The Sustainable Development Challenge:

The Importance of Accounting for the Value of Nature

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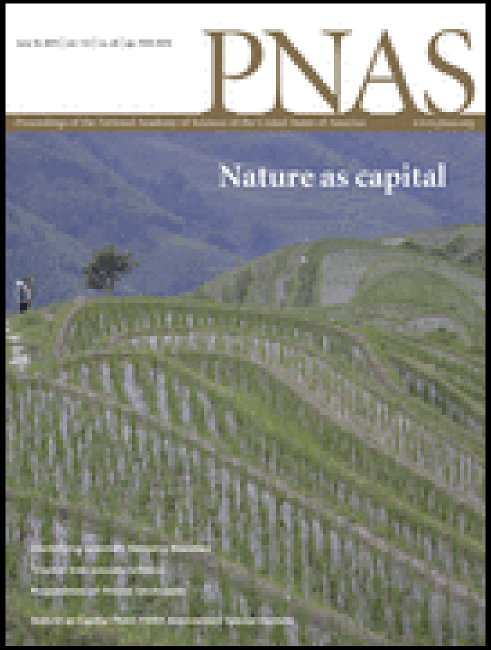
August 27, 2021

The sustainable development challenge

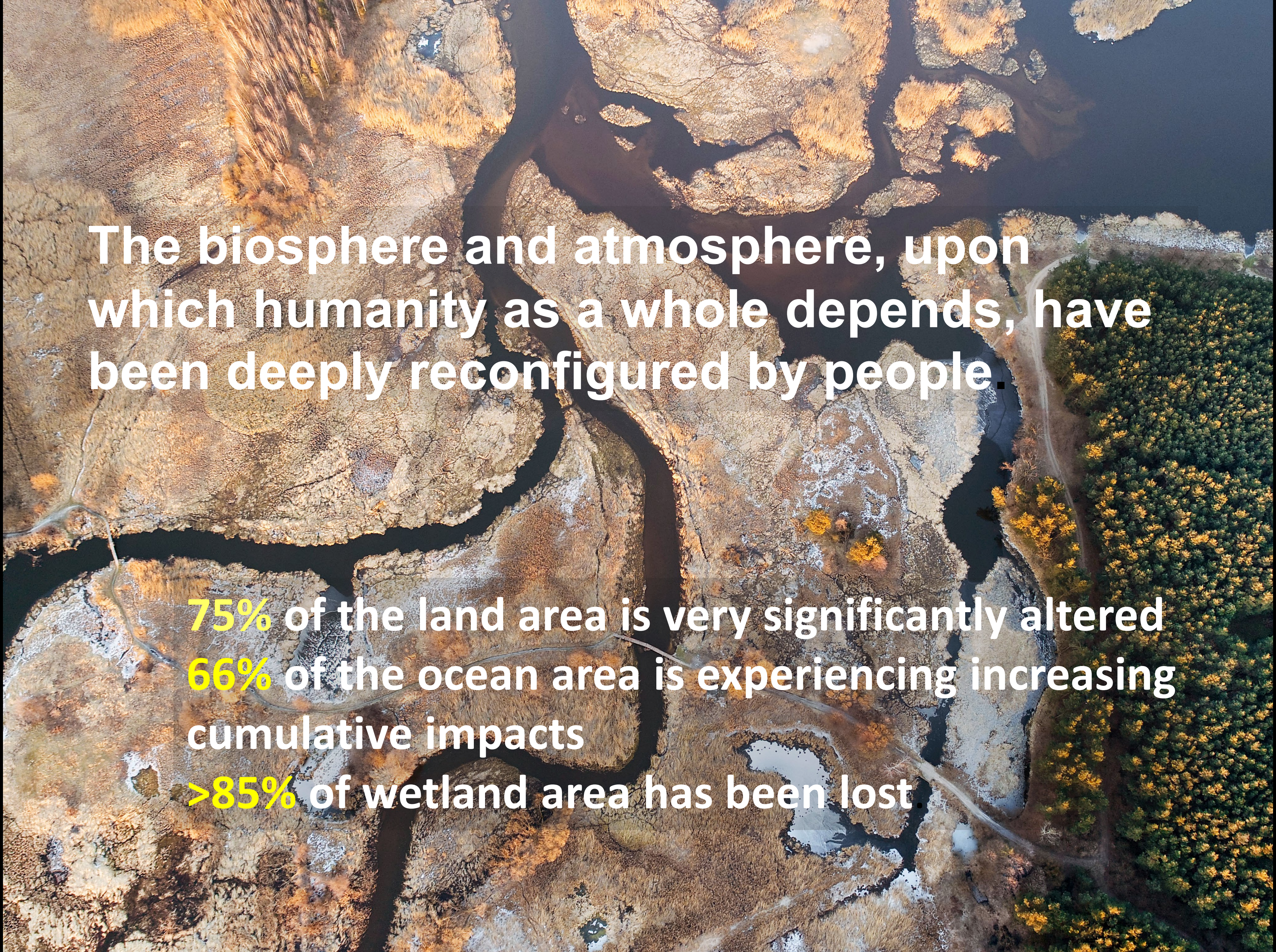
- “The central challenge of the 21st century is to develop economic, social, and governance systems capable of ending poverty and achieving sustainable levels of population and consumption while securing the life-support systems underpinning current and future human well-being”

