LANDSCAPE APPROACHES TRAINING SERIES

Session 2: Linking Ecosystem Service Science& Natural Capital Accounting

THE WORLD BANK
Environment, Natural Resources & Blue Economy

GPS
Global Program on Sustainability

Stephen Polasky

Regents Professor; Fesler-Lampert Professor of Environmental Economics, University of Minnesota

polasky@umn.edu

Stephen's research focuses on issues at the intersection of ecology and economics including the value of ecosystem services and natural capital, biodiversity conservation, land use, sustainability, common property resources, and environmental regulation. He is the co-founder of the Natural Capital Project at Stanford University; a member of the National Academy of Sciences; a Fellow of the Association of Environmental and Resource Economists, the American Academy of Arts and Sciences, and the American Association for the Advancement of Science.

learning objectives

- Understand and apply various methods to value nature.
- Identify, apply and iterate for ways in which natural capital accounting can be incorporated into decision-making processes.

about our workshop

The Great Depression in the 1930s brought about a significant shift in economic policies and use of extended macroeconomic performance metrics such as the GDP, to inform economic decision-making. The Great Degradation of nature in the current times also calls for an urgent realization and development of better and more accurate metrics of ecosystem services to inform decision-making and help guide sustainable development. This session provides an insight into the methods to value nature and incorporate its values into economic and financial decisions. It dives deep into two metrics for ecosystem services – Natural Capital Index (NCI) and Gross Ecosystem Product (GEP) – and the methods to measure these. Finally, the session explores incentives for incorporating the results from these accounting processes into decision-making processes.

Keywords: InVEST, Natural Capital Index, Gross Ecosystem Product, efficiency frontier

Linking Ecosystems and Economic Systems

The Importance of Accounting for the Value of Nature

Stephen Polasky
University of Minnesota &
Natural Capital Project
June 6, 2022

The sustainable development challenge

- "The central challenge of the 21st century is to develop economic, social, and governance systems capable of ending poverty and achieving sustainable levels of population and consumption while securing the life-support systems underpinning current and future human well-being"

June 16, 2015 Special Issue of PNAS

Guerry, Polasky, Lubchenco, et al. 2015.
Natural capital and ecosystem services informing decisions: From promise to practice
PNAS 112: 7348-7355

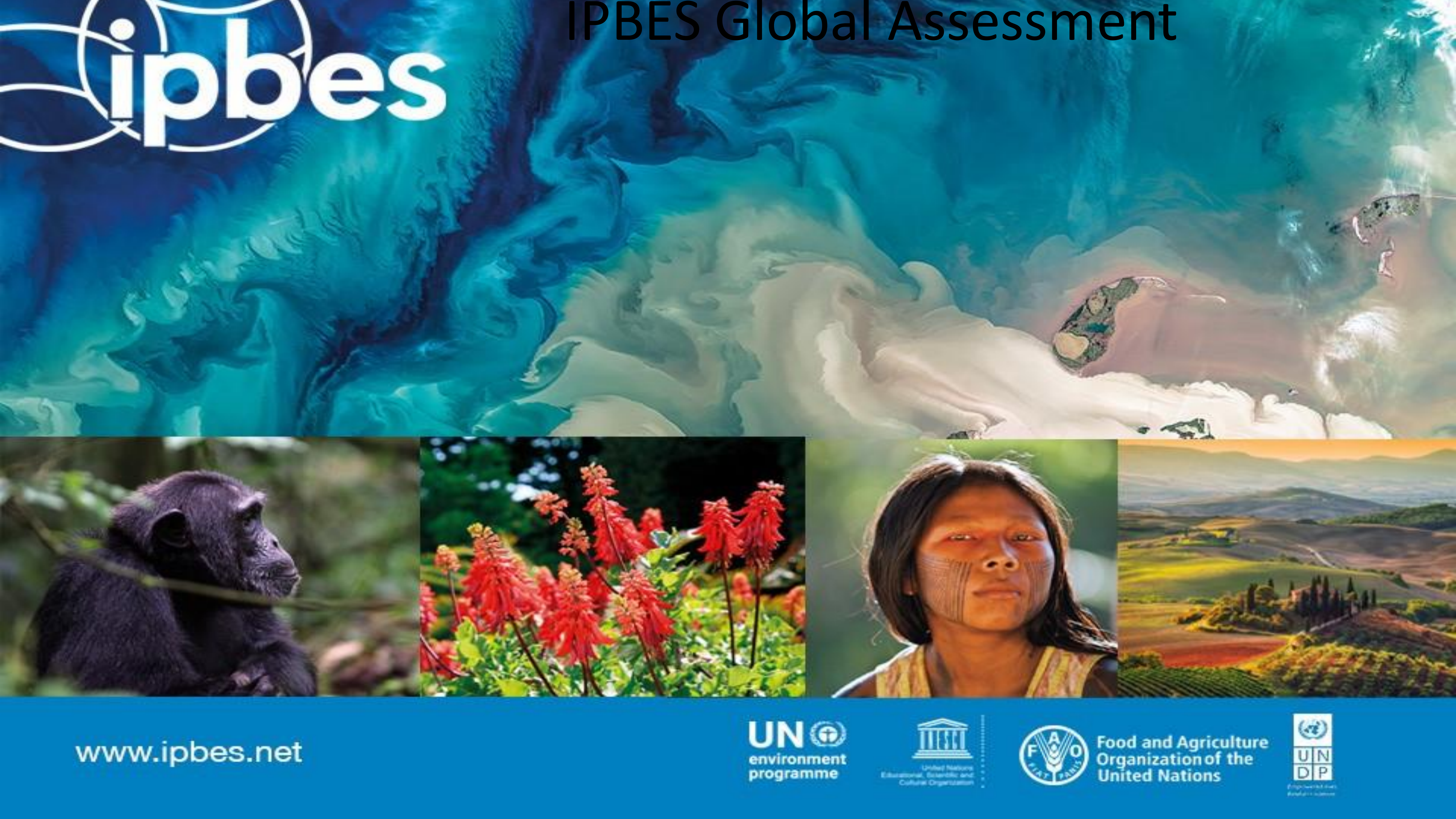
Ecosystem services/nature’s contributions to people

- Nature provide a wide array of benefits (and costs) to people: “ecosystem services” or “nature’s contributions to people”
- Nature as capital: “natural capital”
- Human actions affect natural capital and the ecosystem services they provide
- Ecosystem services often are not factored into important decisions that affect natural capital
- Distortions in decision-making damage natural capital and the provision of ecosystem services making human society and the environment poorer

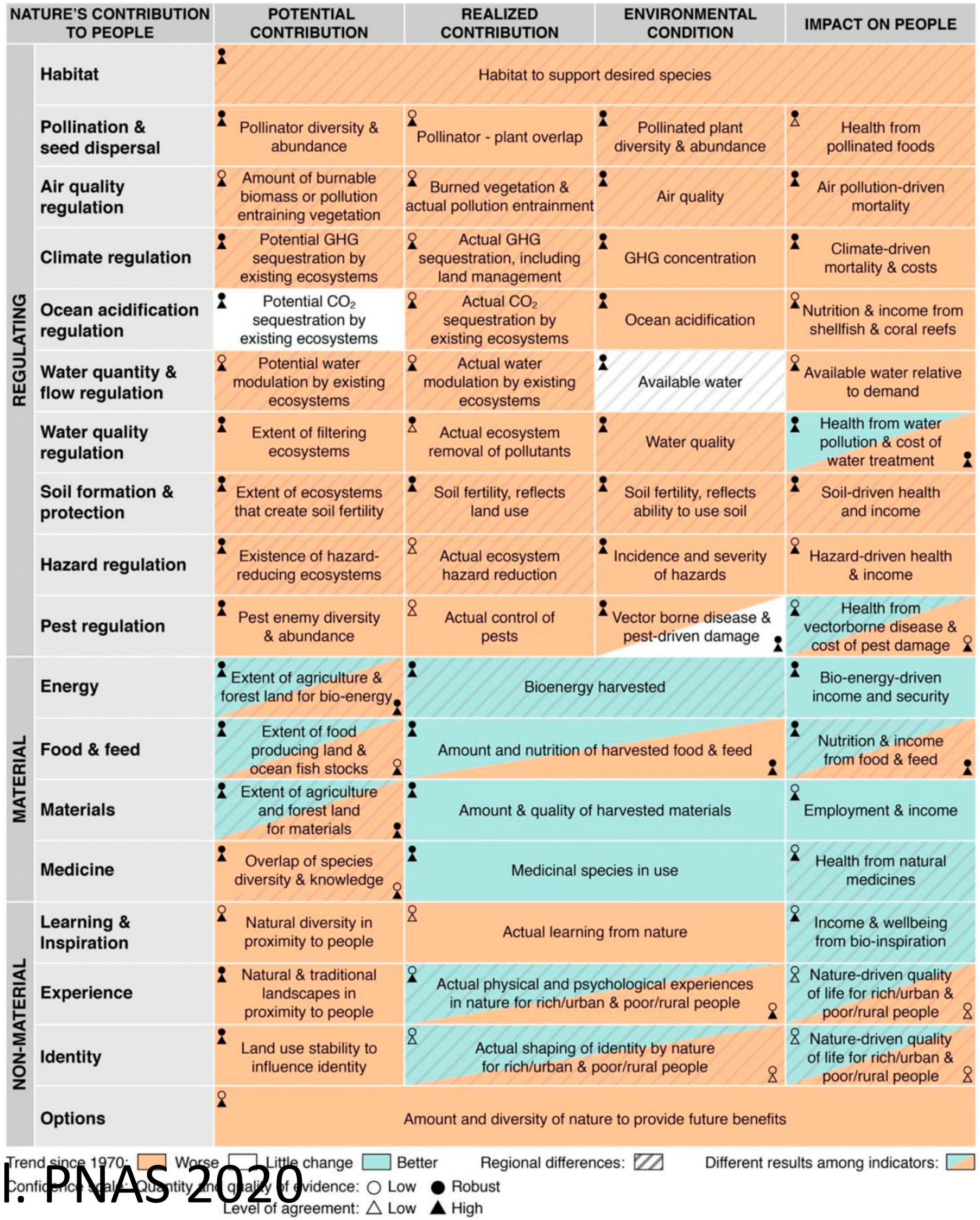
Trends over the past 60 years

- “You get what you pay for.”
- Increase in global GDP since 1960: 6.5 X increase
  - 11.3 trillion in 1960 to 84.9 trillion in 2019 (2010 $)
- Corollary: “You don’t get what you don’t pay for”
- Decline in 14 of 18 categories of nature’s contributions to people

