


# Bringing the Value of Nature into Economics, Finance, and Policy

Stephen Polasky
University of Minnesota
Natural Capital Project
March 19, 2024

# 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"


Guerry, Polasky, Lubchenco, et al. 2015. Natural capital and ecosystem services informing decisions: From promise to practice *Proceedings of the National Academy of Sciences* 112: 7348-7355

# The sustainable development challenge

- Sustainable development challenge
  - Economic development
  - AND
  - Environmental sustainability
- Record of the recent past:
  - Rapid economic growth, but poverty remains prevalent
  - Large declines in natural capital: climate and biodiversity crises

Photo: Nairobi National Park

# Some basics

- Nature provide a wide array of benefits (and costs) to people: “ecosystem services” or “nature’s contributions to people” or “environmental services”
- Natural capital (ecosystems, biodiversity, natural resources): stocks/assets that generate the flow of ecosystem services
- Human actions affect natural capital and the ecosystem services they provide
- The benefits provided by nature often are not factored into important decisions that affect ecosystems
- Distortions in decision-making damage the provision of these benefits making human society and the environment poorer

# IPBES Global Assessment

www.ipbes.net

UN environment programme

Food and Agriculture Organization of the United Nations

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

| | NATURE'S CONTRIBUTION TO PEOPLE | POTENTIAL CONTRIBUTION | REALIZED CONTRIBUTION | ENVIRONMENTAL CONDITION | IMPACT ON PEOPLE |
|---|---|---|---|---|---|
| REGULATING | Habitat | Habitat to support desired species | | | |
| | Pollination & seed dispersal | Pollinator diversity & abundance | Pollinator - plant overlap | Pollinated plant diversity & abundance | Health from pollinated foods |
| | Air quality regulation | Amount of burnable biomass or pollution entraining vegetation | Burned vegetation & actual pollution entrainment | Air quality | Air pollution-driven mortality |
| | Climate regulation | Potential GHG sequestration by existing ecosystems | Actual GHG sequestration, including land management | GHG concentration | Climate-driven mortality & costs |
| | Ocean acidification regulation | Potential $CO_2$ sequestration by existing ecosystems | Actual $CO_2$ sequestration by existing ecosystems | Ocean acidification | Nutrition & income from shellfish & coral reefs |
| | Water quantity & flow regulation | Potential water modulation by existing ecosystems | Actual water modulation by existing ecosystems | Available water | Available water relative to demand |
| | Water quality regulation | Extent of filtering ecosystems | Actual ecosystem removal of pollutants | Water quality | Health from water pollution & cost of water treatment |
| | Soil formation & protection | Extent of ecosystems that create soil fertility | Soil fertility, reflects land use | Soil fertility, reflects ability to use soil | Soil-driven health and income |
| | Hazard regulation | Existence of hazard-reducing ecosystems | Actual ecosystem hazard reduction | Incidence and severity of hazards | Hazard-driven health & income |
| | Pest regulation | Pest enemy diversity & abundance | Actual control of pests | Vector borne disease & pest-driven damage | Health from vectorborne disease & cost of pest damage |
| MATERIAL | Energy | Extent of agriculture & forest land for bio-energy | Bioenergy harvested | | Bio-energy-driven income and security |
| | Food & feed | Extent of food producing land & ocean fish stocks | Amount and nutrition of harvested food & feed | | Nutrition & income from food & feed |
| | Materials | Extent of agriculture and forest land for materials | Amount & quality of harvested materials | | Employment & income |
| | Medicine | Overlap of species diversity & knowledge | Medicinal species in use | | Health from natural medicines |
| NON-MATERIAL | Learning & Inspiration | Natural diversity in proximity to people | Actual learning from nature | | Income & wellbeing from bio-inspiration |
| | Experience | Natural & traditional landscapes in proximity to people | Actual physical and psychological experiences in nature for rich/urban & poor/rural people | | Nature-driven quality of life for rich/urban & poor/rural people |
| | Identity | Land use stability to influence identity | Actual shaping of identity by nature for rich/urban & poor/rural people | | Nature-driven quality of life for rich/urban & poor/rural people |
| | Options | Amount and diversity of nature to provide future benefits | | | |

Trend since 1970: Worse | Little change | Better    Regional differences:    Different results among indicators:
Confidence scale: Quantity and quality of evidence: ○ Low ● Robust
Level of agreement: △ Low ▲ High

Brauman, Garibaldi, Polasky et al. PNAS 2020

# Trends over the past 50 years

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

# Current market incentives are not enough

## 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

# Goal: align incentives through valuation and policy

## Array of investments in nature

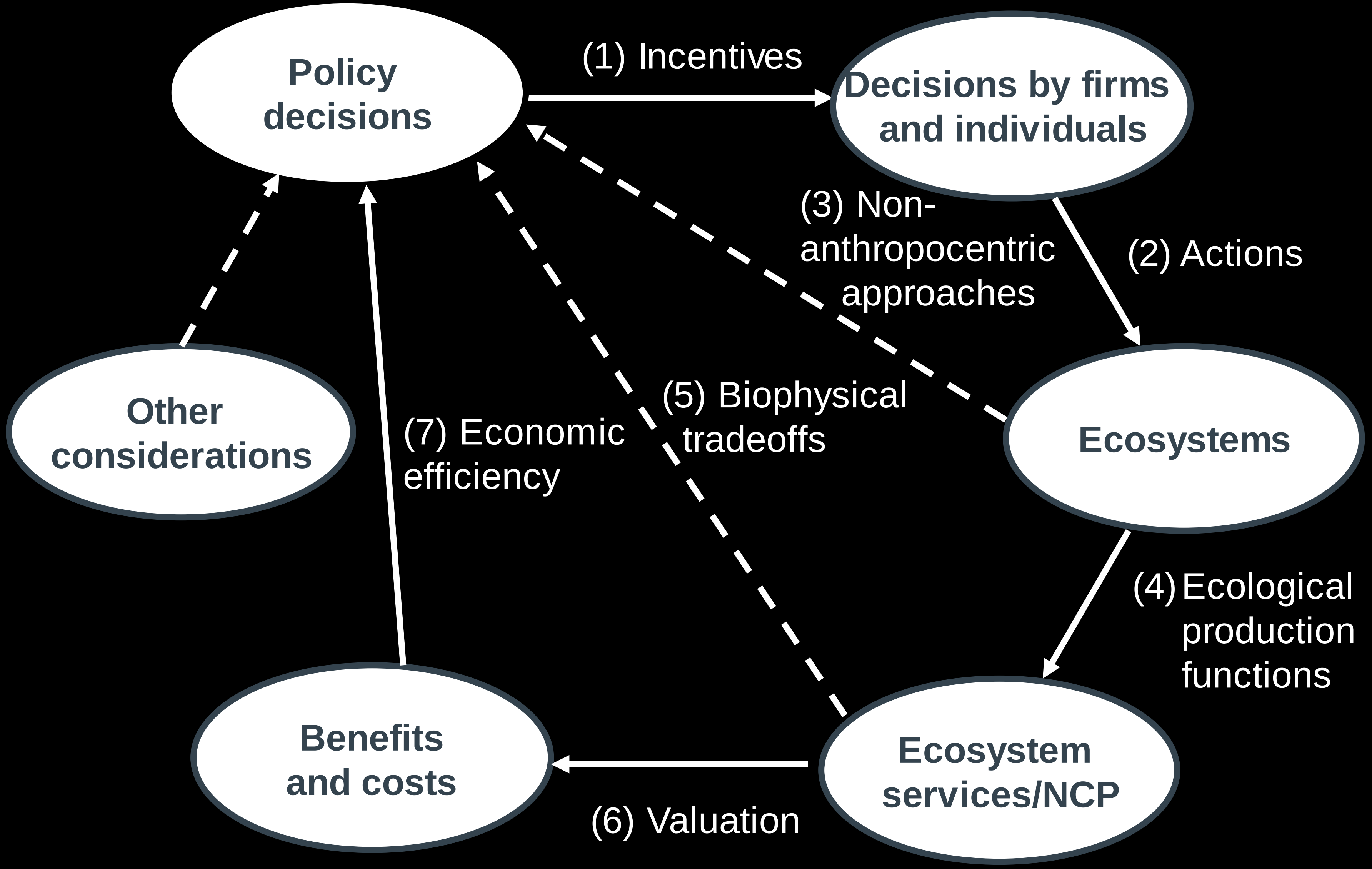
| Unprofitable | Profitable |
|---|---|
| Costs > Benefits | Benefits > Costs |