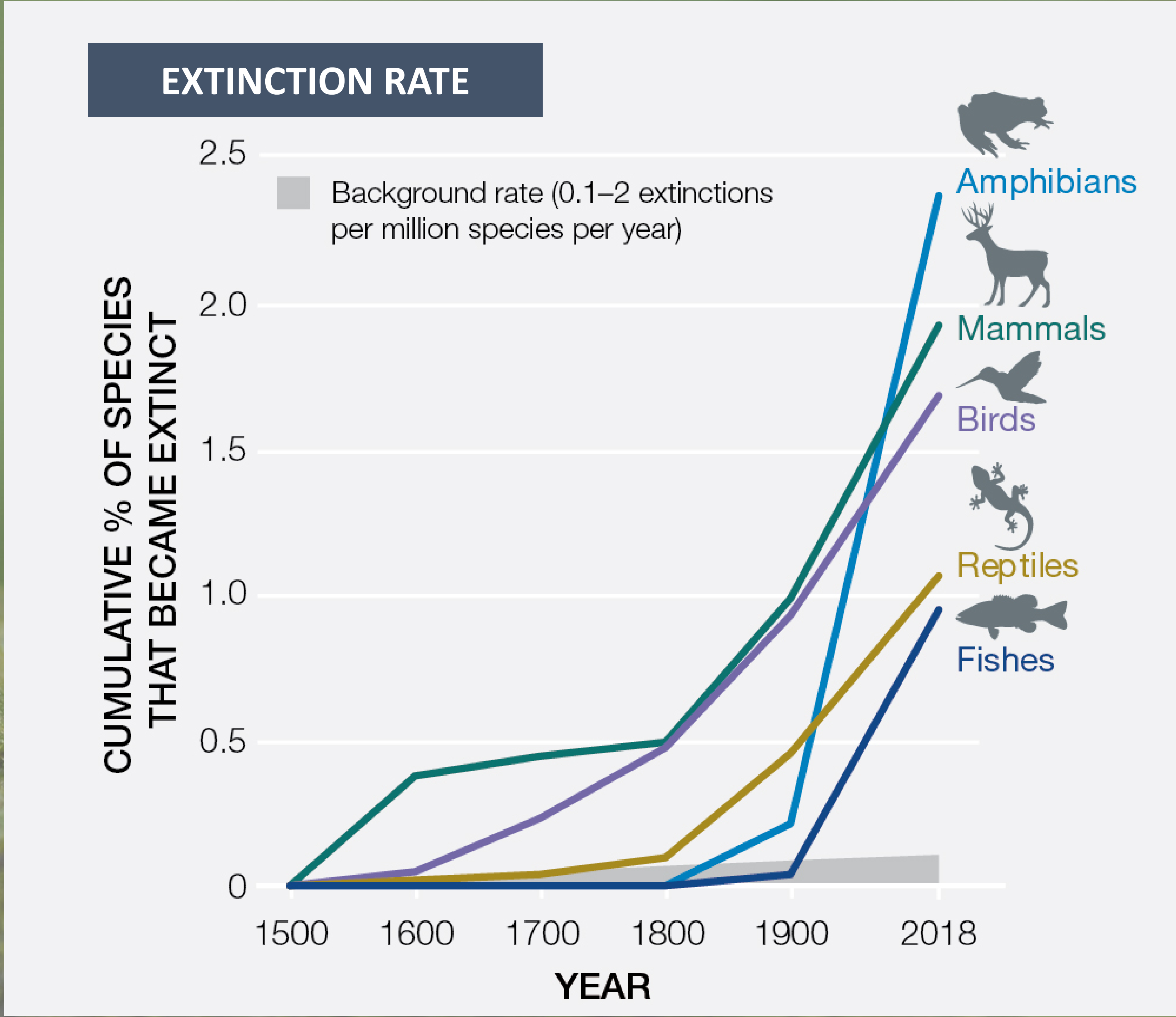


June 16, 2015 Special Issue of PNAS

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


Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Global Assessment (2019)
ipbes
www.ipbes.net
UN environment programme
Food and Agriculture Organization of the United Nations
UNDP


The biosphere and atmosphere, upon which humanity as a whole depends, have been deeply reconfigured by people.
75% of the land area is very significantly altered
66% of the ocean area is experiencing increasing cumulative impacts
>85% of wetland area has been lost.

