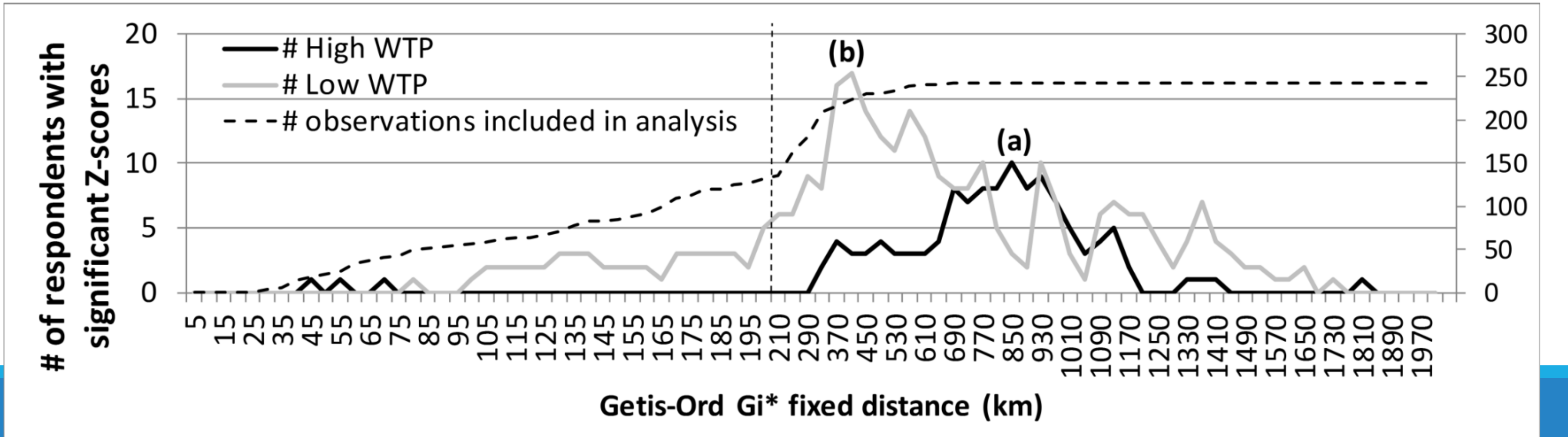


Figure 2.2 Marginal Benefits and Scale over Distance (or Populations Over Greater Areas)

Other Values are Patchy (Johnston et al. 2015, Land Economics)





But Isn't *Some* Number Better than No Number?

- The use of questionable or inaccurate methods to estimate ecosystem values is risky.
  - Can lead to misguided actions and investments.
  - Can lead to perverse or unintended consequences.
  - Can lead to values being discounted or ignored by decision-makers (if they are viewed as widely invalid).
  - Can lead to values (and decisions based on those values) being overturned during legal challenge.
  - Can erode public trust in science and management.

Some Final Considerations

- It is important to involve both natural and social scientists from the outset of the analysis, from question formation through valuation.
- Major errors are often made when analyses seek to “scale up” ecosystem service values measured over small changes or areas to much larger changes or areas.
    - Values change over (1) quantities of an ecosystem service, (2) areas, and (3) affected populations.
- Because of this, it can be challenging to map ecosystem services across the landscape.
- A larger number of ecosystem services (or more of one ecosystem service) are not always better than a smaller number. Consider water levels in a river…

Concluding Comments

- Ecosystem services quantification and valuation can provide information to help ensure that decisions account for the human benefits provided by ecosystems.
- Valuation is particularly important when tradeoffs or costs are involved.
- Validity and accuracy of ecosystem service valuation depends on an application of appropriate methods to well-defined ecosystem services and beneficiary groups.
- Ecosystem service valuation requires an understanding of the causal chain linking actions to BRIs to benefits.
- Relevant valuation methods depend on the type of values to be measured.

Concluding Comments

- Different types of values can be measured, depending on the goals of the analysis and the type of ecosystem services under consideration.
- Ecosystem service values generally change over different areas, beneficiaries and service quantities. Accurate valuation should account for these differences
- Primary valuation or benefit transfer can be used, depending on the policy context, accuracy needs and data availability.
- Be cautious of valuation toolboxes or tools, without an understanding of the underlying methods.
- Inaccurate value estimation can lead to decisions with perverse and unintended consequences. "A Big Number" can be a bad idea if the number is meaningless or (badly) wrong.

Questions?

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Take Aways

- ES can be incorporated into existing decision processes in various ways
  - Flexibility in how ES included based on needs and capacity
- It is helpful to understand the chain of custody of information to allow hand-offs between ecological and social analysis
- It is important to understand needed technical capacity
- It is important to move forward despite existing data and modeling gaps and work to fill them

Discussion

1. Your questions, thoughts and input…
2. Would this ES framework work for you?
3. Would there be value in developing formal training? What would that look like?