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

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

Photocredit: Daniel M. Caceres

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




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

# 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

Photo: Juizhaigou
Stephen Polasky

# 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


Manufacturing
Construction
Transportation
Communication

Agriculture
Forestry
Tourism

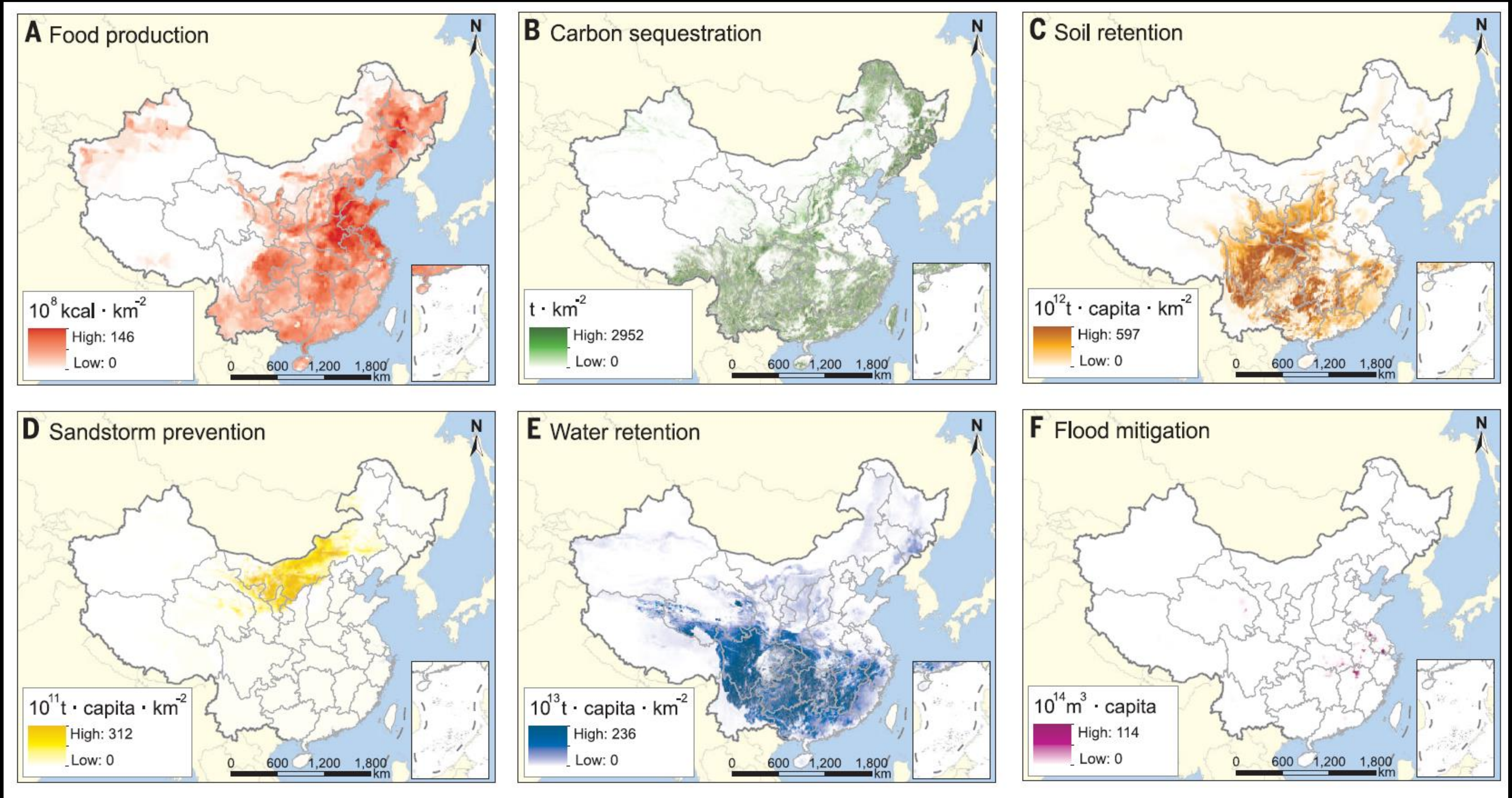
Flood Protection
Air & Water
Purification
Crop Pollination
(Mental Health)

Ouyang et al. 2020 PNAS

# 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

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



# 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

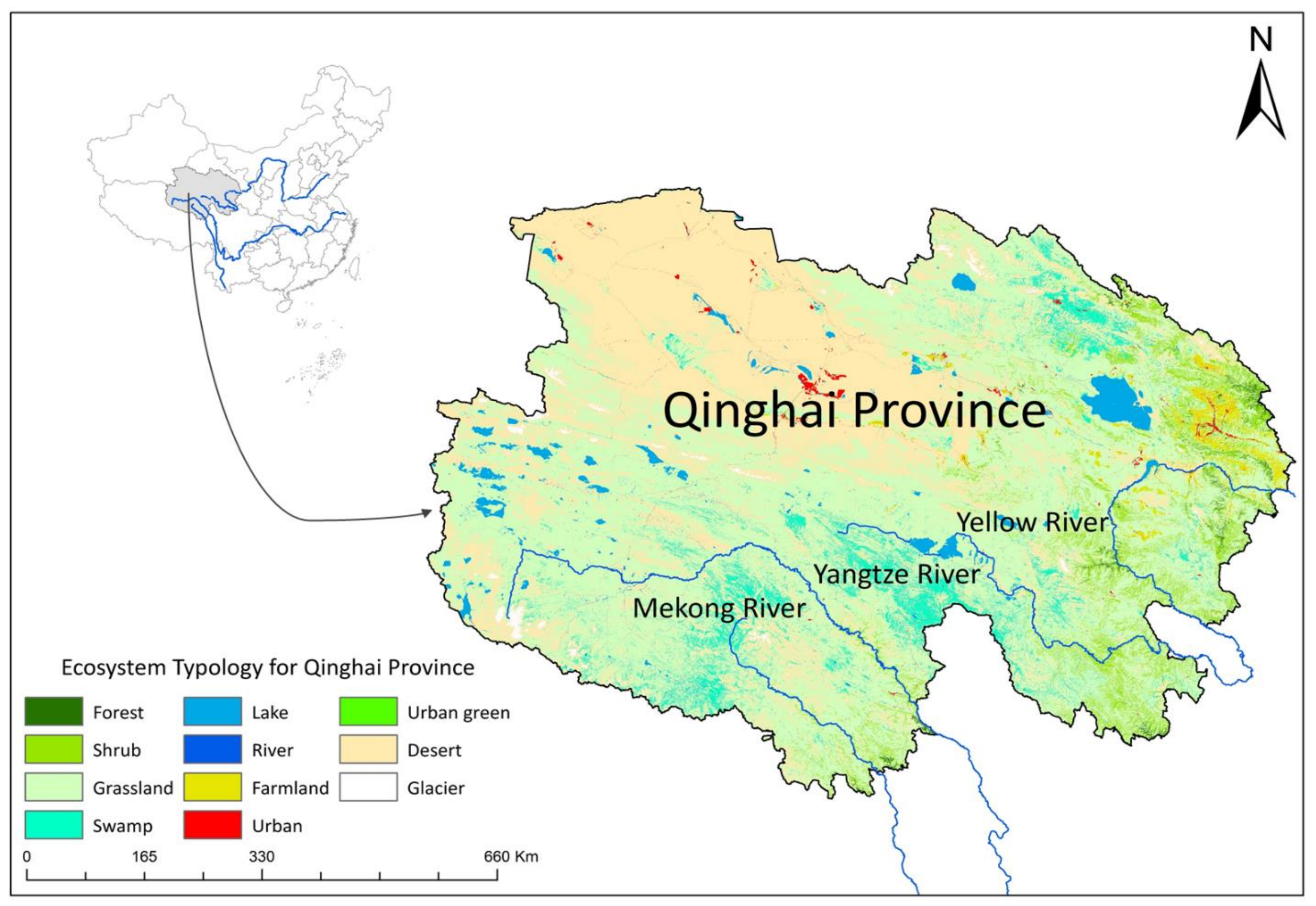
# Pricing ecosystem goods and service flows

- 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)