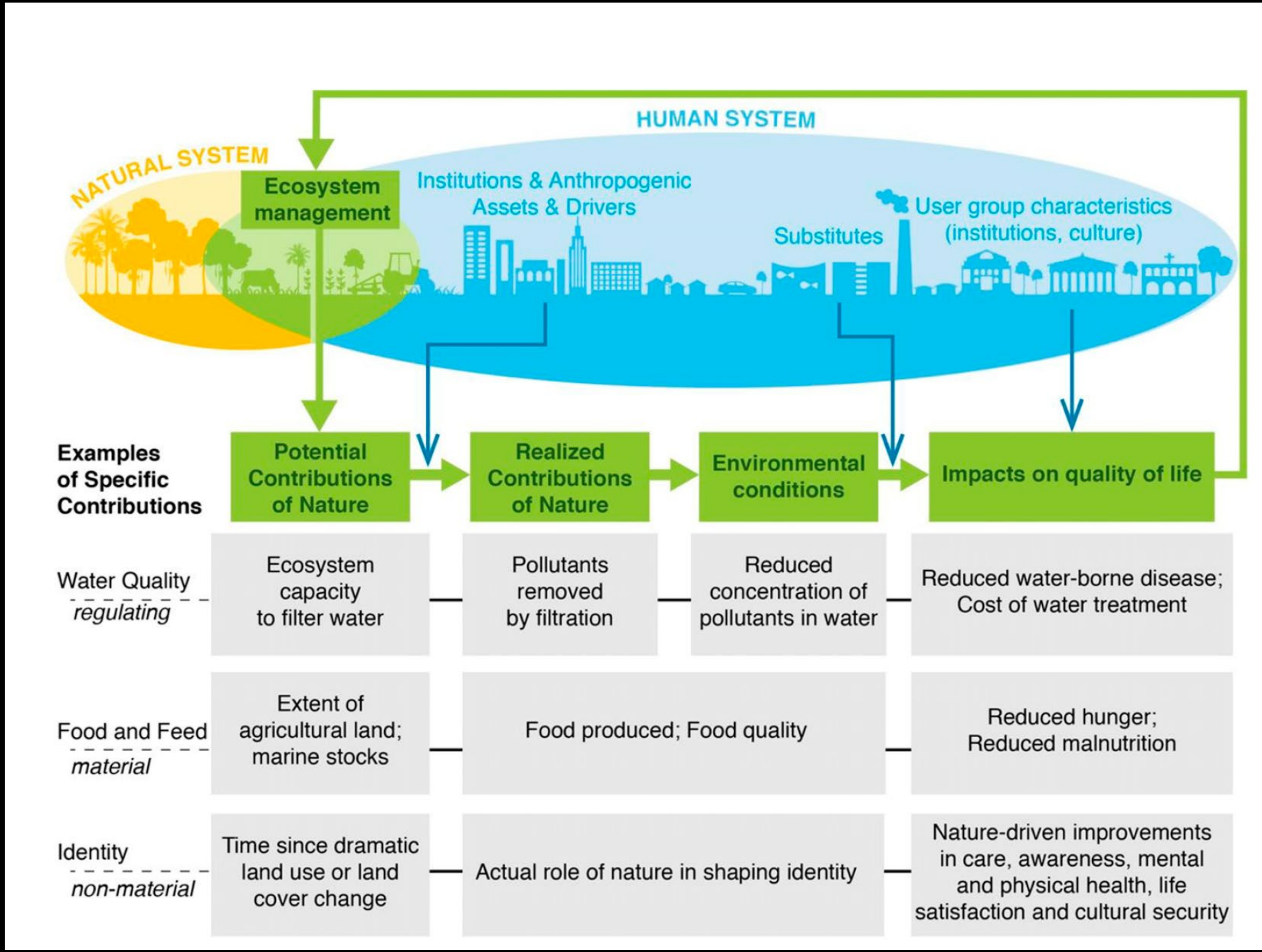


EXTINCTION RATE
Background rate (0.1–2 extinctions per million species per year)
CUMULATIVE % OF SPECIES THAT BECAME EXTINCT
2.5
2.0
1.5
1.0
0.5
0
1500
1600
1700
1800
1900
2018
YEAR
Amphibians
Mammals
Birds
Reptiles
Fishes

Nature and its vital contributions to people are deteriorating worldwide

Global trends in nature's contributions to people

Brauman et al. 2020 Proceedings of the National Academy of Sciences 17: 32799-32805