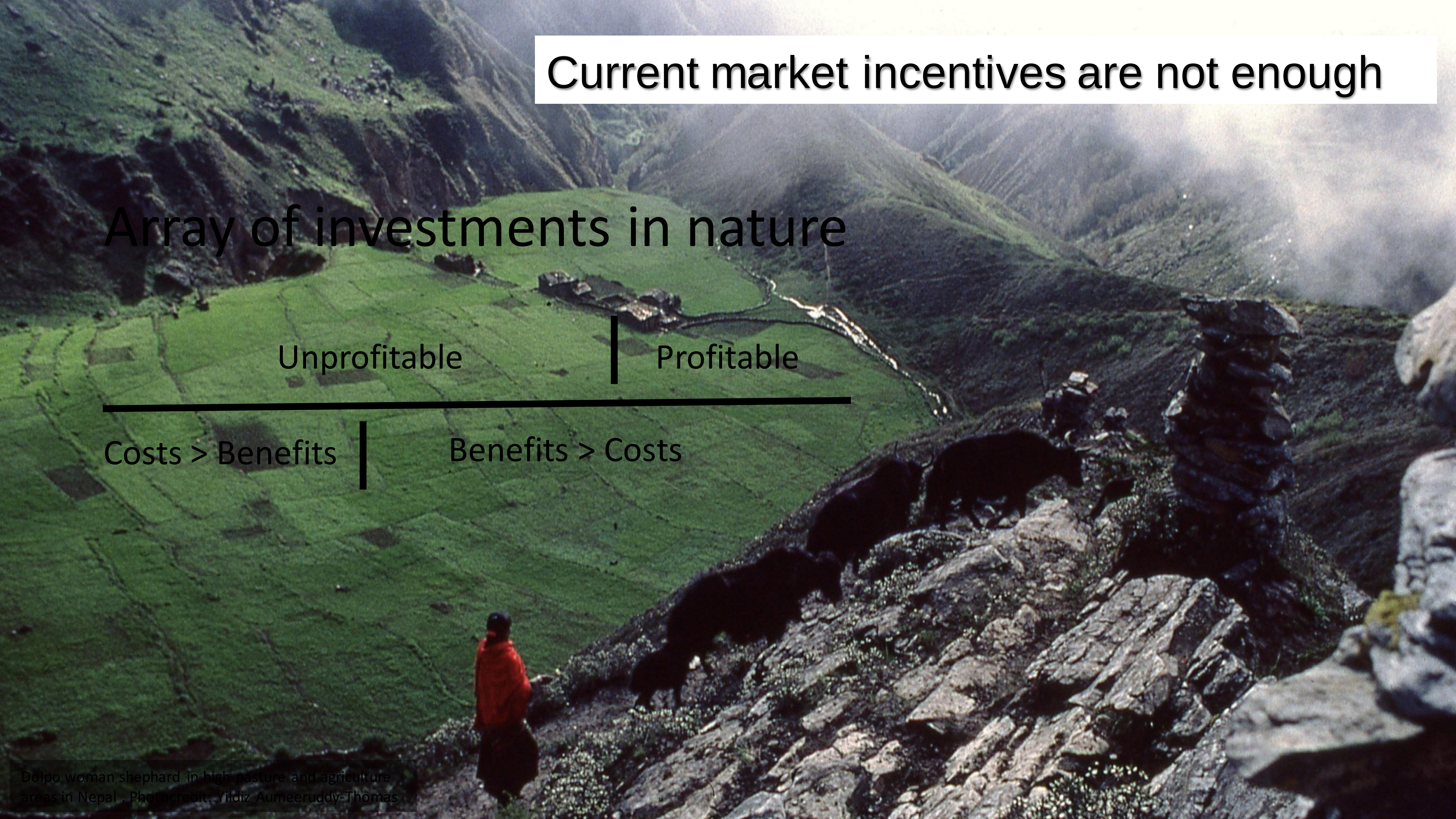
IPBES Global Assessment



Downward trend in the majority of nature's contributions to people over the past 50 years



Brauman, Garibaldi, Polasky et al. PNAS 2020

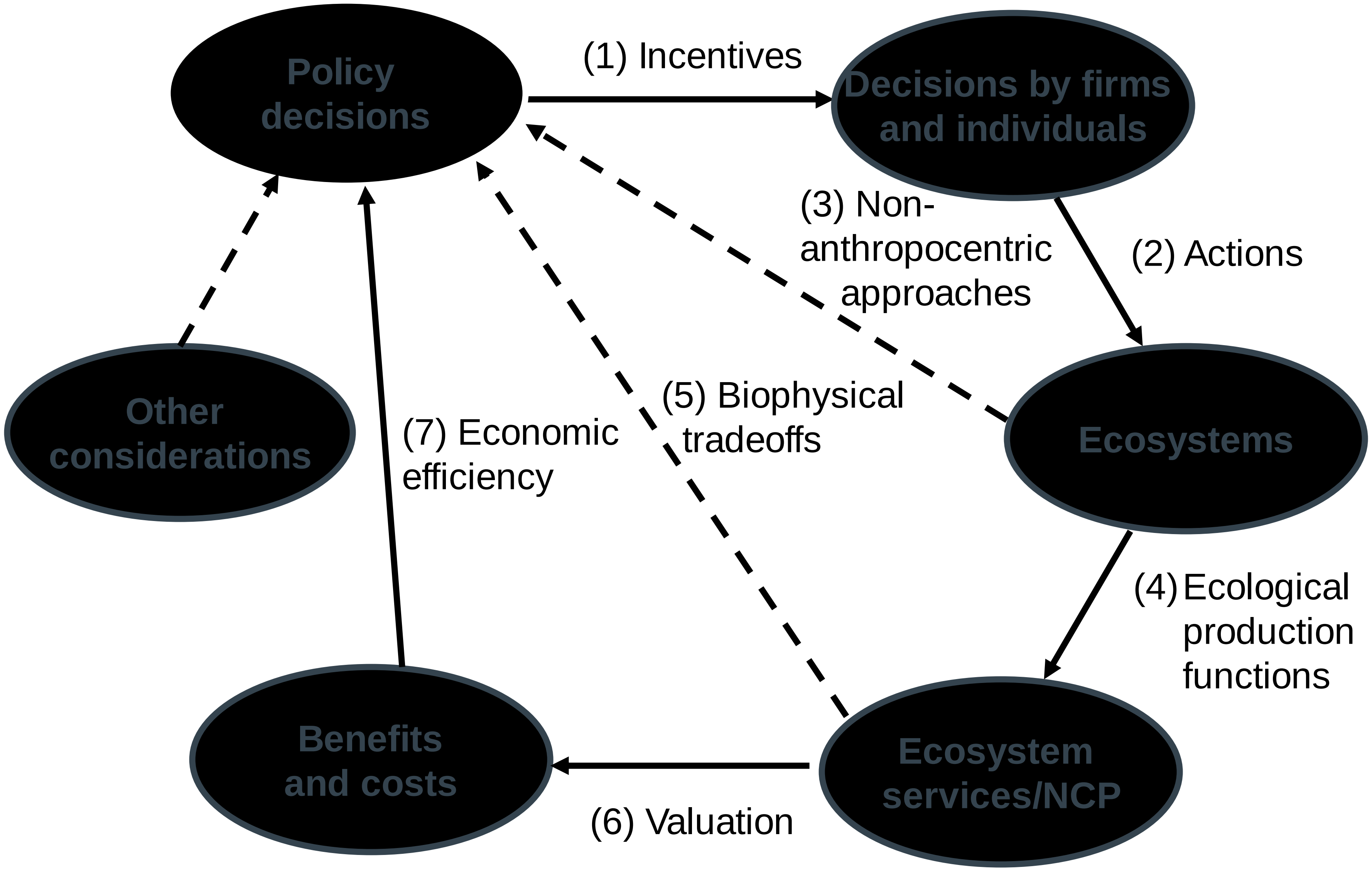


Dolpo woman shephard in high pasture and agriculture areas in Nepal . Photocredit: Yildiz Aumeeruddy-Thomas

Incorporating the multiple values of nature into economic incentives can generate better ecological, economic and social outcomes

Photocredit Daniel M. Cáceres

Research agenda for valuing nature:
Ecosystem services/nature's contributions to people



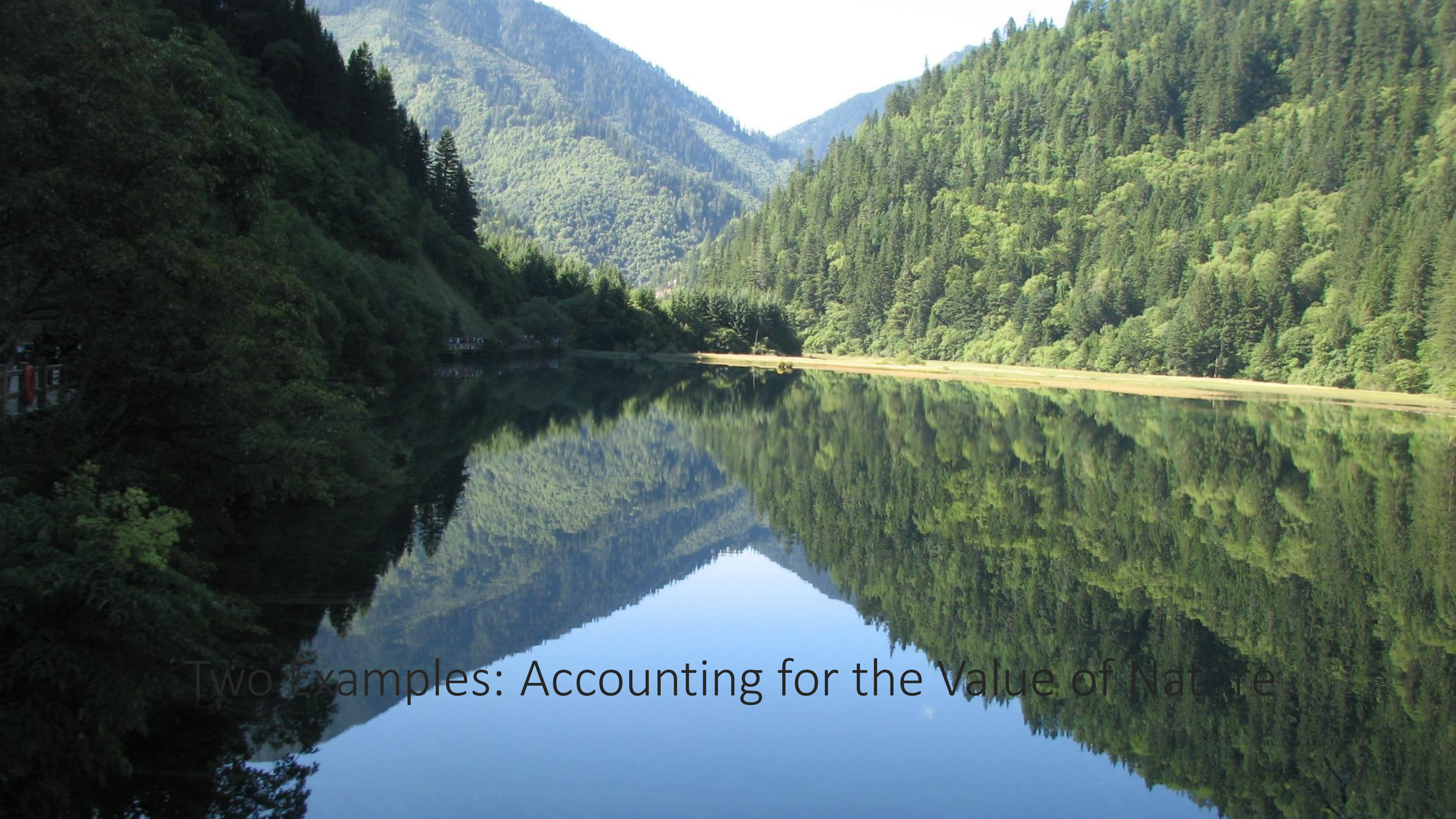
Polasky & Segerson. 2009. *Annual Review of Resource Economics* 1: 409-434.