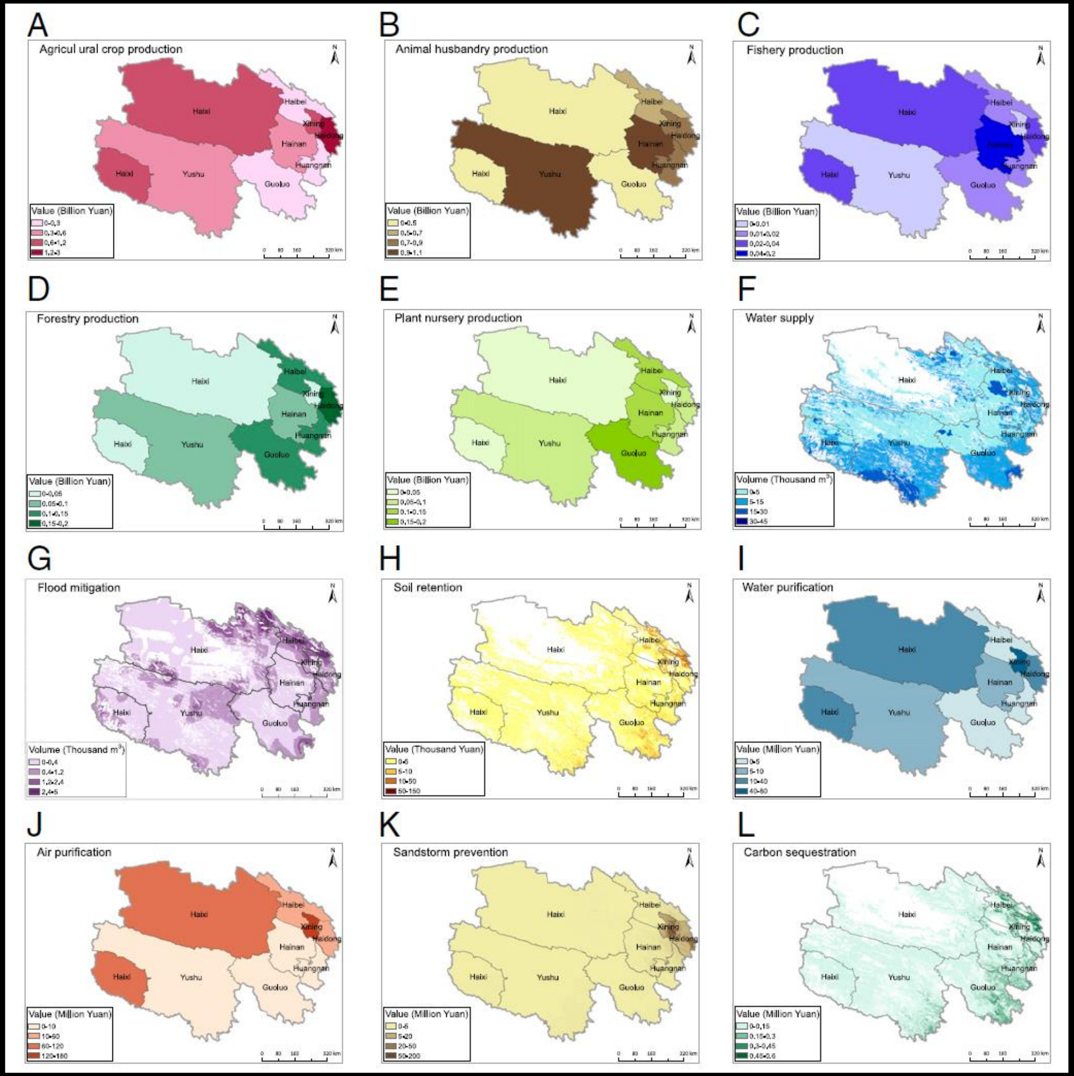
# Steps to compute GEP

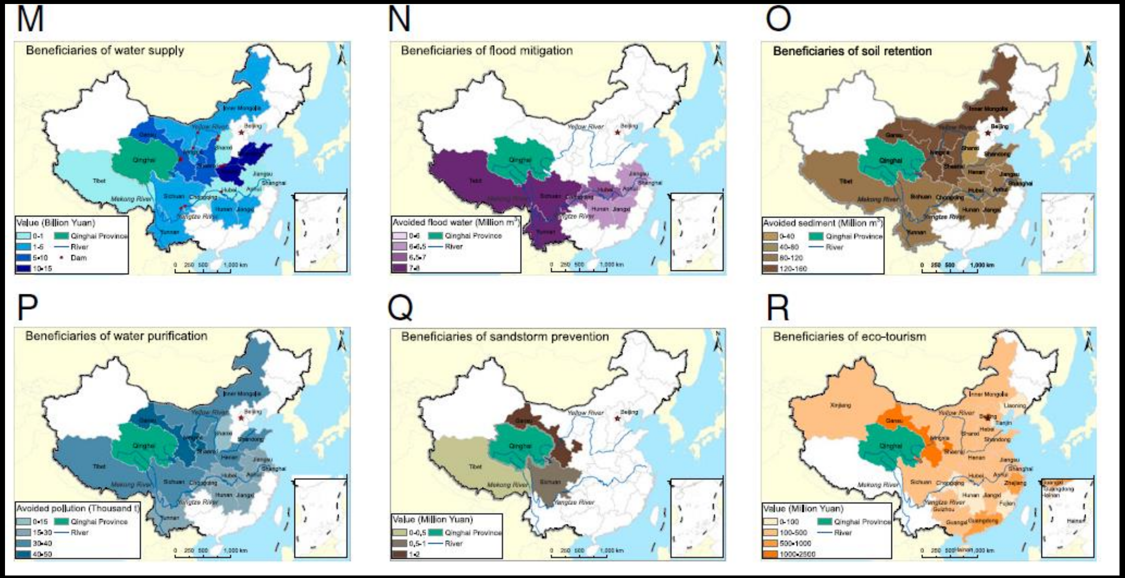
1. Track the magnitude and condition of biophysical stocks of natural capital (lands, waters, and their biodiversity)
2. Translate into flows of ecosystem goods and services
3. Price ecosystem goods and service flows to get value
4. Aggregate across goods and services to get GEP

# Case study: Qinghai Province



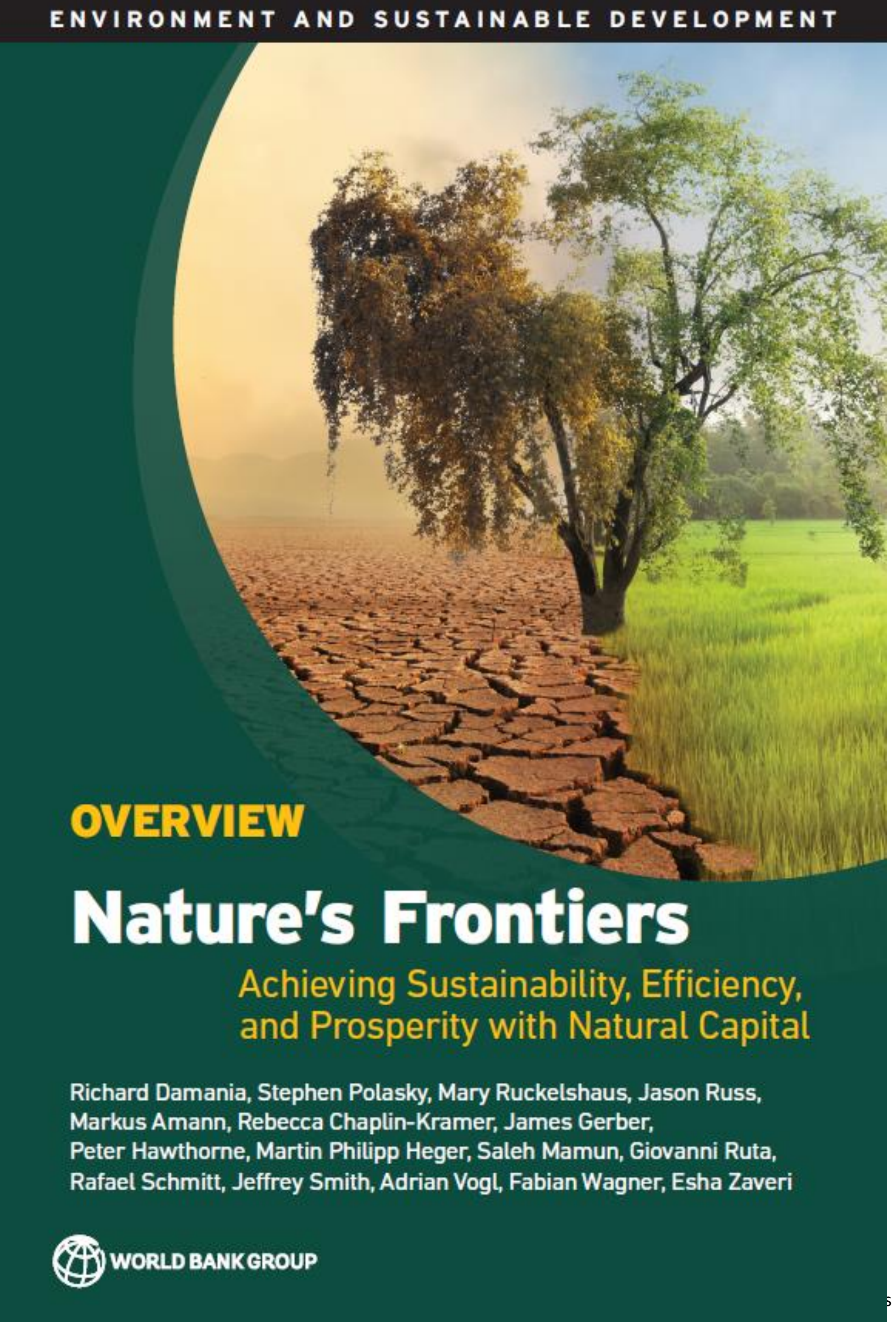
# Generation of ecosystem services (A – L) and beneficiaries of services (M – R)



# 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$^3$t) | 1652.1 | 1.0 | 1.2 | 3091.2 | 5.6 | 3.0 | 4.2 | 310.6 | 4.6 | 482.1 |
| | | Animal husbandry production (x10$^3$t) | 458.7 | 1.1 | 1.4 | 724 | 5.8 | 3.1 | 4.2 | 266.4 | 4.7 | 419.4 |
| | | Fishery production (x10$^3$t) | 1.2 | 0.01 | 0.01 | 10.6 | 0.3 | 0.1 | 0.3 | 2351.5 | 0.3 | 3375.0 |
| | | Forestry production (x10$^3$m$^3$) | 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$^9$m$^3$) | | 5.3 | 6.5 | | 13.8 | 7.4 | 6.4 | 86.5 | 8.5 | 160.4 |
| | | Water use in industry (x10$^9$m$^3$) | | 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$^9$m$^3$) | 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$^3$t) | 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$^9$t) | 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 |




s accessi

# Frontiers for Sustainable Development Through Landscape Efficiency

Stephen Polasky, Peter Hawthorne, Rebecca Chaplin-Kramer, James Gerber, Saleh Mamun, Mary Ruckelshaus, Jason Russ, Rafael Schmitt, Jeffrey Smith, Adrian Vogl, Adam Castonguay, James Douglass, Virginia Kowal, Ian Madden, Richard Sharp, Brent Sohngen, Jinfeng Chang, Gretchen Daily, Martin Heger, Matthew Holden, Justin Johnson, Lisa Mandle, Eve McDonald-Madden, Urvashi Narain, Deepak Ray, Giovanni Ruta, Paul West, Stacie Wolny, Esha Zaveri, Richard Damania

Photo: Juizhaigou
Stephen Polasky

# Nature’s Frontiers

- Goal: find land use pattern that optimizes for multiple benefits

- Land uses:
  - Cropland (irrigated v. rainfed intensified, best management practices)
  - Grazing
  - Forestry
  - Natural habitat

- Multiple benefits
  - Net income from crops, livestock, timber
  - Carbon storage
  - Biodiversity

- Accounting for multiple benefits can improve sustainable environmental and economic outcomes

Photo: Stephen Polasky

# Modeling approach

**Analyze current landscape and potential alternative landscapes**

## Economic metrics (net returns)

- Cropland production
  - Multiple management choices
- Forestry
- Grazing
- Transition costs

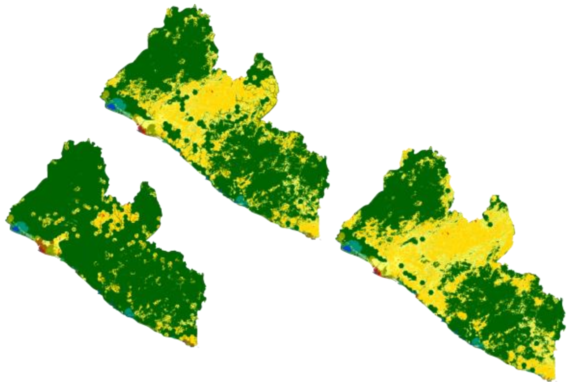
## Ecosystem metrics

- Carbon storage/greenhouse gas emissions
- Biodiversity
- (Water quality, other ecosystem services)