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			
REGULATING	Pollination & seed dispersal	Pollinator diversity & abundance	Pollinator - plant overlap	Pollinated plant diversity & abundance	Health from pollinated foods
REGULATING	Air quality regulation	Amount of burnable biomass or pollution entraining vegetation	Burned vegetation & actual pollution entrainment	Air quality	Air pollution-driven mortality
REGULATING	Climate regulation	Potential GHG sequestration by existing ecosystems	Actual GHG sequestration, including land management	GHG concentration	Climate-driven mortality & costs
REGULATING	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
REGULATING	Water quantity & flow regulation	Potential water modulation by existing ecosystems	Actual water modulation by existing ecosystems	Available water	Available water relative to demand
REGULATING	Water quality regulation	Extent of filtering ecosystems	Actual ecosystem removal of pollutants	Water quality	Health from water pollution & cost of water treatment
REGULATING	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
REGULATING	Hazard regulation	Existence of hazard-reducing ecosystems	Actual ecosystem hazard reduction	Incidence and severity of hazards	Hazard-driven health & income
REGULATING	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
MATERIAL	Food & feed	Extent of food producing land & ocean fish stocks	Amount and nutrition of harvested food & feed		Nutrition & income from food & feed
MATERIAL	Materials	Extent of agriculture and forest land for materials	Amount & quality of harvested materials		Employment & income
MATERIAL	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
NON-MATERIAL	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
NON-MATERIAL	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
NON-MATERIAL	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

Incorporating the multiple values of ecosystem functions and of nature’s contribution to people into economic incentives can generate better ecological, economic and social outcomes

Photocredit: Daniel M. Cáceres

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

Central role for economists in analyzing sustainable development

National Academies Colloquium on
"Economics, Environment, and Sustainable Development"

PNAS

Role of economics in analyzing the environment and sustainable development

Stephen Polasky[a,b,1], Catherine L. Kling[c,d], Simon A. Levin[a,c,e], Stephen R. Carpenter[a,f], Gretchen C. Daily[a,g,h,i], Paul R. Ehrlich[a,g], Geoffrey M. Heal[j], and Jane Lubchenco[a,k]

PNAS | March 19, 2019 | vol. 116 | no. 12 | 5233–5238

Central role for economists in analyzing sustainable development

- “The discipline of economics arguably should play a central role in meeting the sustainable development challenge.”
- “The core question at the heart of sustainable development is how to allocate the finite resources of the planet to meet ‘the needs of the present, without compromising the ability of future generations to meet their own needs’” (Brundtland Report 1987)
- “The application of economic principles and empirical findings should be a central component in the quest to meet the aspirations of humanity for a good life given the finite resources of the earth.”

Central role for economists

- Extensive work by economists that integrates other natural and social sciences into a policy-relevant framework on sustainable development challenges
- Some positive examples:
  - Climate change integrated assessment models
  - Sustainable use of common property resources
  - Ecosystem services and natural capital modeling

Challenge for economists – and environmental economists in particular

- “Despite these examples…the center of gravity in the analysis of sustainable development remains in the natural sciences, and the center of gravity in economics remains far removed from the challenge of sustainable development.”

Challenge for environmental economists

- The fields of ecological, environmental, and resource economics are not core fields within economics
  - Only a small minority of the top economics departments have fields in ecological, environmental, or resource economics
- Few ecological, environmental, or resource economics publications in flagship journals
  - *American Economic Review* in 2018: only two papers listed classification codes for renewable resources and conservation, nonrenewable resources and conservation, energy economics, or environmental economics (one of these was "Narrative sign restrictions for SVARs")

Challenge for economists: Working with other disciplines

- "While natural science understanding is insufficient on its own to achieve sustainable development, the same is true of economics. Economists alone do not have the knowledge base supplied by the natural sciences necessary to understand the complex ecological systems within which the economic system operates and on which economic activity causes impacts. Progress in sustainable development requires collaboration between social scientists, including economists and natural scientists."

- "Though all disciplines are in someway insular. . .this trait peculiarly characterizes economics" (Fourcade et al. 2015 *Journal of Economic Perspectives* 29: 89-114)
  - The percentage of within-field citations in economics: 81%, versus 59% for political science, 53% for anthropology, and 52% for sociology (Jacobs 2013. *In Defense of Disciplines: Interdisciplinarity and Specialization in the Research University.* Univ of Chicago Press)

Important role for economists in sustainable development

- The challenge of achieving sustainable development is large and pressing
- Need economists to play a larger role
- Need more and better economics to integrate with other natural and social sciences to do policy-relevant research on sustainable development

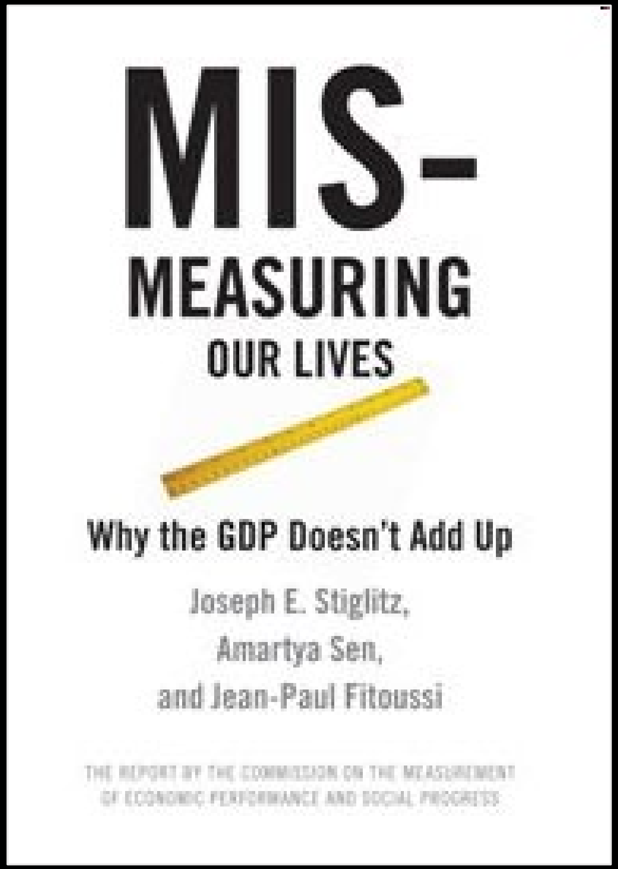
Examples of integrated analysis of sustainable development issues incorporating the value of nature