InVEST and The Natural Capital Project

InVEST

integrated valuation of ecosystem services and tradeoffs

- Partnership of Stanford University, University of Minnesota, Chinese Academy of Sciences, Stockholm Resilience Center, The Nature Conservancy, and WWF
- InVEST is an open-source software tool to estimate 20+ ecosystem services
- Spatially-explicit, high-resolution, processed-based ecological production functions (and some valuation), global extent



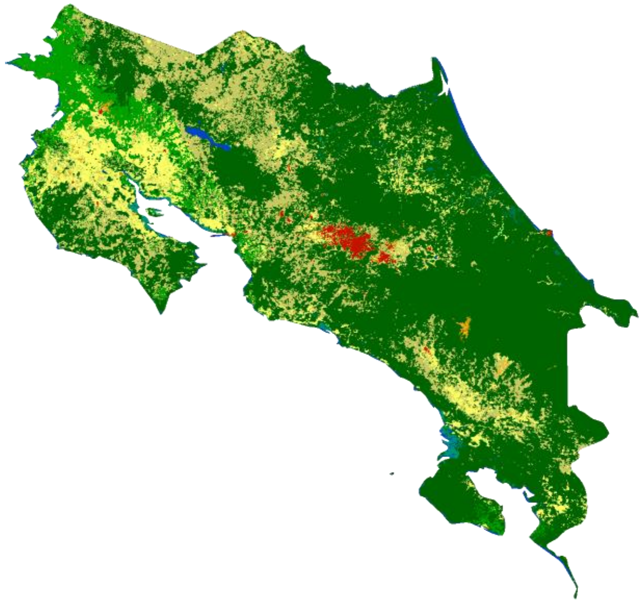
Two Examples: Accounting for the Value of Nature

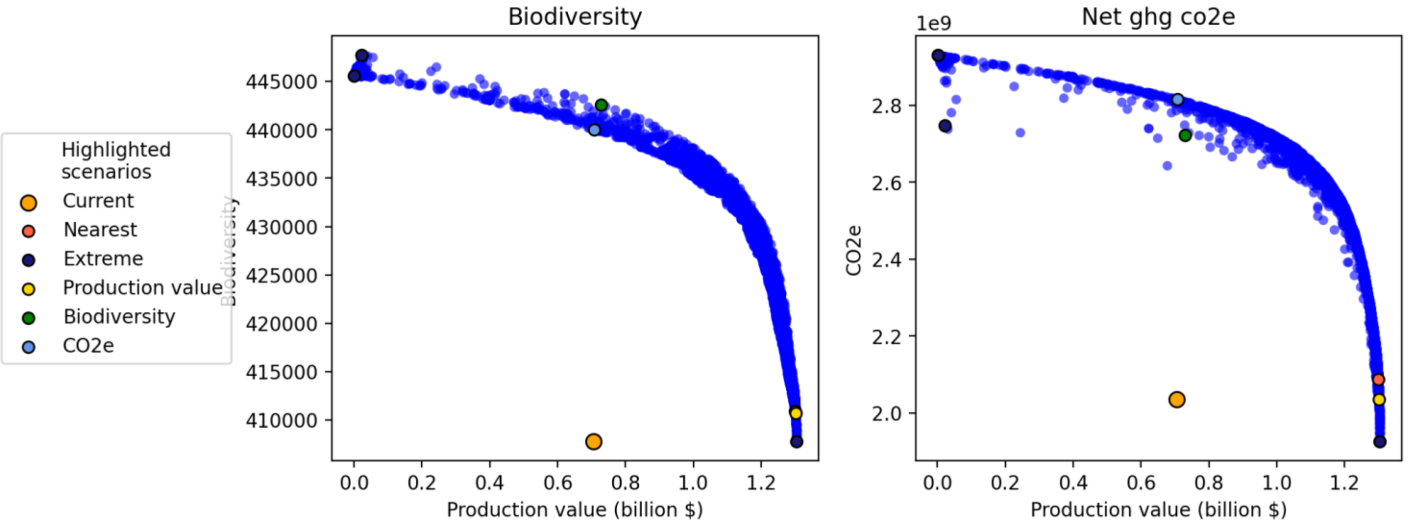
Two Examples

1. Natural Capital Index (NCI)
2. Gross Ecosystem Product (GEP)

Preliminary: Do not reproduce or d
these results without permission

Natural Capital Index:
A collaboration between the Natural Capital Project and the World Bank



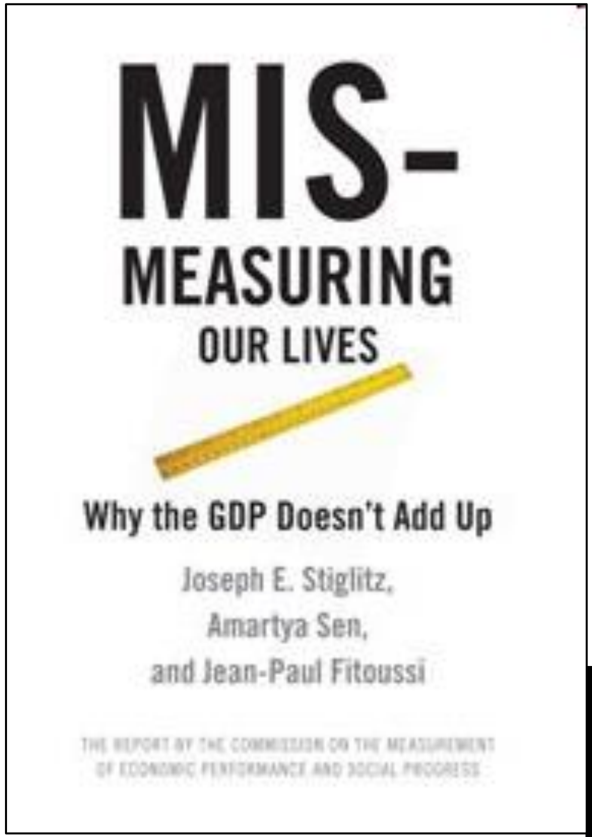


Natural Capital Index (NCI) project overview

- Goal: to provide national-scale indicators on the efficiency of sustainable natural capital management
- NCI assesses the value of the sustainable provision of multiple ecosystem services relative to the maximum feasible combinations of these services
- 146 countries using globally available data
    - All countries greater than 10,000 km^2 except ~15 countries with data issues

What to report: Metrics

- Some ecosystem services can be aggregated into a monetary measure of value (agricultural crops, animal products, timber)
- Some ecosystem services & biodiversity are difficult to measure in monetary units
- Stiglitz et al. (2010) hybrid approach: monetize some services, report other services in biophysical units
    - Dashboard analogy



NCI approach: Output metrics

- Monetary returns
  - Agricultural crops
  - Grazing
  - Forestry
- Greenhouse gas emissions
  - CO_2 storage and emissions
  - Methane emissions
- Biodiversity
  - Potential species richness
  - Threatened and endangered species
  - Endemic species
  - Rare ecoregions
  - Key biodiversity areas
  - Forest intactness
- Water quality
  - Drinking water quality – mix of surface and ground water [not included in current set of results]

NCI approach: Management options

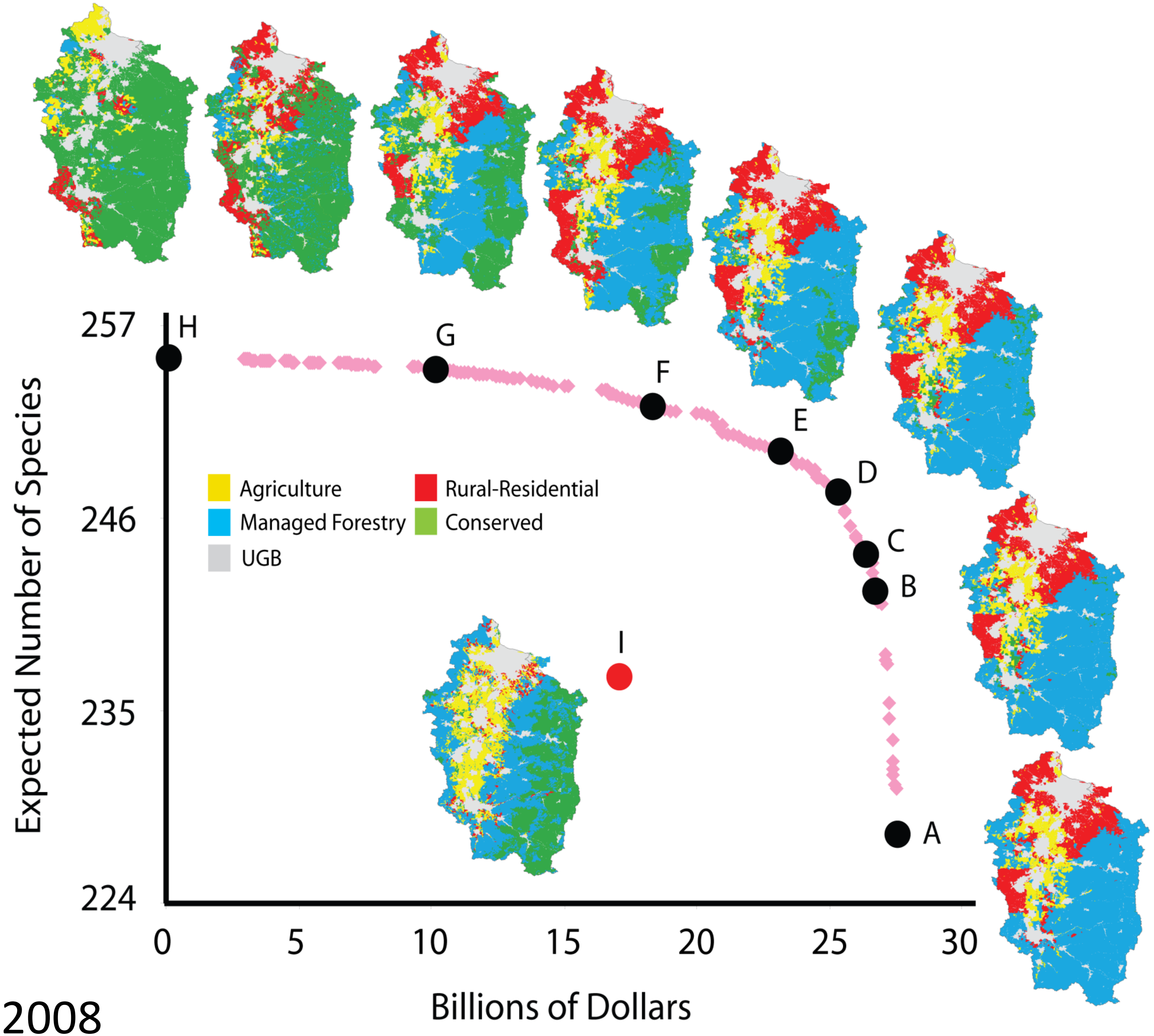
- Current sustainable land management
- Restoration to potential natural vegetation
- Forestry
- Grazing
- Crop production (10 options)
  - Current management or current management with expanded footprint (2 options)
  - Combinations of (8 options)
    - Irrigated or rainfed
    - Current crop footprint or expanded footprint
    - Best management practices or no best management practices