Landscape alternatives → Economic and environmental models

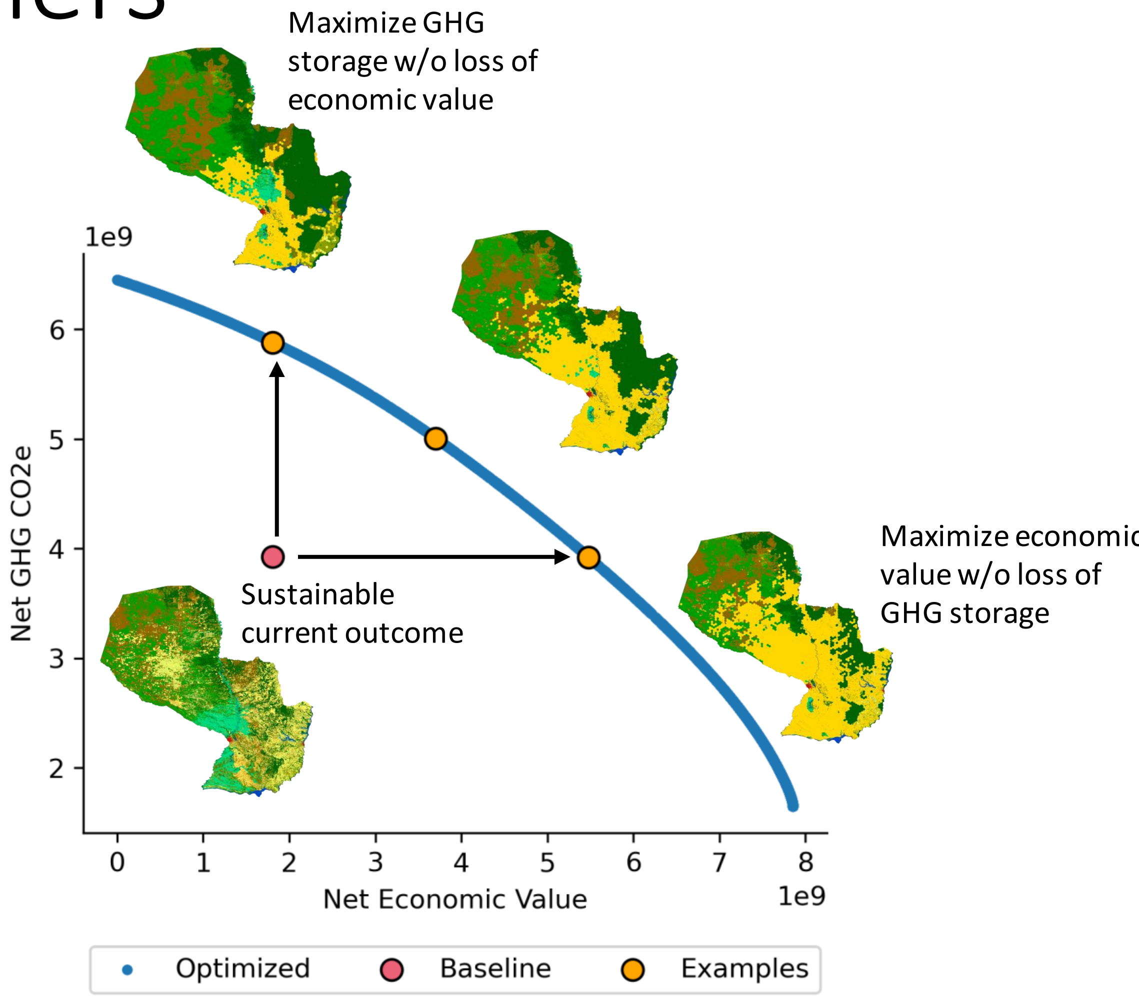
Input data → Economic and environmental models

Economic and environmental models → Optimization → Optimized land use options



# Landscape efficiency frontiers

- Landscape efficiency frontiers: achieve highest feasible combinations of environmental and economic outcomes
- Use optimization methods to find frontiers
- Compare with score for current landscapes to find degree of potential improvement



# Landscape efficiency frontiers (146 countries)

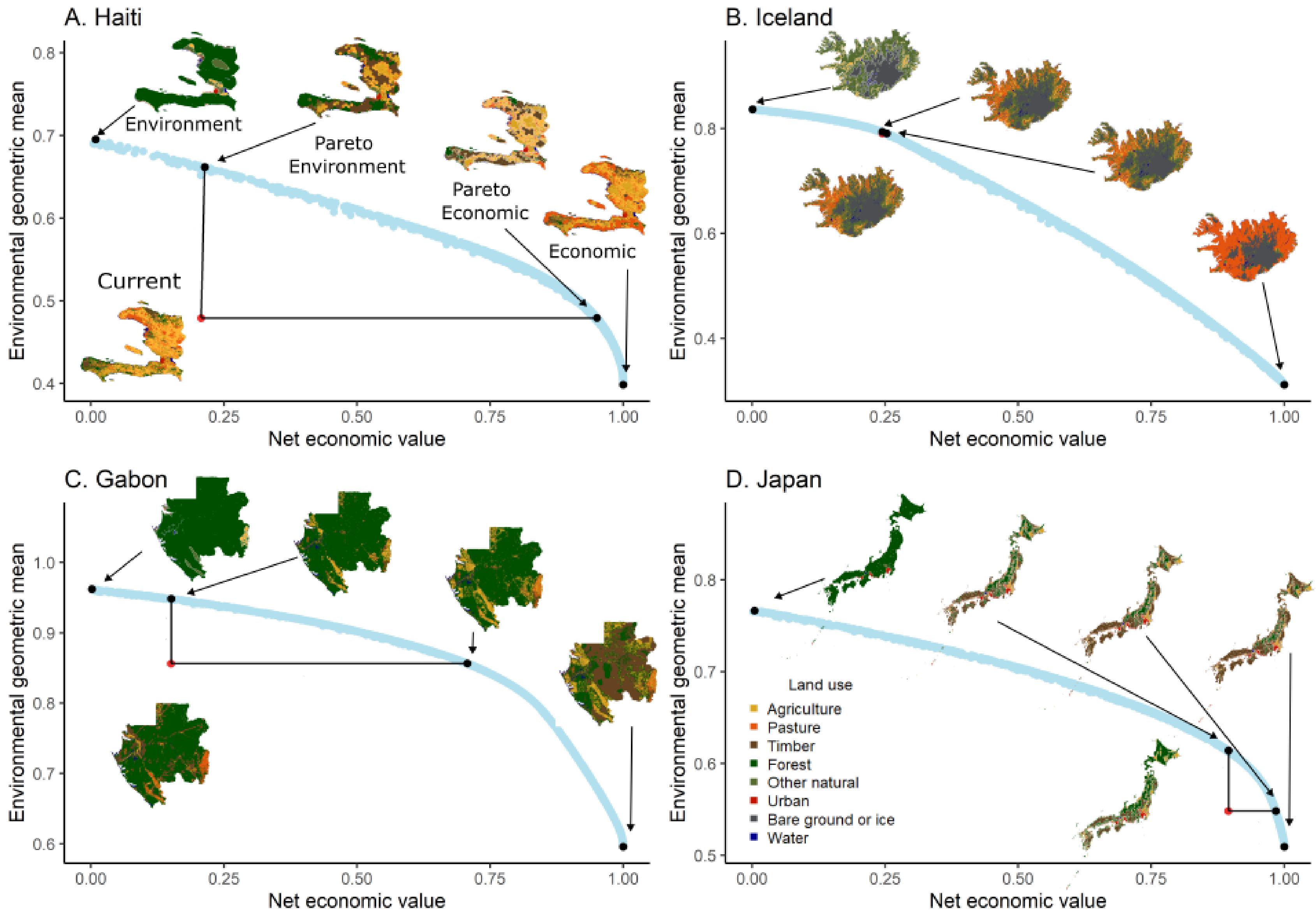
Typology of countries:

A. Large potential efficiency gains

B. Tradeoffs

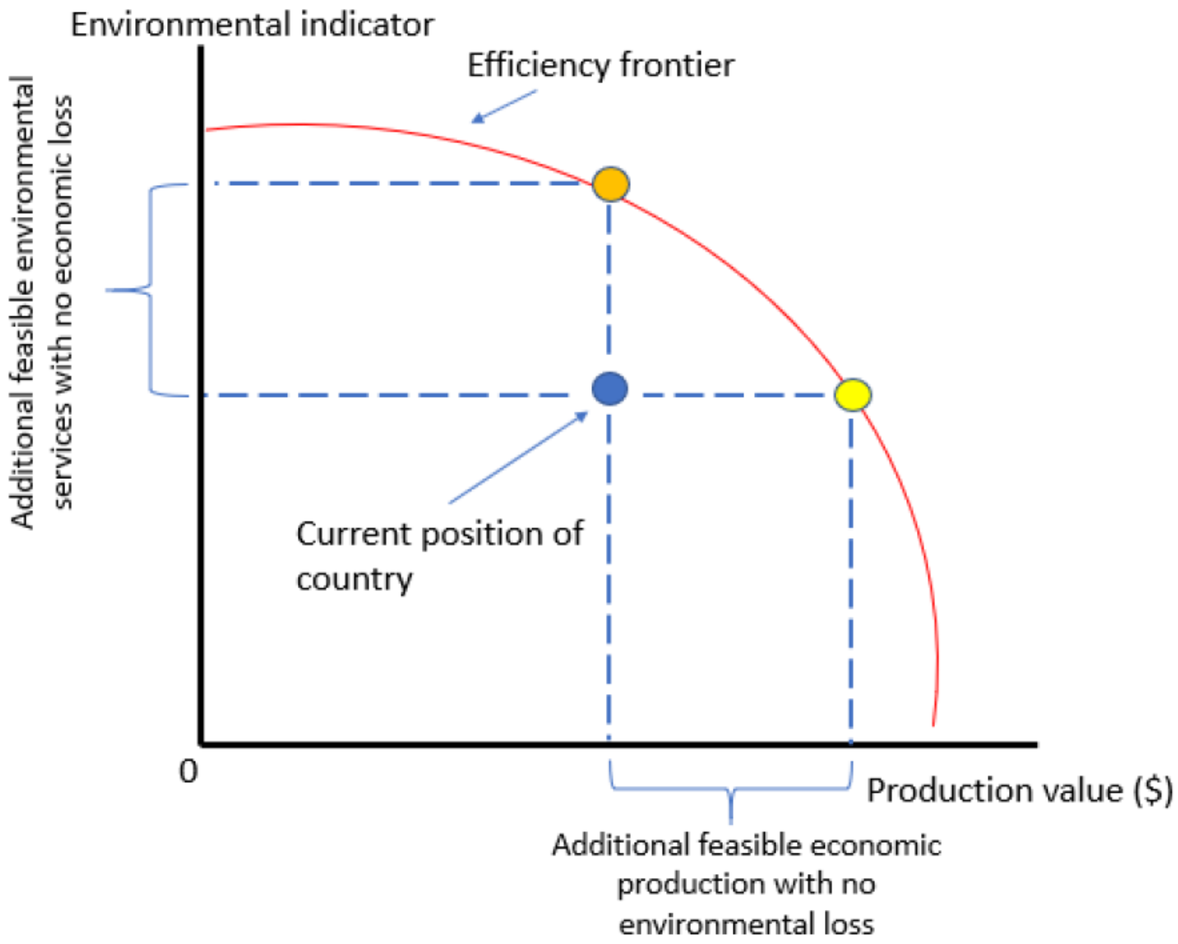
C. Low-income low-development: large potential gains in economic development