Gross Ecosystem Product (GEP) for Sustainable Development

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

Moving beyond GDP

- Widespread recognition of the need to move beyond GDP
- Need better measures of ecological, economic, and social performance



Current dominance of GDP

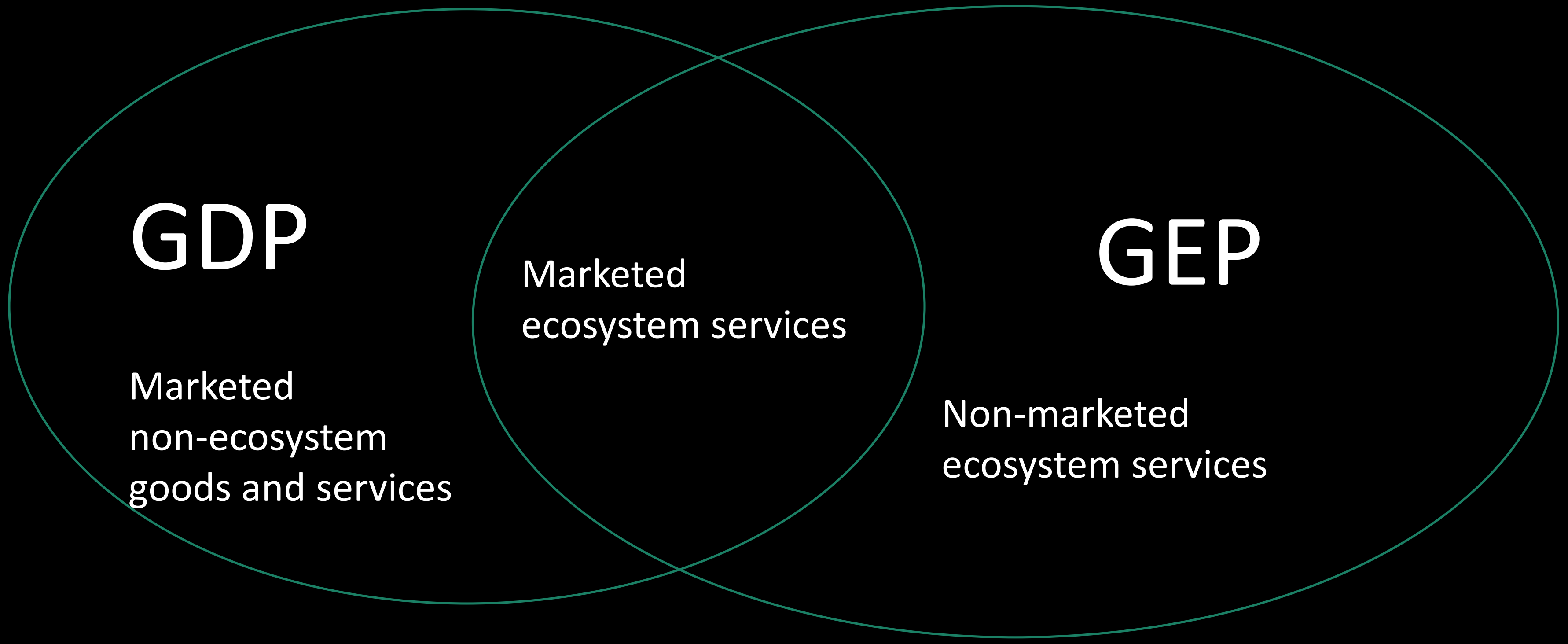
- GDP provides clear and easily understood signal of economic performance (“headline number”)
- Currently lack an equivalent clear and easily understood signal of ecological performance

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

- GDP: summary statistic that measures the flow of income from marketed goods and services
- GEP: summary statistics that measures the flow of value from ecosystem goods and services



GEP and the system of natural capital and ecosystem service accounts

- Creating natural capital and ecosystem services accounts:

1. Tracking the magnitude and condition of biophysical stocks of natural capital (lands, waters, and their biodiversity)
2. Translating these stocks into flows of ecosystem goods and services
3. Pricing ecosystem goods and service flows
4. Aggregating into GEP

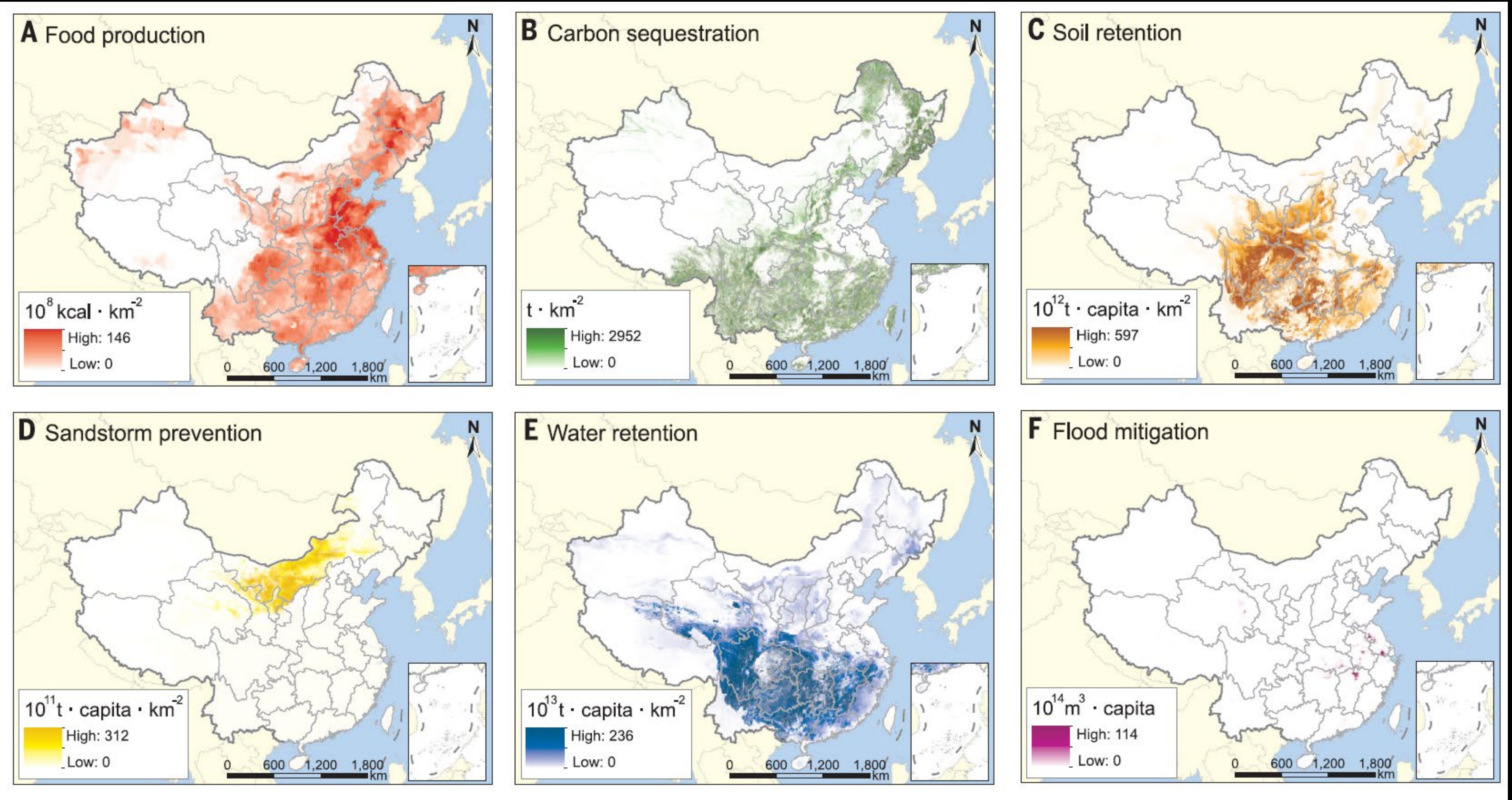
Tracking the magnitude and condition of biophysical stocks of natural capital