NCI approach: Management options to output metrics

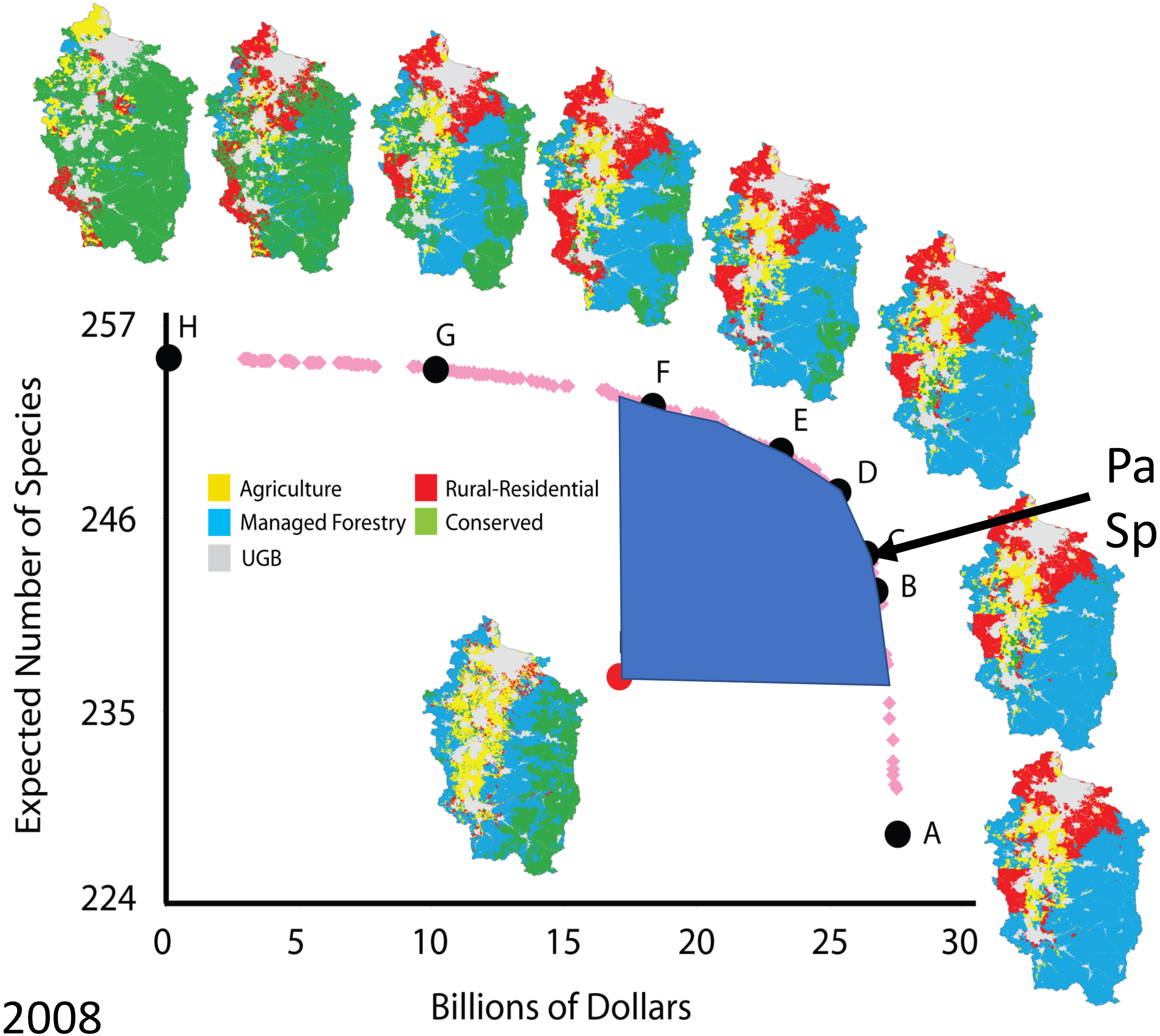
- InVEST models plus biodiversity, grazing, forestry models
- Inputs:
  - Biophysical data (land cover, digital elevation maps, precipitation, stream maps, soil, carbon storage potential, crop productivity, forest productivity, grazing productivity, biodiversity…)
  - Economic data (prices, production costs, transport costs, land transition costs)
  - Map of land use and land management (ESA 2015 global land cover)
- Output: monetary returns, greenhouse gas, biodiversity, water quality

NCI approach: Efficiency frontier

- Find the efficiency frontier for each country and compare it to the current outcome (baseline)
- Optimization: choose a land management option for each cell that maximizes a weighted sum of outputs
    - Trace out the efficiency frontier by varying the weights