D. Highly developed: large potential restoration gains

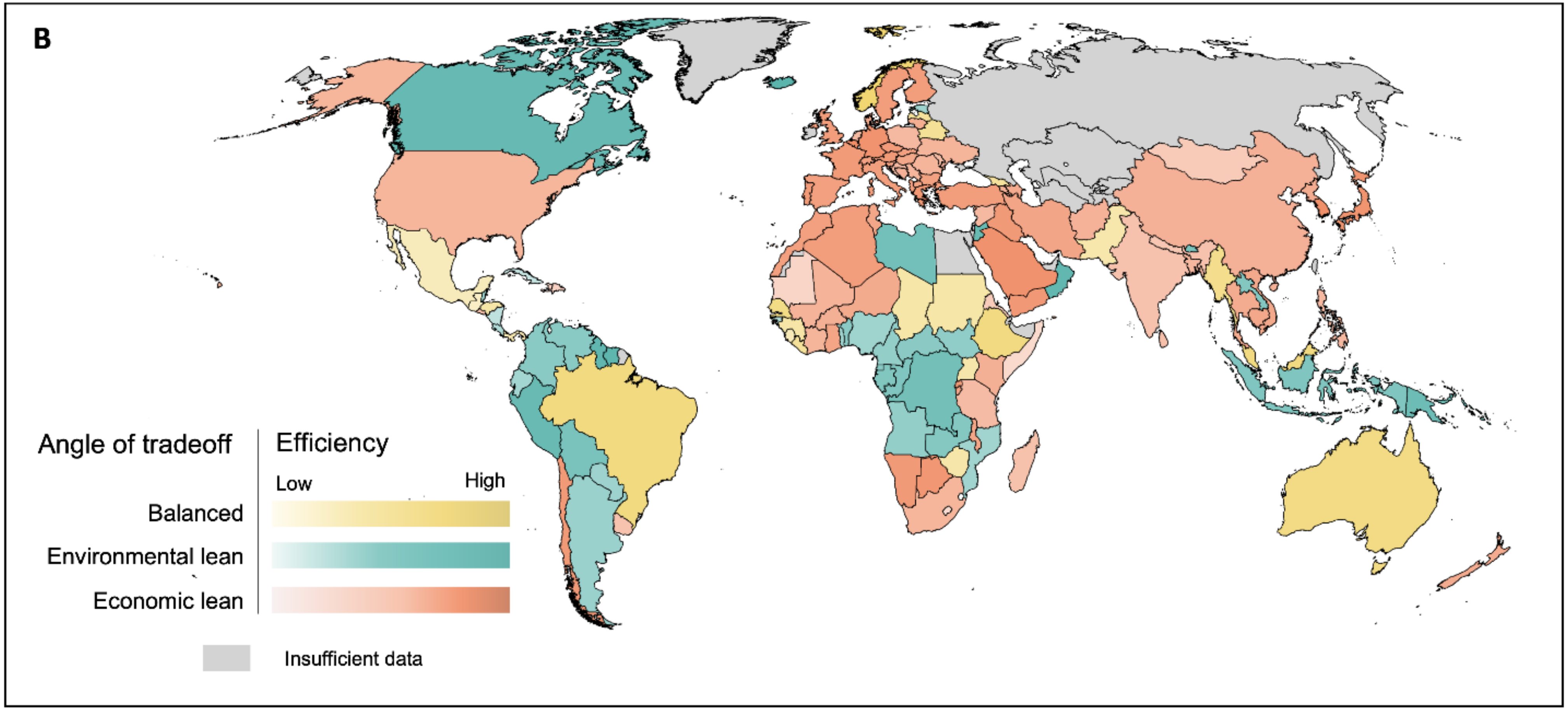


# Large potential gains across 146 countries

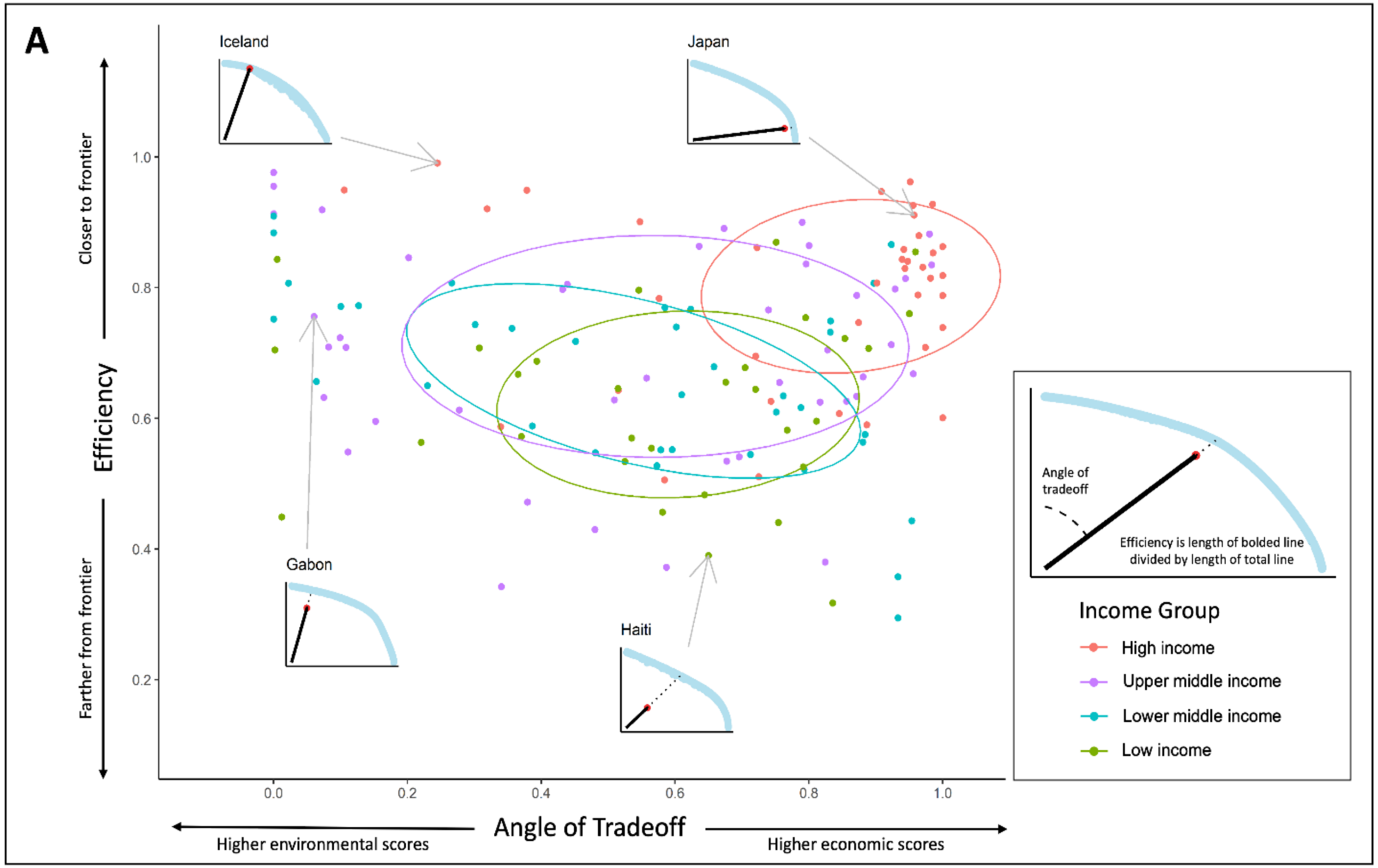
- More than 233 billion metric tons of $CO_2E$ could be sequestered without adverse economic impacts (~4 years of global emissions)
- Or
- Annual returns from crops, grazing, forestry could be increased by >$368 billion without loss to biodiversity or GHG sequestration