- 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

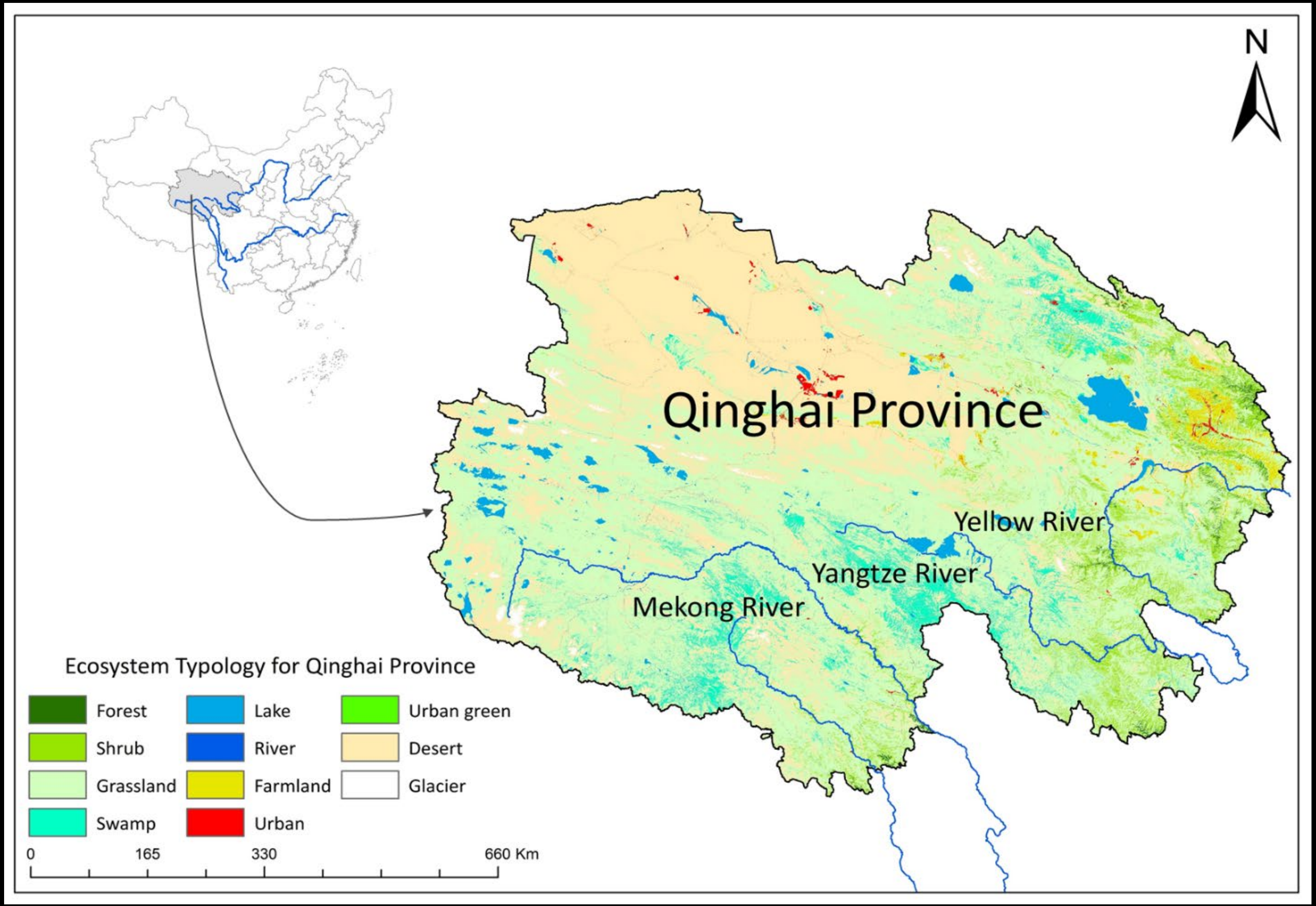
- The value of some ecosystem goods and services can be imputed by estimating the value of marginal product, for example the value of water retention services for hydropower production (Guo et al., 2000), pollination for crop production (Ricketts et al. 2004)