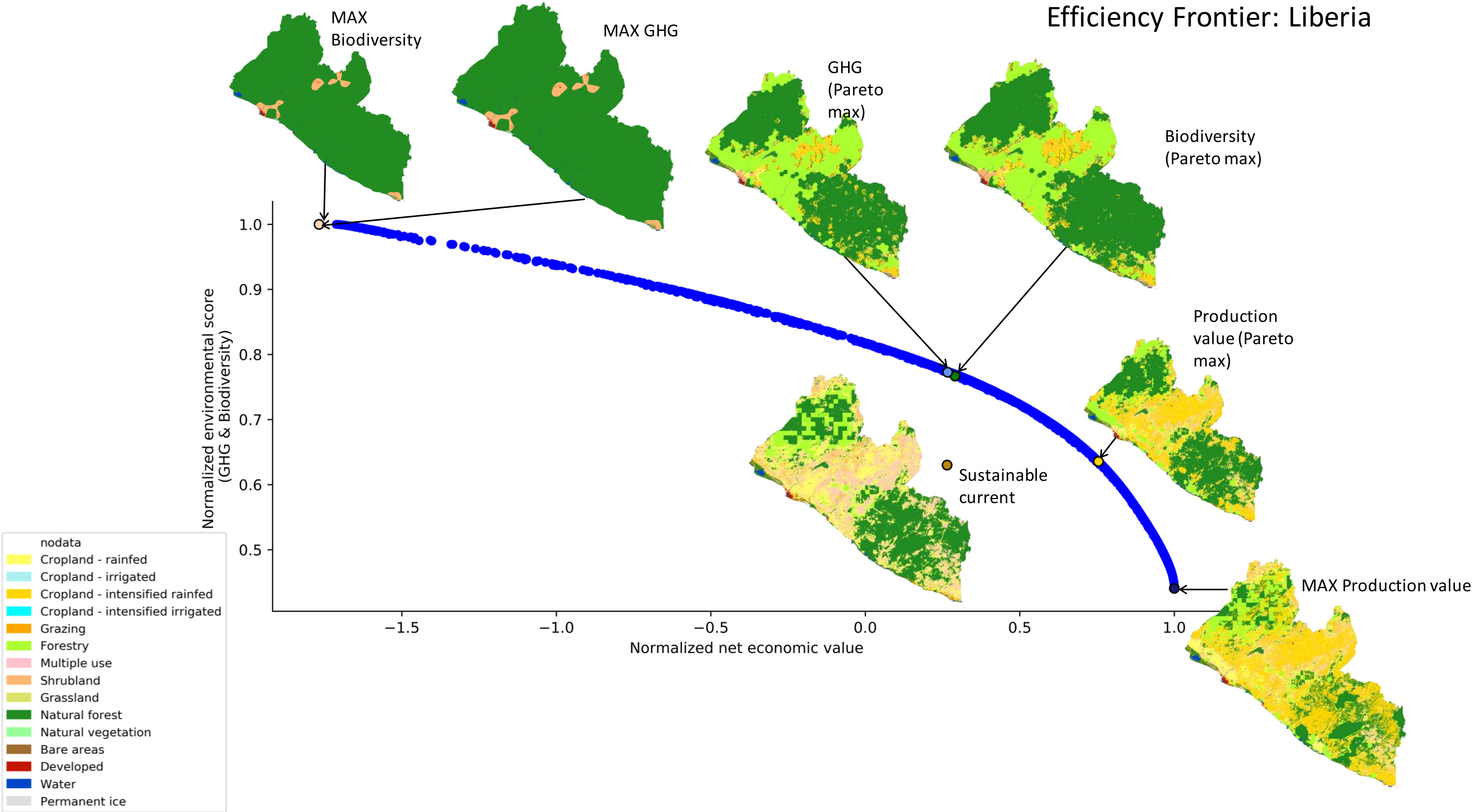


Polasky et al. 2008

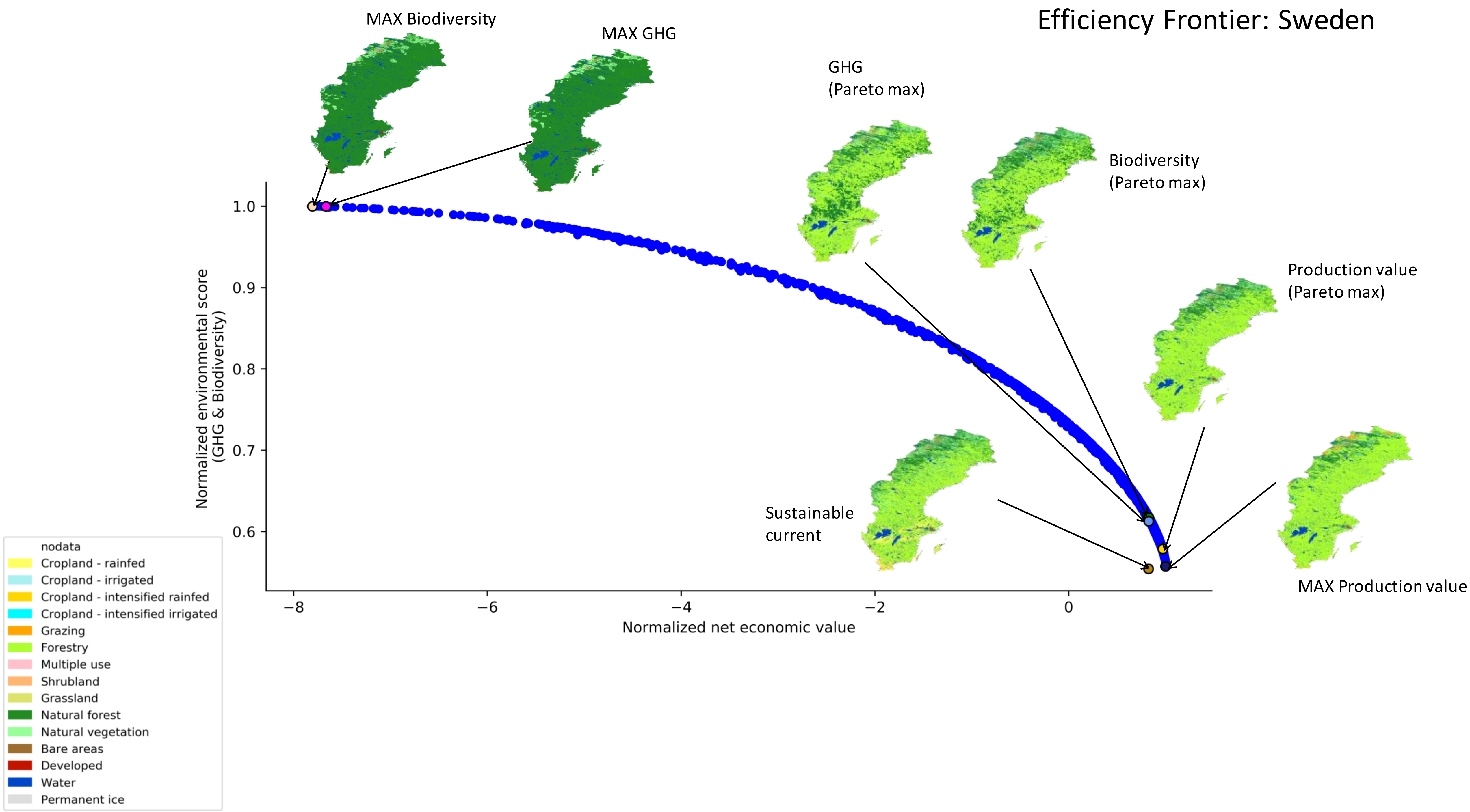


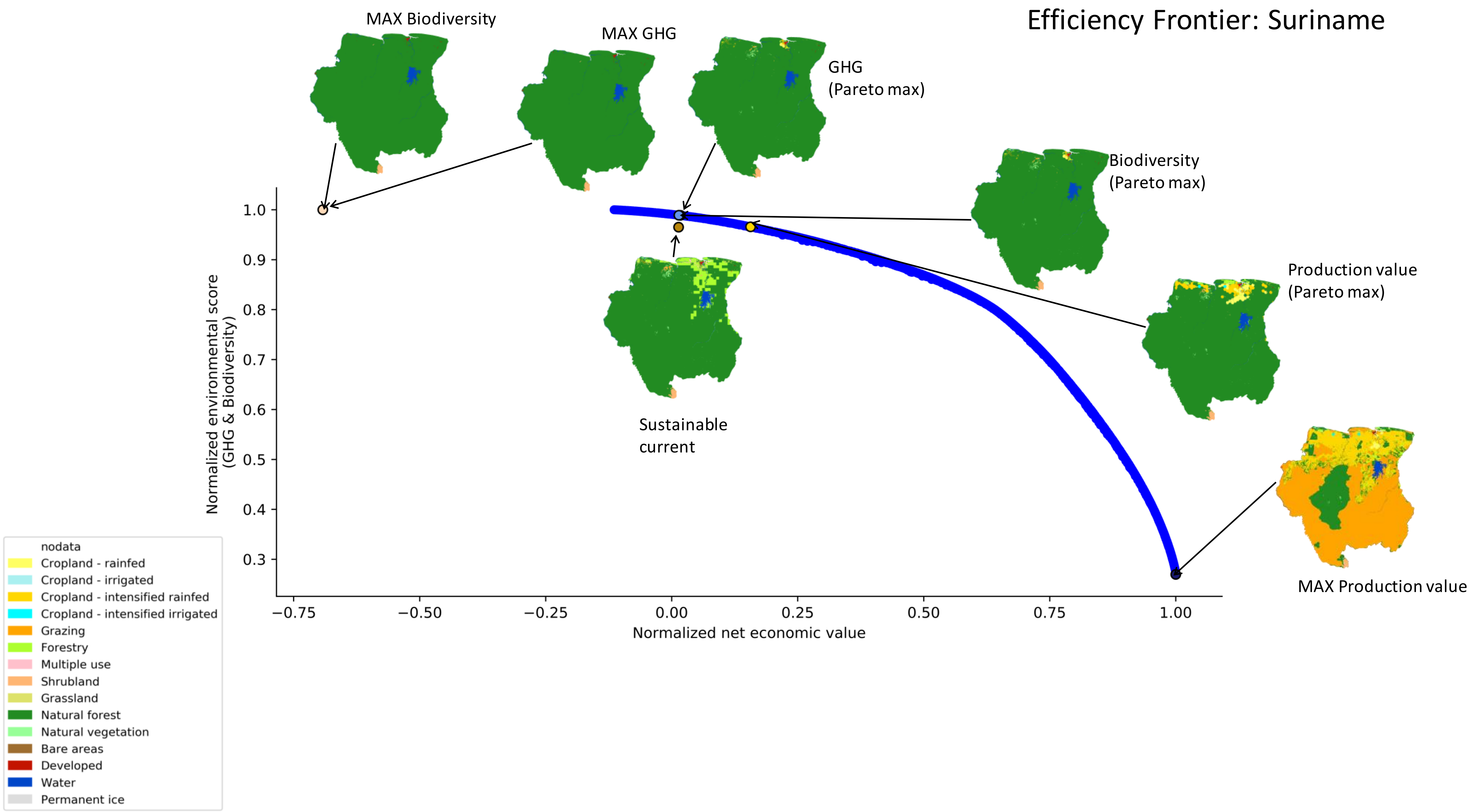
Pareto Improving Space

Polasky et al. 2008

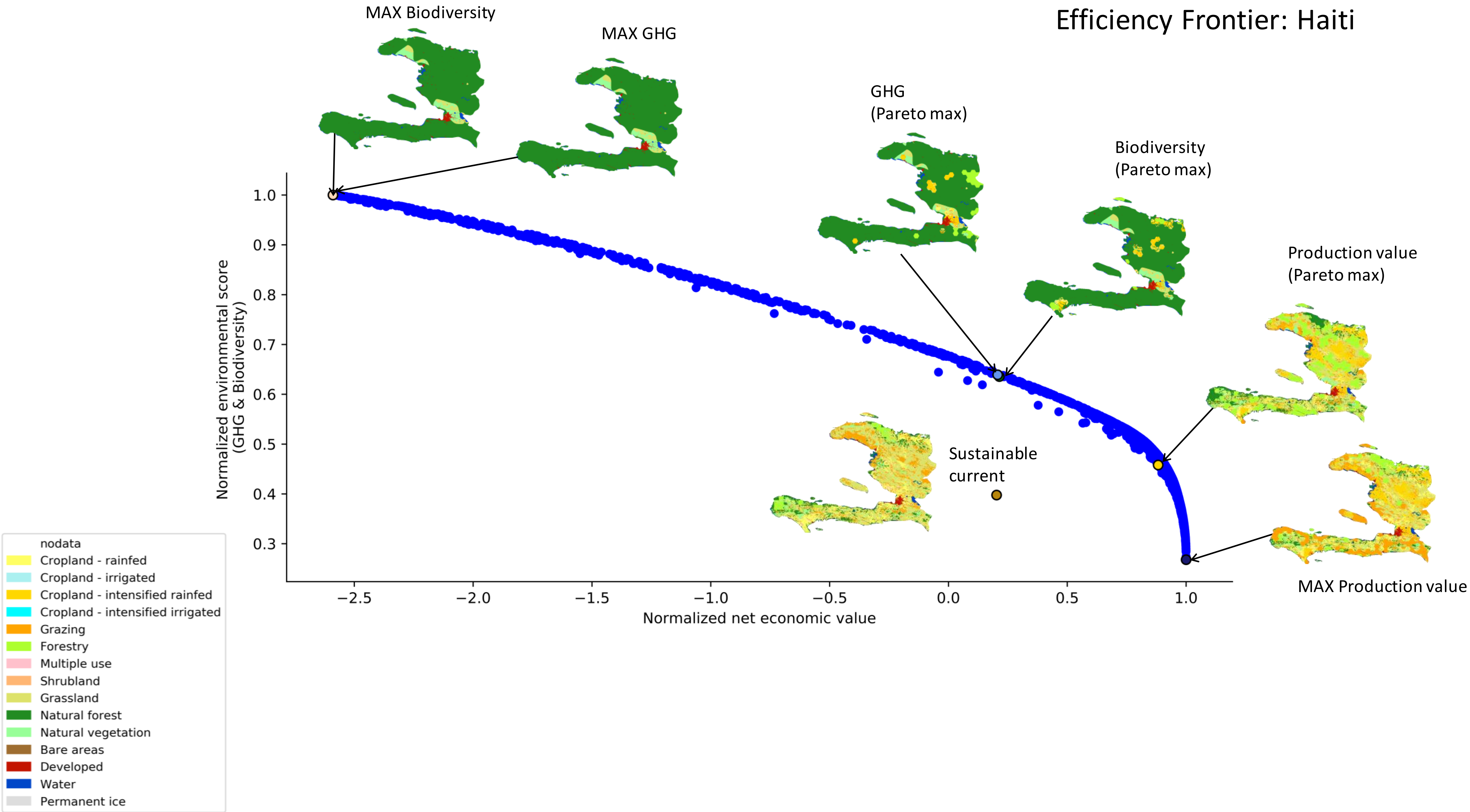


Efficiency Frontier: Liberia
MAX Biodiversity
MAX GHG
GHG (Pareto max)
Biodiversity (Pareto max)
Production value (Pareto max)
Sustainable current
MAX Production value
Normalized environmental score (GHG & Biodiversity)
Normalized net economic value
1.0
0.9
0.8
0.7
0.6
0.5
−1.5
−1.0
−0.5
0.0
0.5
1.0
nodata
Cropland - rainfed
Cropland - irrigated
Cropland - intensified rainfed
Cropland - intensified irrigated
Grazing
Forestry
Multiple use
Shrubland
Grassland
Natural forest
Natural vegetation
Bare areas
Developed
Water
Permanent ice


Efficiency Frontier: Sweden
MAX Biodiversity
MAX GHG
GHG
(Pareto max)
Biodiversity
(Pareto max)
Production value
(Pareto max)
Sustainable
current
MAX Production value
Normalized environmental score
(GHG & Biodiversity)
1.0
0.9
0.8
0.7
0.6
−8
−6
−4
−2
0
Normalized net economic value
nodata
Cropland - rainfed
Cropland - irrigated
Cropland - intensified rainfed
Cropland - intensified irrigated
Grazing
Forestry
Multiple use
Shrubland
Grassland
Natural forest
Natural vegetation
Bare areas
Developed
Water
Permanent ice



Efficiency Frontier: Suriname
MAX Biodiversity
MAX GHG
GHG
(Pareto max)
Biodiversity
(Pareto max)
Production value
(Pareto max)
Sustainable
current
MAX Production value
Normalized environmental score
(GHG & Biodiversity)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
Normalized net economic value
nodata
Cropland - rainfed
Cropland - irrigated
Cropland - intensified rainfed
Cropland - intensified irrigated
Grazing
Forestry
Multiple use
Shrubland
Grassland
Natural forest
Natural vegetation
Bare areas
Developed
Water
Permanent ice



Efficiency Frontier: Haiti
MAX Biodiversity
MAX GHG
GHG
(Pareto max)
Biodiversity
(Pareto max)
Production value
(Pareto max)
Sustainable
current
MAX Production value
Normalized environmental score
(GHG & Biodiversity)
Normalized net economic value
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
nodata
Cropland - rainfed
Cropland - irrigated
Cropland - intensified rainfed
Cropland - intensified irrigated
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Forestry
Multiple use
Shrubland
Grassland
Natural forest
Natural vegetation
Bare areas
Developed
Water
Permanent ice

Examples: NCI Scores and efficiency frontiers: Haiti, Liberia, Suriname, Sweden

Country	% Maximum Monetary Returns	% Maximum Biodiversity	% Maximum Carbon	NCI Score
Haiti	0.203	0.621	0.255	0.618
Liberia	0.351	0.848	0.777	0.820
Suriname	0.014	0.970	0.961	0.974
Sweden	0.823	0.639	0.485	0.928