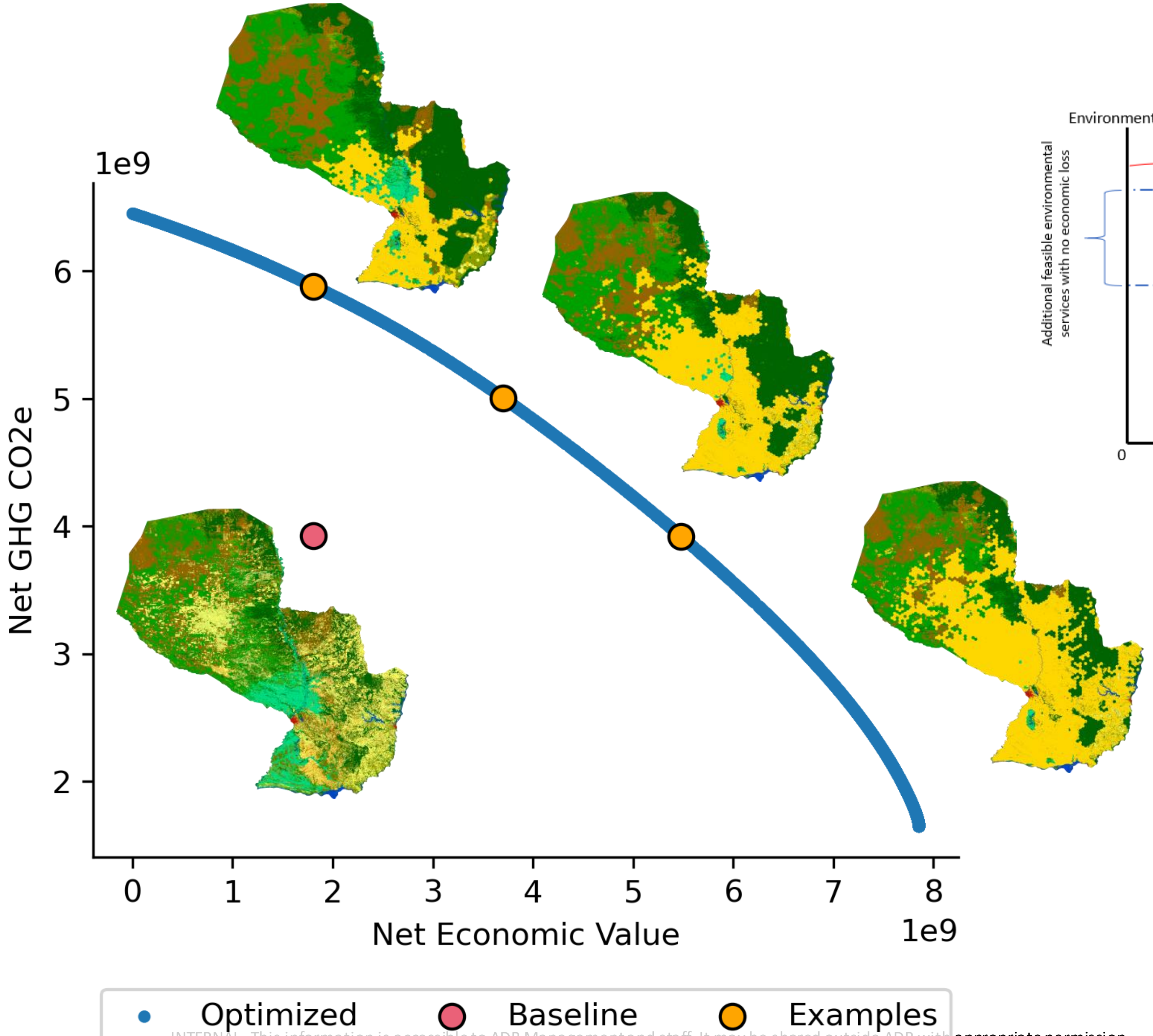
# Environmental/economic orientation and efficiency by country

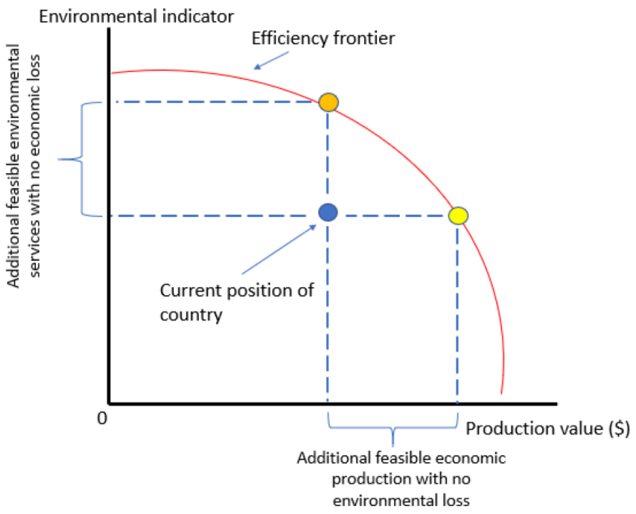


# Summary statistics on current performance by income group



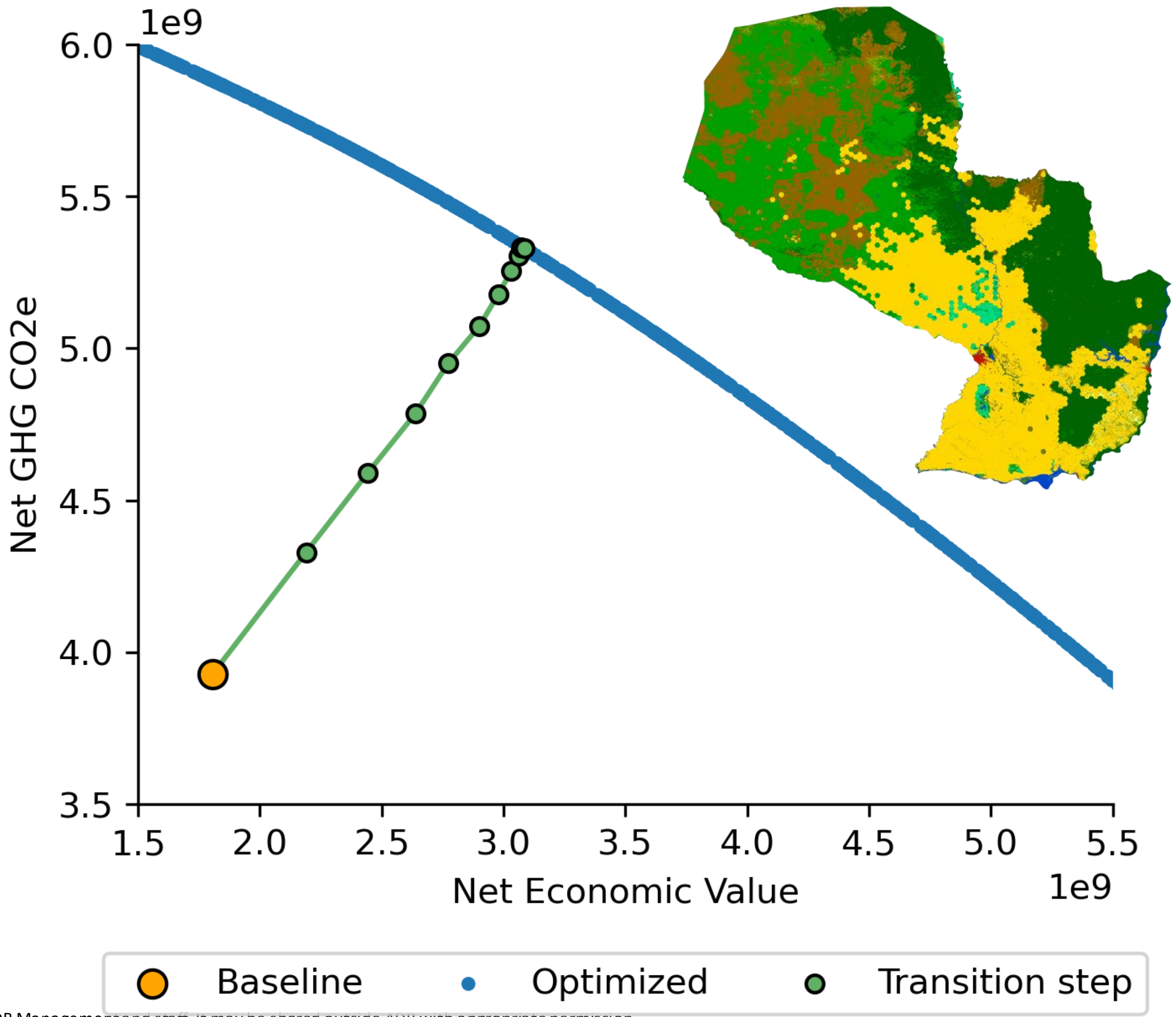
# Frontier analysis illustrates what is potentially feasible