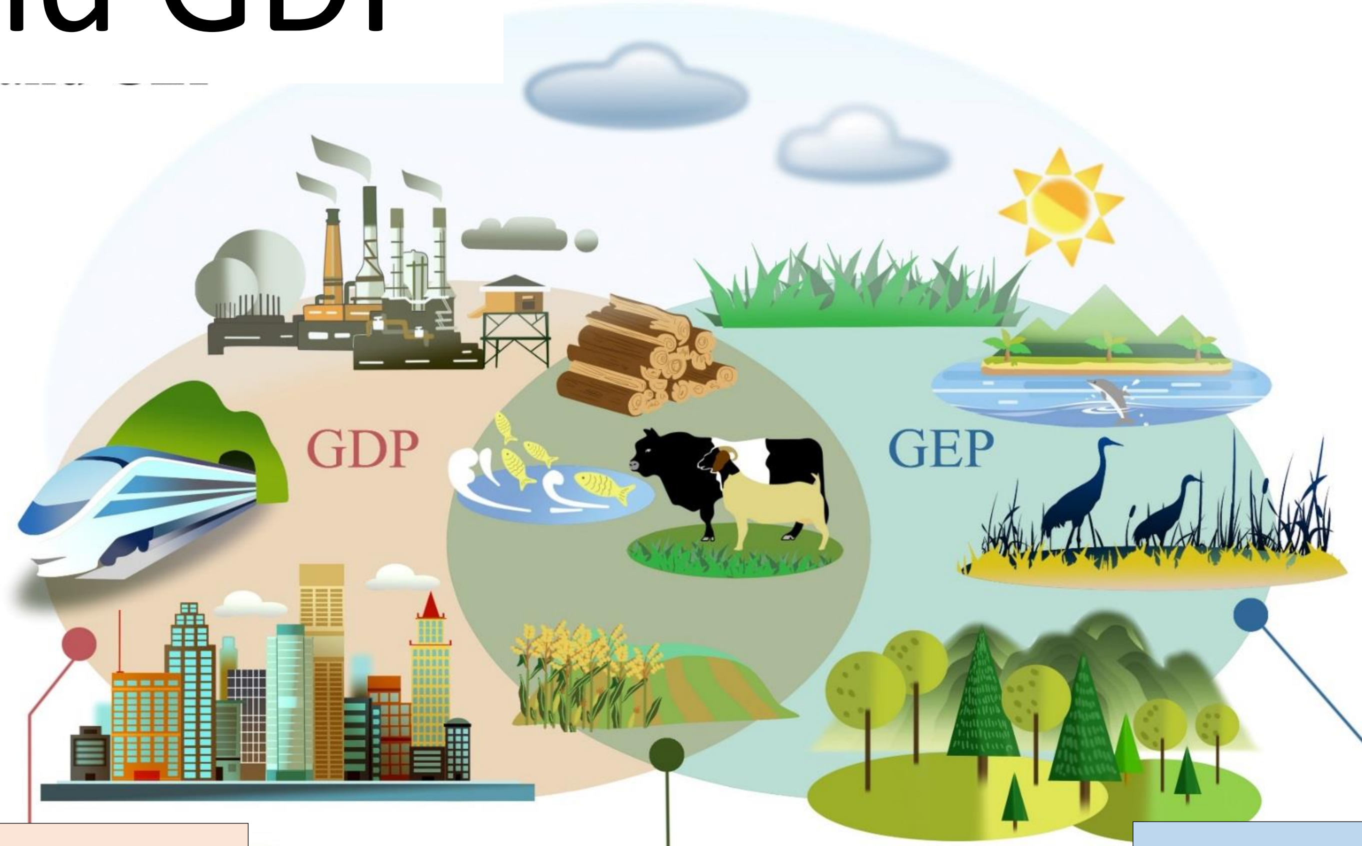
Gross Ecosystem Product (GEP)

Ouyang, Z., C. Song, H. Zheng, S. Polasky, Y. Xiao, I.J. Bateman, J. Liu,
M. Ruckelshaus, F. Shi, Y. Xiao, W. Xu, Z. Zou, G.C. Daily. 2020.
Using Gross Ecosystem Product (GEP) to value nature in decision-making
Proceedings of the National Academy of Sciences 117 (25) 14593-14601

China’s efforts to develop GEP

- China is developing a new measure of ecological performance: Gross Ecosystem Product (GEP)
- The aim of GEP accounting:
  - Reveal the contribution of ecosystems to the economy and human well-being
  - Show the ecological connections among regions
  - Basis for compensation from beneficiaries to suppliers of ecosystem services
  - Serve as a performance metric for government officials
- GEP will be reported alongside GDP

GEP and GDP



Manufacturing
Construction
Transportation

Agriculture
Forestry
Tourism

Flood Protection
Air & Water Purification
Crop Pollination

Ouyang et al. 2020 P

Steps to compute GEP

1. Track the magnitude and condition of biophysical stocks of natural capital (lands, waters, and their biodiversity)
2. Translate into flows of ecosystem goods and services
3. Price ecosystem goods and service flows to get value
4. Aggregate across goods and services to get GEP

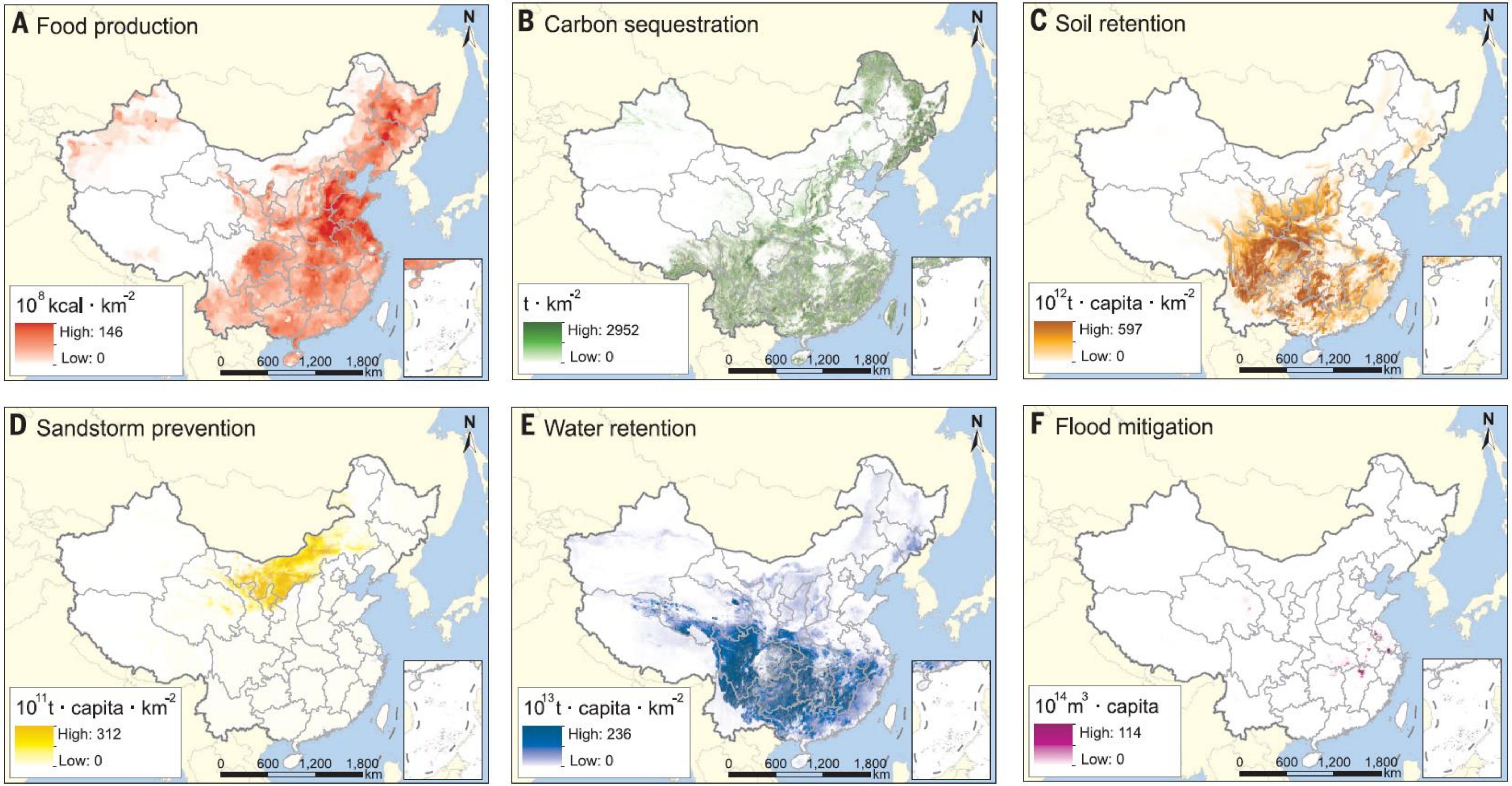
Tracking the magnitude and condition of biophysical stocks of natural capital

- Stocks of natural capital are an important measure in their own right AND give rise to the flow of ecosystem goods and services
- In China, a systematic measurement of natural capital was undertaken as part of the China Ecosystem Assessment (CEA)
- CEA measured the extent and quality of all ecosystem types across mainland China (Ouyang et al. 2016)
- The CEA is now ongoing on a 5-year cycle and is supported by a new 1.76 billion yuan investment in China’s Digital Earth (Guo 2018)

Translating natural capital stocks into flows of ecosystem goods and services

- Use of Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST; Sharp et al. 2017)
  - Take land cover and other biophysical data as inputs
  - Set of models that calculate biophysical measure of flow of services
  - For some models, InVEST also calculates a monetary value of the flow of services

Ouyang et al. 2016. Improvements in ecosystem services from investments in natural capital. *Science* 352: 1455-1459.



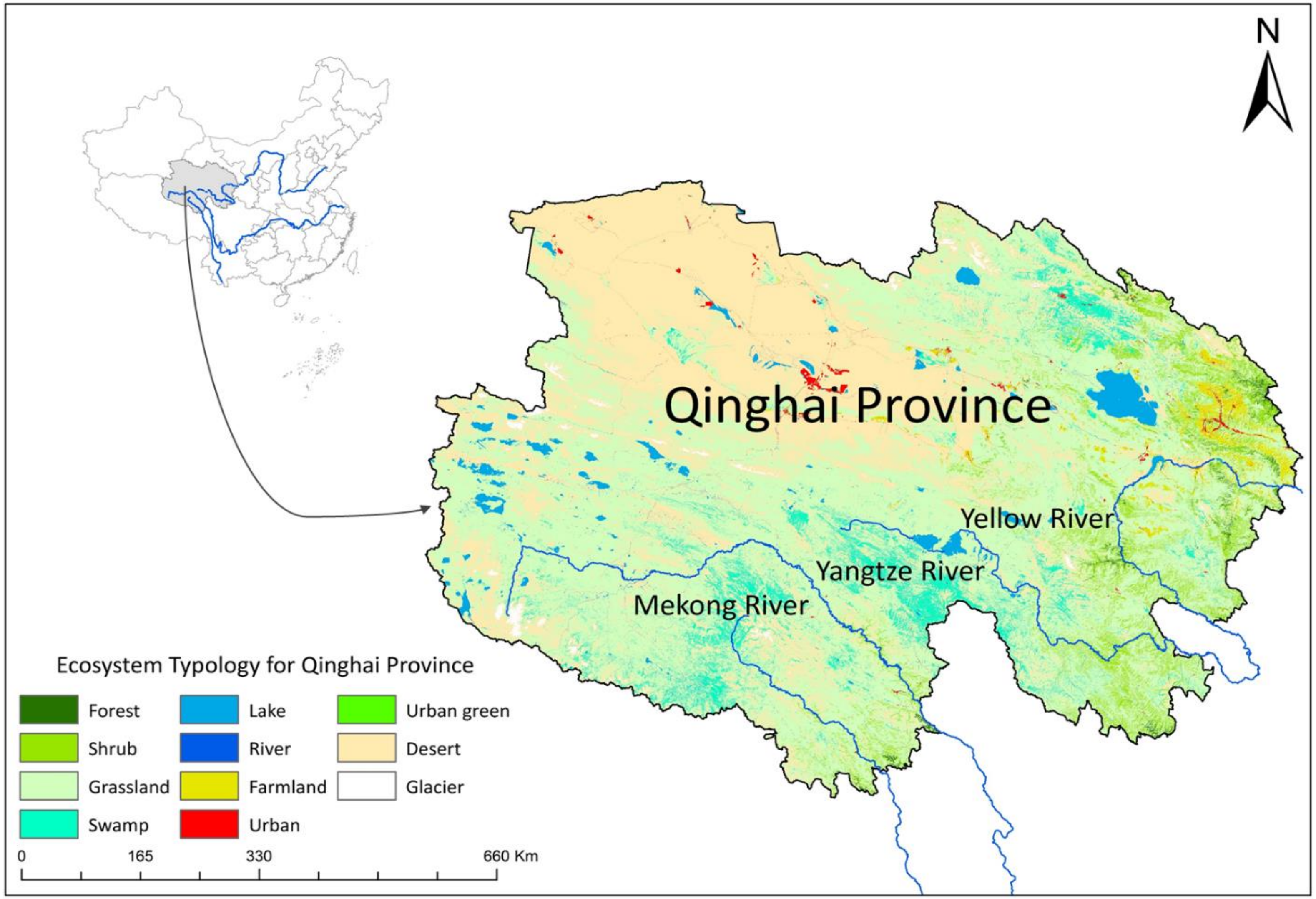
Pricing ecosystem goods and service flows

- Many ecosystem goods and services do not have a readily observable market price and are excluded from GDP
- GEP addresses this omission by estimating price analogues for non-market ecosystem goods and services
- Most common methods: imputed values for inputs and replacement cost
- The value of some ecosystem goods and services can be imputed by estimating the value of marginal product, for example the value of water retention services for hydropower production (Guo et al., 2000), pollination for crop production (Ricketts et al. 2004)
- Replacement cost: how much it would cost to replace the ecosystem good or service (e.g., the cost of removing nutrients via water treatments plants)
    - Only valid only the alternative is the lowest-cost way to provide the good or service, and when people would be willing to pay the cost of replacement to provide the good or service (Shabman and Batie 1978)

Aggregating into GEP

- Aggregate the values of ecosystem goods and services into a single GEP metric
  - Want complete coverage of all important ecosystem goods and services
  - Avoid double-counting
- GEP: measure of the value of the contribution of nature to income flows
  - GEP is not green GDP
  - Cannot sum GEP to GDP as GEP contains elements that also are part of GDP (e.g., inputs into final goods and services)

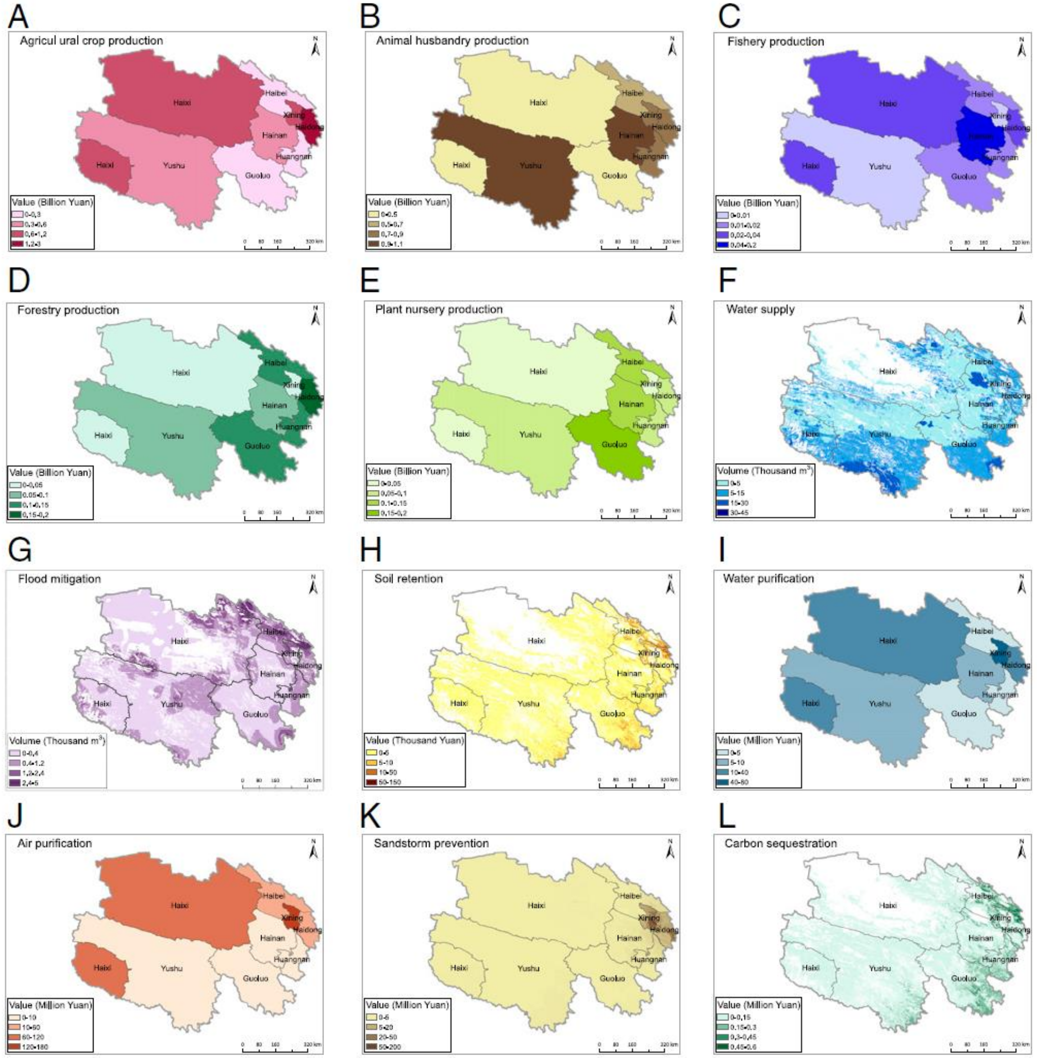
Case study: Qinghai Province

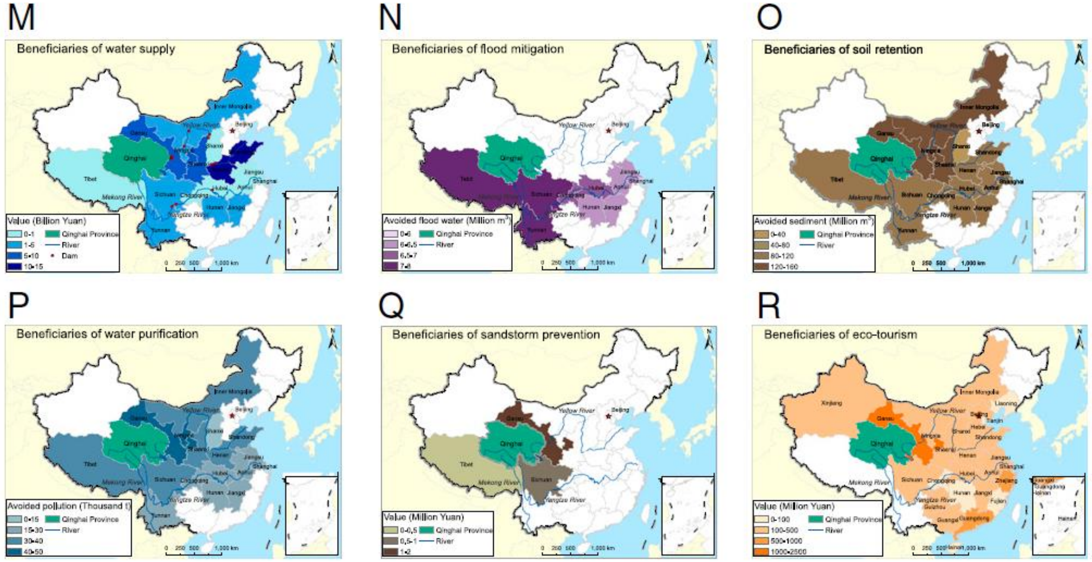


GEP Accounting in Qinghai (2000 – 2015)