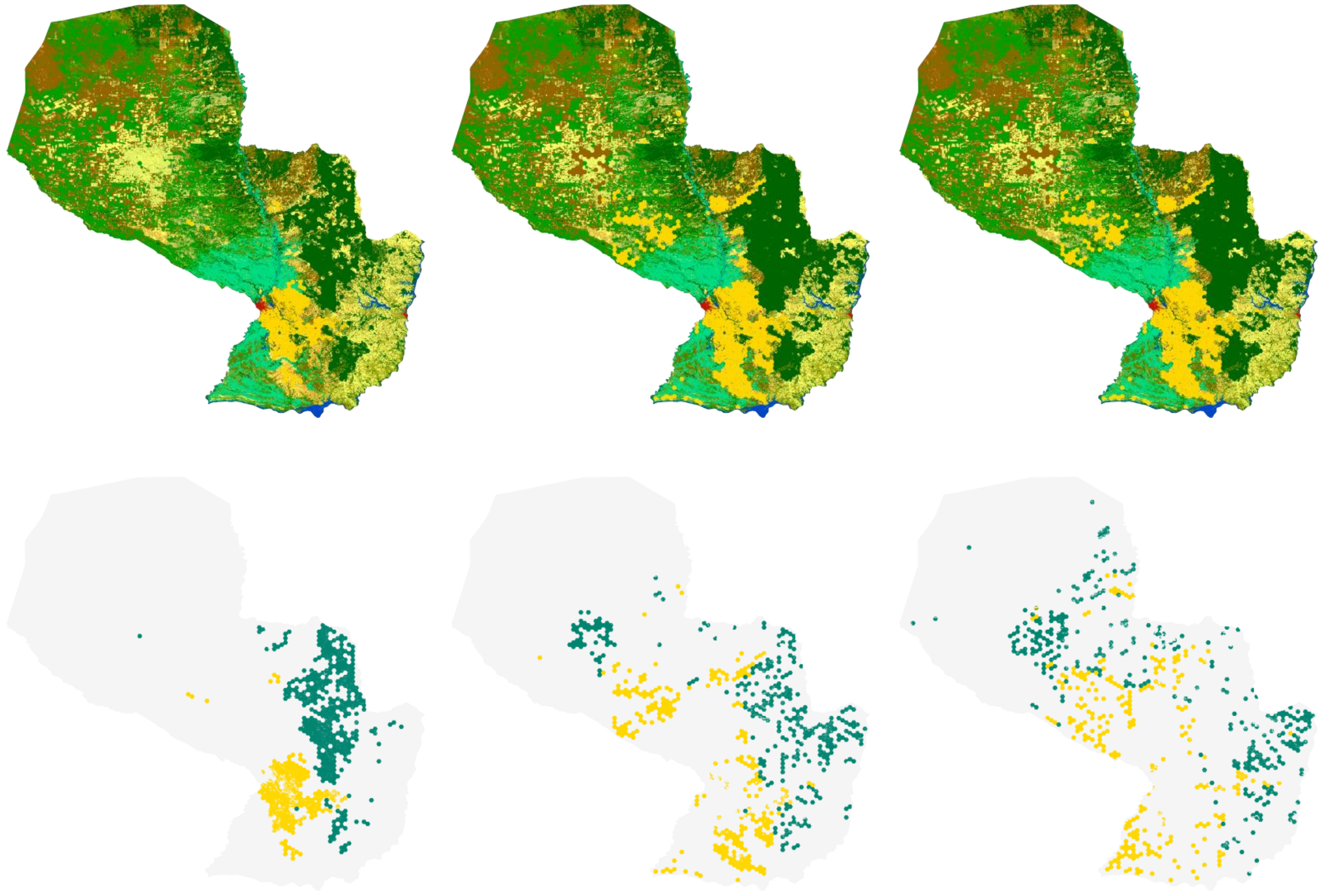



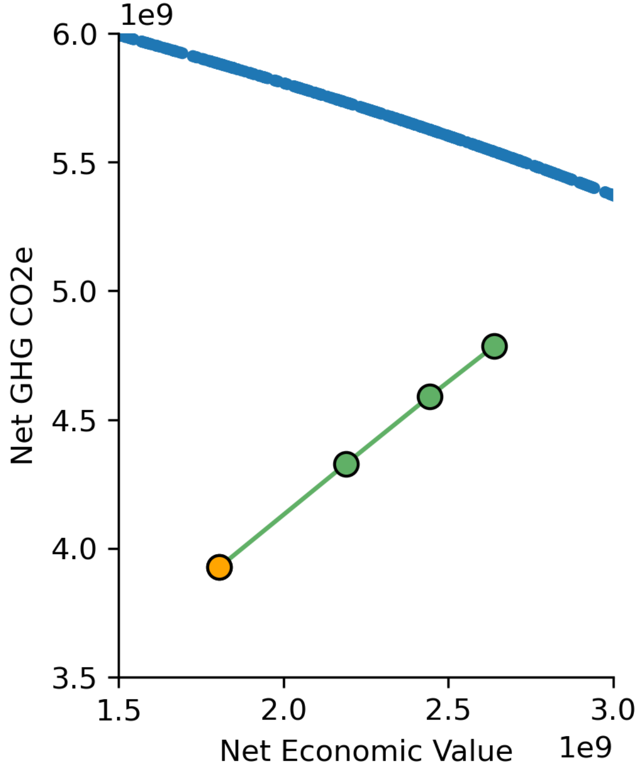
# Transition pathways show incremental steps

- Smaller-scale changes that yield benefits across all objectives



# Example of 3 transition steps






% of possible gains obtained:

- Economic: 65%
- Carbon storage: 61%

# POLICY OPTIONS

- Payment for ecosystem services
- Rezoning land
- Pricing
- certification and green labeling
- Subsidy reform
- Sustainable, non-consumptive forest utilization
- Increased training and skills for farmers
- More secure tenure and property rights
- Reallocation from lower to high value use
- Strengthening protected area management
- Restore degraded lands
- Groundwater recharge and restoration
- and more …

# Global Earth-Economy Modeling



PNAS

RESEARCH ARTICLE | ECONOMIC SCIENCES
ENVIRONMENTAL SCIENCES


## Investing in nature can improve equity and economic returns


Justin Andrew Johnson[a,1], Uris Lantz Baldos[b], Erwin Corong[b], Thomas Hertel[b], Stephen Polasky[a,1], Raffaello Cervigni[c], Toby Roxburgh[d], Giovanni Ruta[c], Colette Salemi[e], and Sumil Thakrar[a]

# The Global Earth-Economy Model in a nutshell

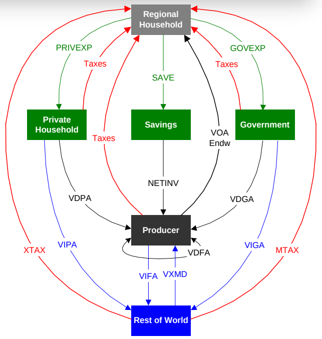
Policy changes

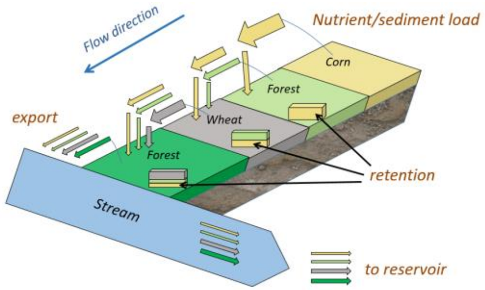
- Fiscal reform
- Expansion of PES
- Intensification of agriculture
- Trade policies

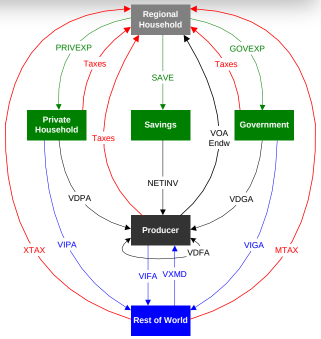
1. *Pollination*
2. *Timber*
3. *Fisheries*
4. *Carbon*

- **GDP**
- **Welfare**
- **Factor use**

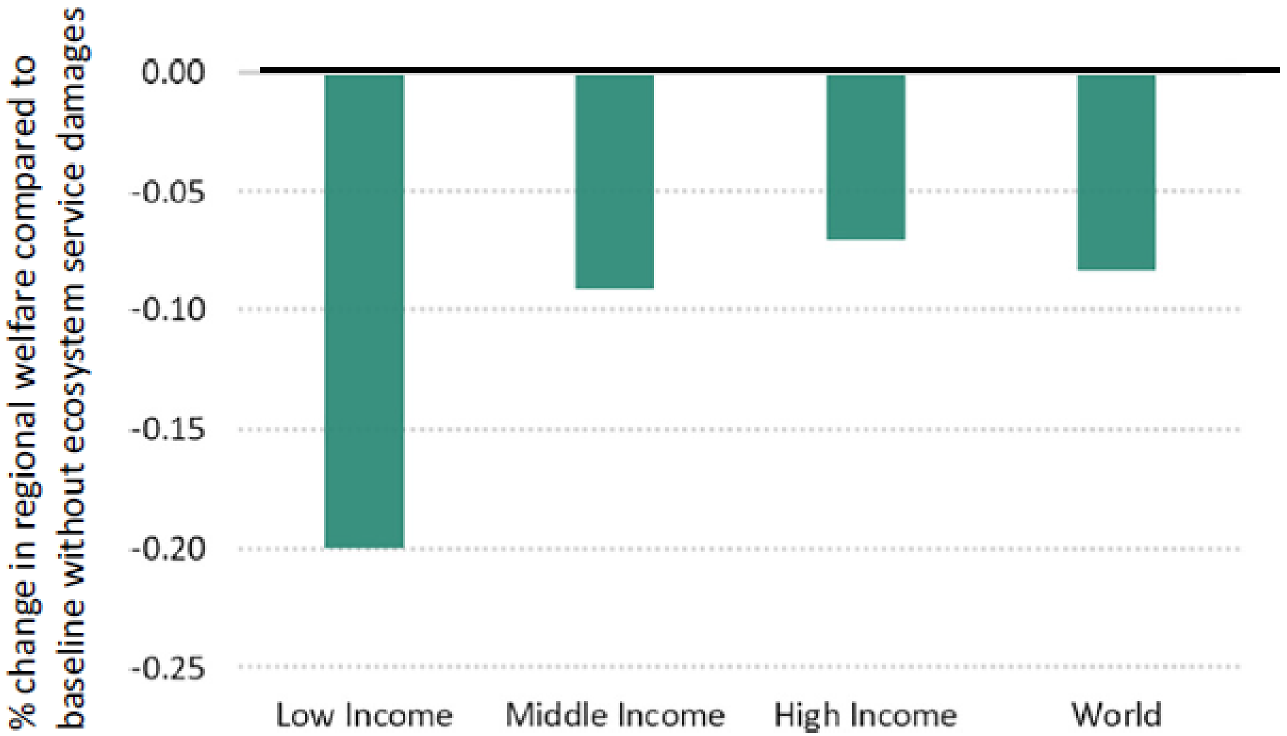
CGE Economic Model (without ES) → Change in land use → Natural Capital → Ecosystem Services Model → CGE Economic Model



# Change in monetary measure of regional welfare to 2030 due to losses of ecosystem services under business-as-usual (BAU)

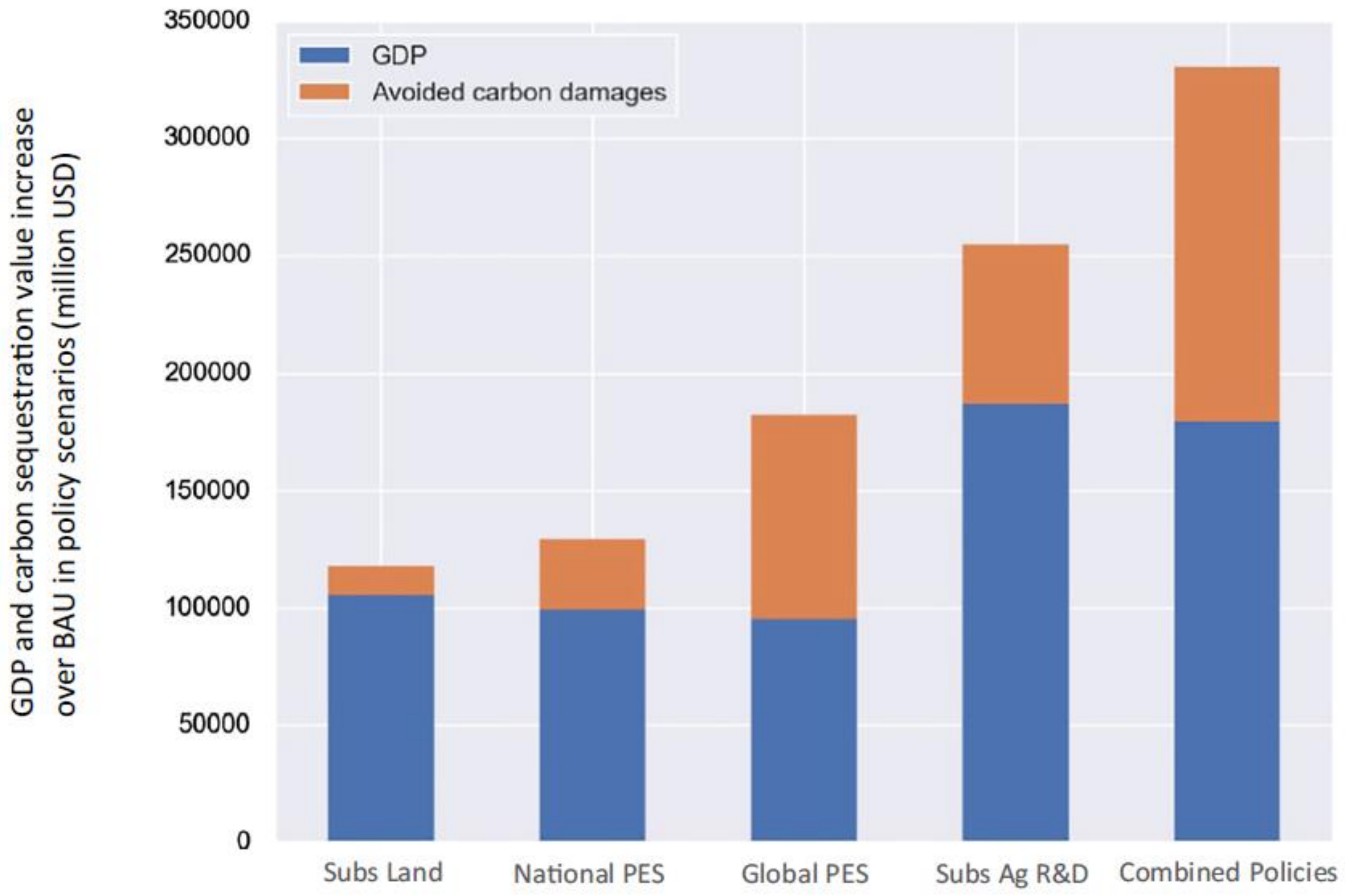


# How can policies improve outcomes?

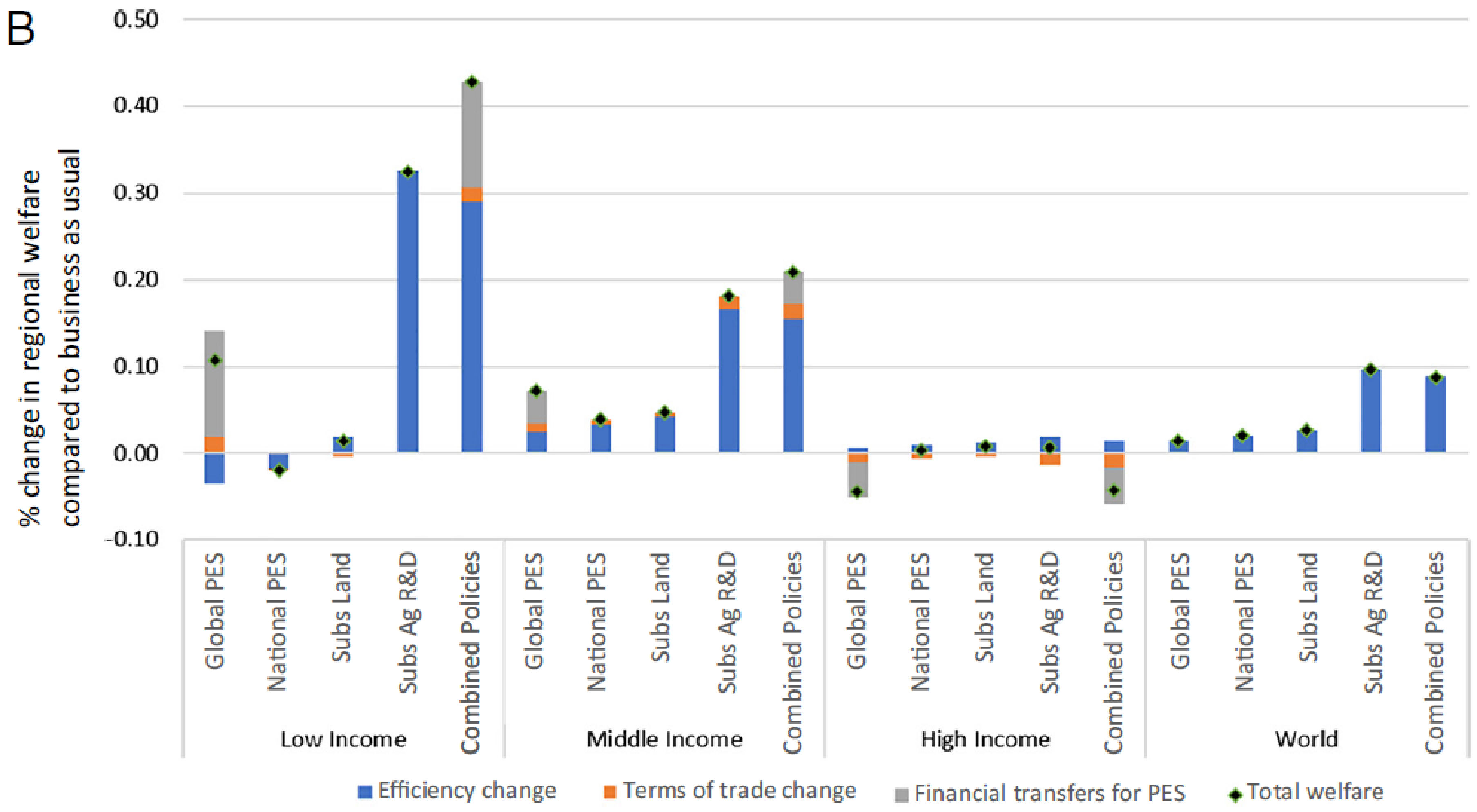
- Three policies assessed with GTAP-InVEST

1. Remove agricultural production subsidies
2. Payments for ecosystem services (local version, global version)
3. Agricultural research and development

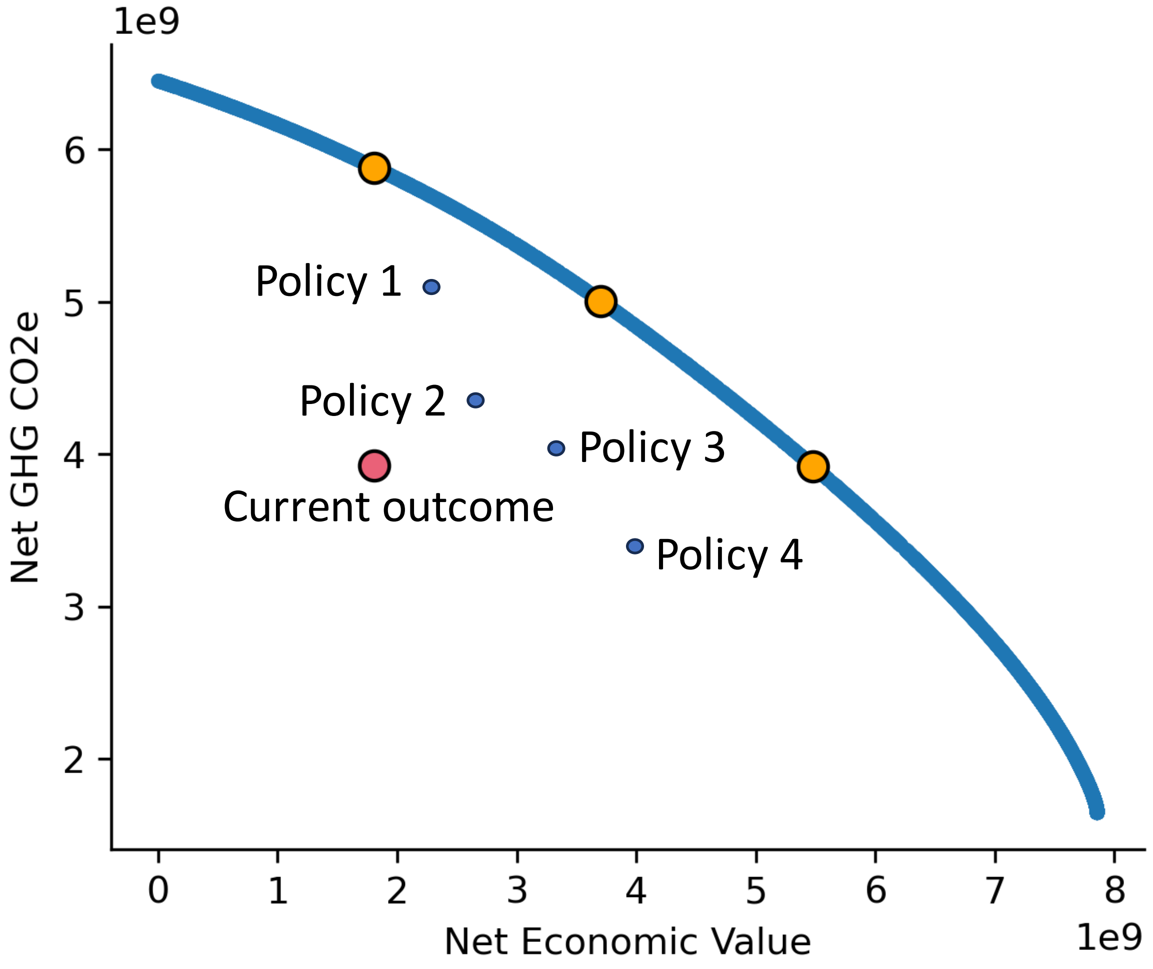
# Gains in GDP and avoided carbon damages under different policies relative to BAU



# Gains/losses to different income groups under alternative policies



# Combining Earth-economy models and nature's frontiers (the next research frontier)



# Summary

- 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


Questions?
Photo: Juizhaigou
Stephen Polasky