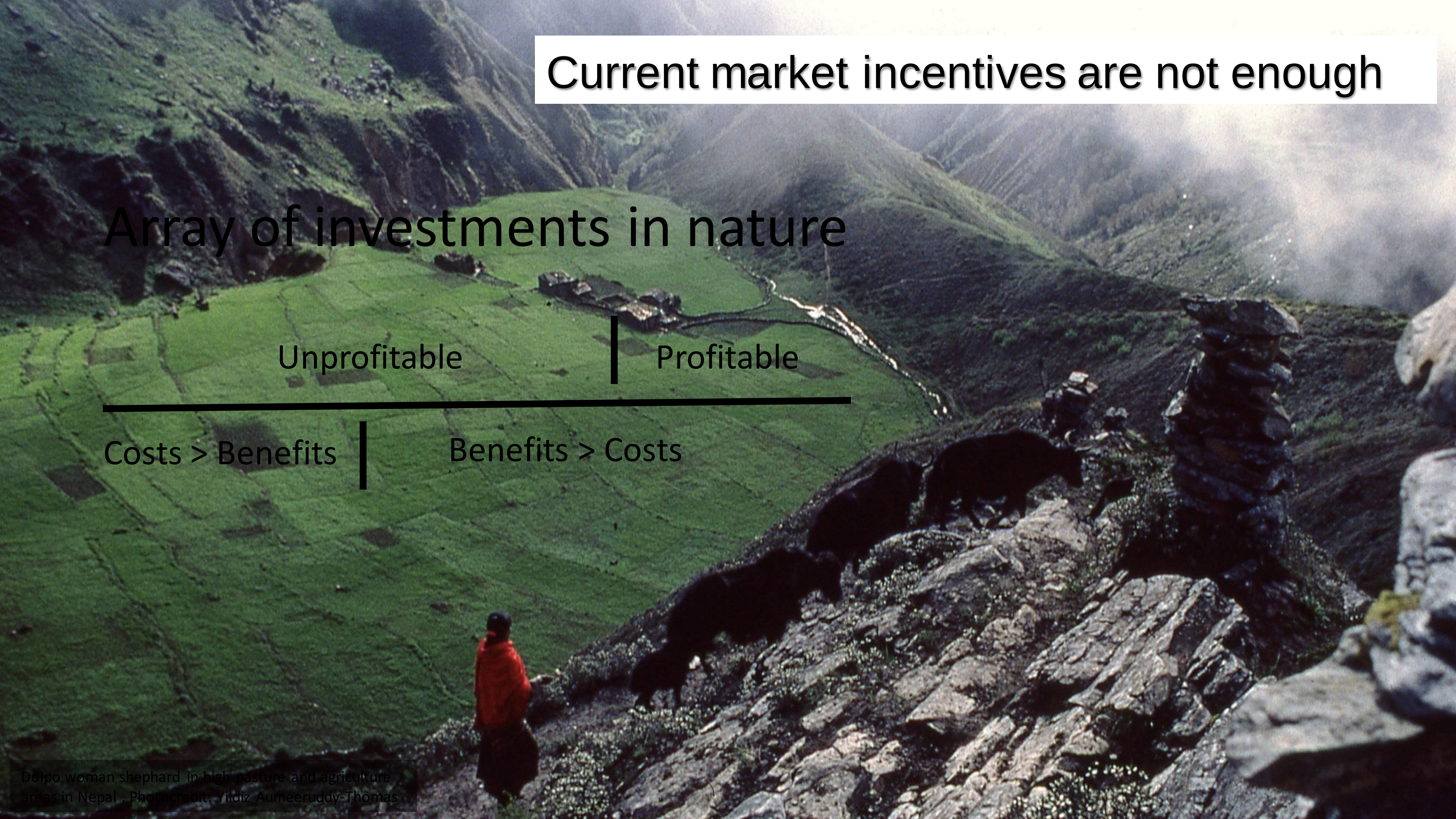
Types of service	Category of ecosystem services	Accounting items	2000			2015			2000-2015 (constant price)		2000-2015 (current price)	
			Bio-physical quantity	Monetary value (Billion Yuan)	% of total value	Bio-physical quantity	Monetary value (Billion Yuan)	% of total value	Amount of change (Billion Yuan)	% change	Amount of change (Billion Yuan)	% change
Material services	Production of ecosystem goods	Agricultural crop production ($x10^3t$)	1652.1	1.0	1.2	3091.2	5.6	3.0	4.2	310.6	4.6	482.1
		Animal husbandry production ($x10^3t$)	458.7	1.1	1.4	724	5.8	3.1	4.2	266.4	4.7	419.4
		Fishery production ($x10^3t$)	1.2	0.01	0.01	10.6	0.3	0.1	0.3	2351.5	0.3	3375.0
		Forestry production ($x10^3m^3$)	1800	0.2	0.2	825	0.7	0.4	0.5	247.1	0.6	392.1
		Plant nursery production ($x10^9$)	0.3	0.2	0.2	11	0.7	0.4	0.5	190.8	0.6	312.2
		Total		2.5	3.0		13.1	7.1	9.7	284.1	10.7	444.5
	Water supply	Water use in downstream agricultural irrigation ($x10^9$ m^3)		11.8	14.5		15.0	8.1	-1.5	-9.3	3.2	26.8
		Water use in households ($x10^9m^3$)		5.3	6.5		13.8	7.4	6.4	86.5	8.5	160.4
		Water use in industry ($x10^9m^3$)		19.4	23.8		29.2	15.8	2.2	8.1	9.8	50.5
		Hydropower production ($x10^9$ kwh)	21.3	11.3	13.9	92	48.8	26.3	37.5	331.6	37.5	331.6
		Total		47.8	58.7		106.7	57.6	44.5	71.6	58.9	123.3
Regulating services	Flood mitigation	Flood mitigation ($x10^9m^3$)	0.07	0.02	0.03	0.07	0.03	0.02	0.001	2.3	0.01	45.0
	Soil retention and non-point pollution prevention	Retained soil ($x10^9$ t)	0.4	4.8	5.9	0.4	7.0	3.8	0.13	1.9	2.1	44.5
		Retained N ($x10^3$ t)	9.8	0.01	0.01	10	0.02	0.01	0.0003	1.9	0.01	103.9
		Retained P ($x10^3t$)	0.7	0.002	0.002	0.7	0.002	0.001	0.00004	2.0	0.00004	2.0
	Water purification (wetland)	COD purification ($x10^3$ t)	33.2	0.02	0.03	104.3	0.1	0.1	0.10	214.0	0.1	528.0
		NH-N purification ($x10^3$ t)	3.5	0.00	0.004	10	0.02	0.01	0.01	186.8	0.01	473.6
		TP purification ($x10^3$ t)	-	-	-	0.9	0.003	0.001	-	-	-	-
	Air purification	SO_2 purification ($x10^3$ t)	32.0	0.02	0.02	150.8	0.2	0.1	0.15	370.9	0.2	841.8
		NO_x purification ($x10^3$ t)	-	-	-	117.9	0.1	0.1	-	-	-	-
		Dust purification ($x10^3$ t)	105.5	0.02	0.02	246	0.04	0.02	0.02	133.3	0.02	133.3
	Sandstorm prevention	Sand retention ($x10^9t$)	0.3	21.4	26.2	0.5	31.7	17.1	1.5	4.9	10.3	48.2
	Carbon sequestration	Carbon sequestration ($x10^9$ t)	0.01	2.0	2.4	0.02	4.7	2.5	1.9	67.4	2.7	137.3
		Total		28.3	34.7		43.9	23.7	3.9	9.8	15.6	55.3
Non-material services	Eco-tourism	Tourists ($x10^6$ persons)	3.2	3.0	3.7	23.2	21.6	11.7	21.2	4988.4	18.6	621.3
Grand Total				81.5	100.0		185.4	100.0	79.3	74.9	103.9	127.5

Generation of ecosystem services (A – L) and beneficiaries of services (M – R)





From valuing to implementation: Incentives for ecosystem services



Dolpo woman shephard in high pasture and agriculture areas in Nepal . Photocredit: Yildiz Aumeeruddy-Thomas

Providing economic incentives

Array of investments in nature

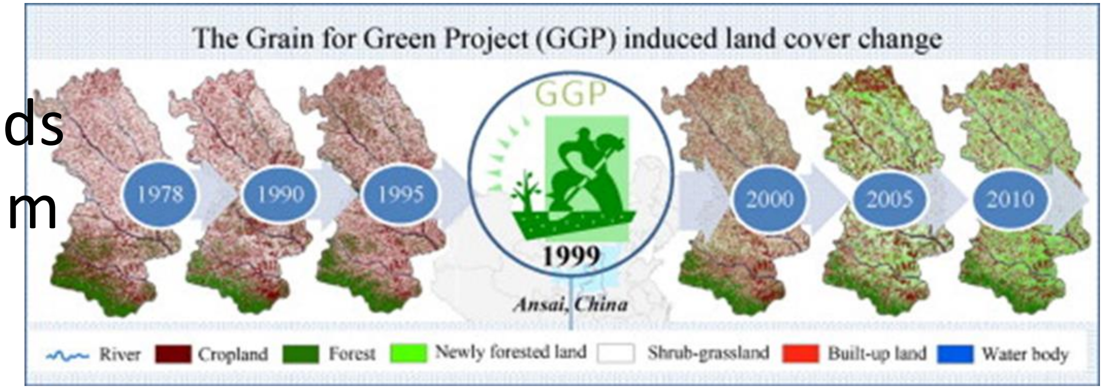
Unprofitable	Profitable
Costs > Benefits	Benefits > Costs

Dolpo woman shephard in high pasture and agriculture areas in Nepal . Photocredit: Yildiz Aumeeruddy-Thomas

Government programs that pay for conservation

US: Conservation Reserve Program

China: Sloping lands conversion program (Grain for green program)



Zhou et al. 2012. Ecological Indicators 23: 88-94

Water funds in Latin America

Source: https://www.fondosdeagua.org/en/results-and-publications/results/

Commodity certification schemes

FSC

CERTIFIED SUSTAINABLE PALM OIL RSPO
CERTIFIED
Contains certified sustainable palm oil.
www.rspo.org

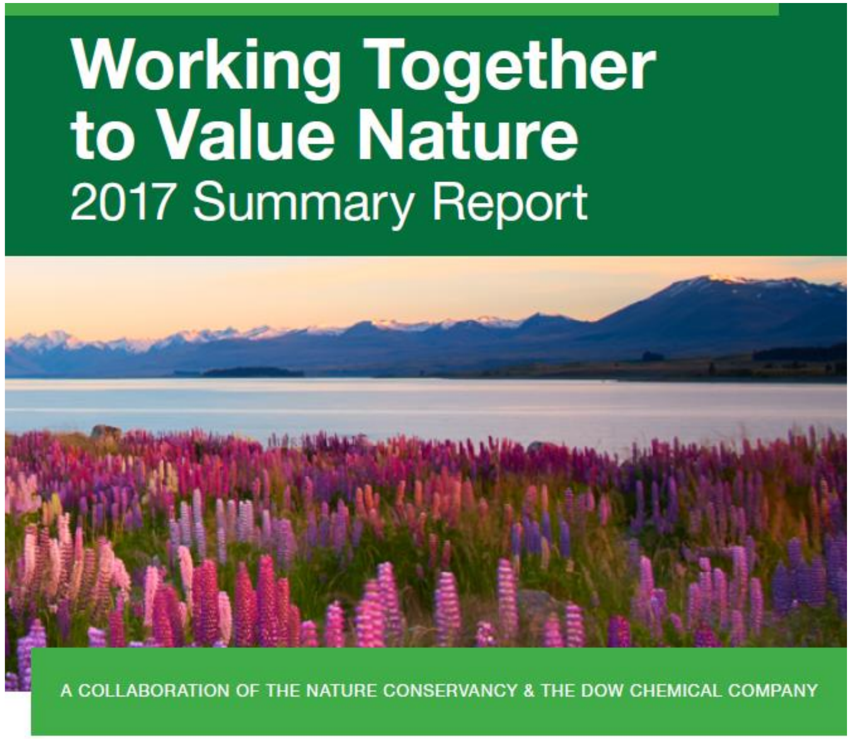
ENVIRONMENTAL MANAGEMENT SYSTEM
ISO 14001

CERTIFIED SUSTAINABLE SEAFOOD
MSC
www.msc.org

BONSUCRO
The global sugarcane platform

BACP
Round Table on Responsible Soy

Corporate sustainability (ESG)



The Nature Conservancy

DOW

Unilever

SUSTAINABLE AGRICULTURE

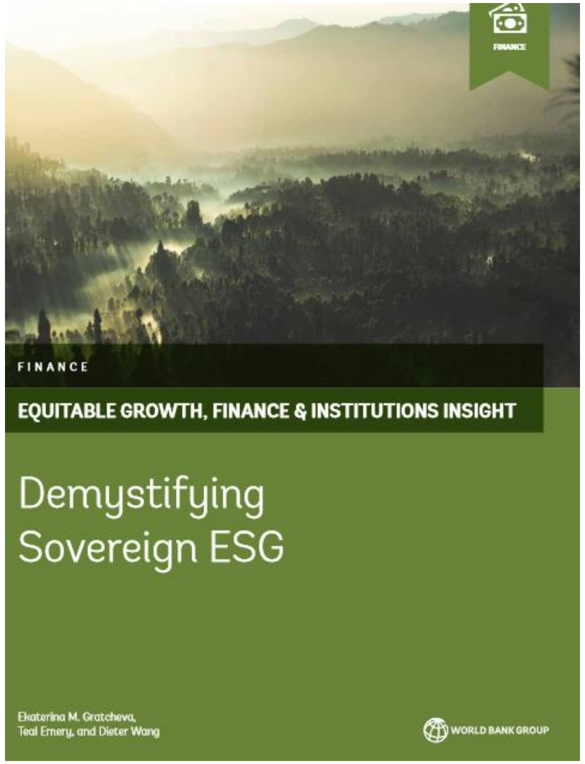
CODE 2017

Sustainable/green finance

GFL Green Finance for Latin America and the Caribbean

GREEN BOND TRANSPARENCY PLATFORM

Inter American Development Bank



CENTRE ON GREEN FINANCE AND INVESTMENT

OECD

Conclusions

- Great demand for this kind of information:
  - National governments
  - Multilateral development banks (e.g., World Bank)
  - NGOs (e.g., WWF)
  - Business (IPBES for Business)
- Need to improve our ability to supply relevant information
- Important research agenda for incorporating natural capital and ecosystem services into economic and financial systems
  - Improvements in globally available data relevant to natural capital
  - Efficient processing of very large data
  - Better modeling of the flows of ecosystem services
  - Linkages of ecosystem service models and economic models

Conclusions

- The Great Depression in the 1930s led society to realize the urgent need for better macroeconomic performance metrics, such as GDP, to help guide economic policy
- The current "Great Degradation" in nature should lead society to realize the urgent need for better metrics of ecosystem services and natural capital and incorporating these into decision-making to help guide sustainable development

Thank you!

Questions?