- 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



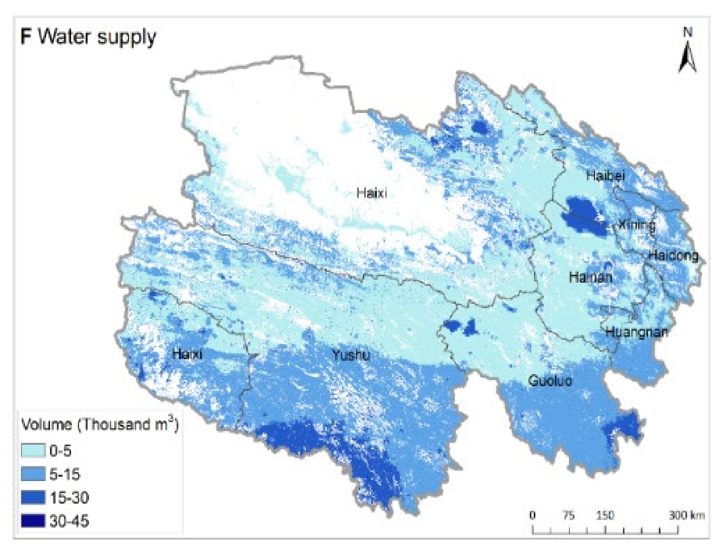
Set of ecosystem goods and services

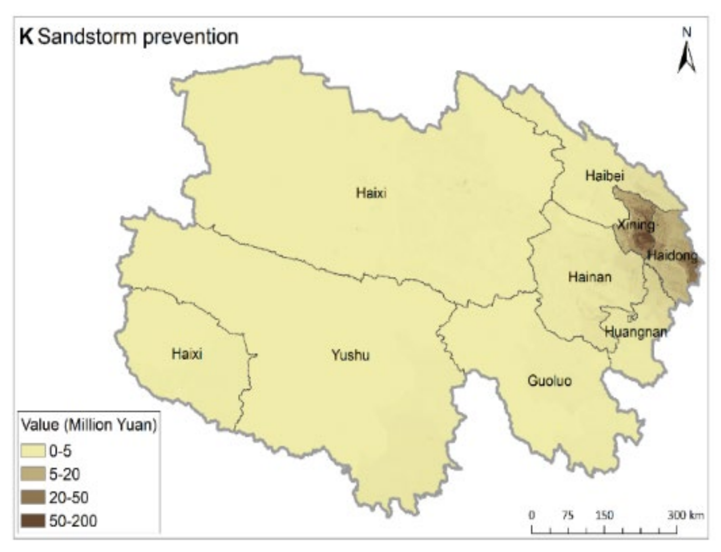
- Provisioning goods (and services)
  - Crop and animal agricultural production, forest products, fishery production, nursery production, water supply
- Regulating (goods and) services
  - Soil retention, sandstorm prevention, flood mitigation, air purification, water purification, carbon sequestration
- Cultural (goods and) services
  - Ecotourism

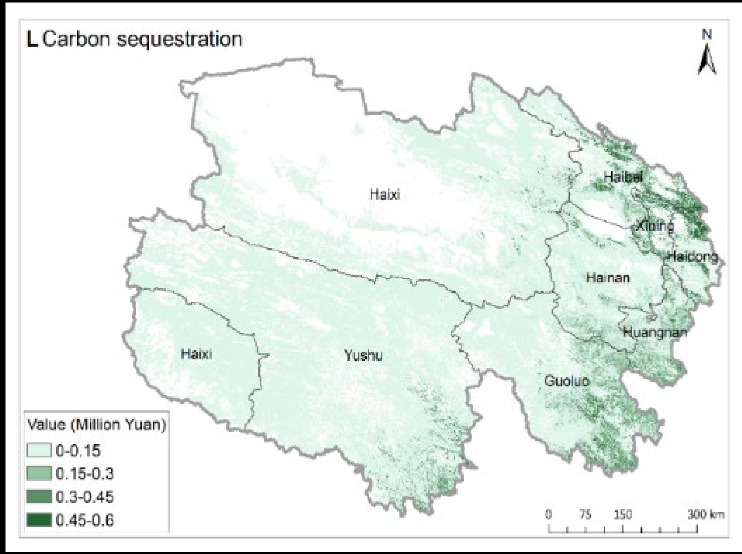
GEP Accounting in Qinghai (2000 – 2015)

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

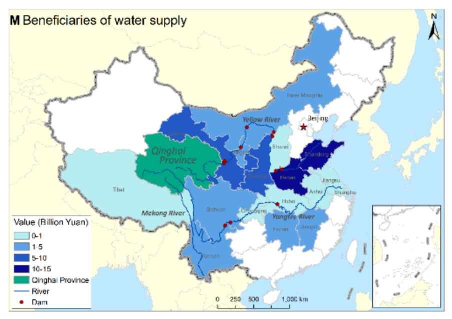
Where ecosystem services are generated

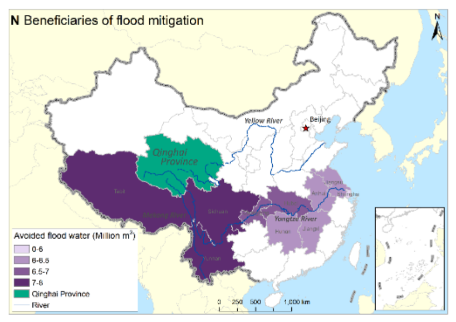


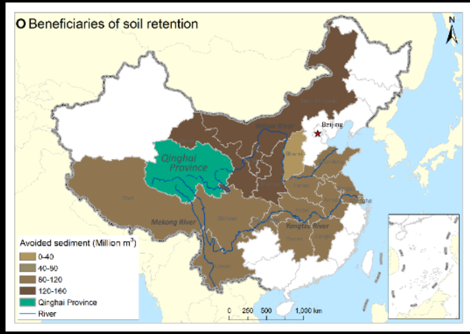


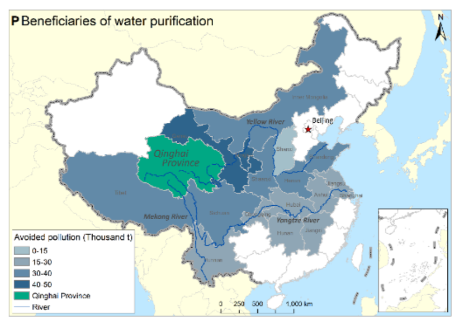


Location of beneficiaries









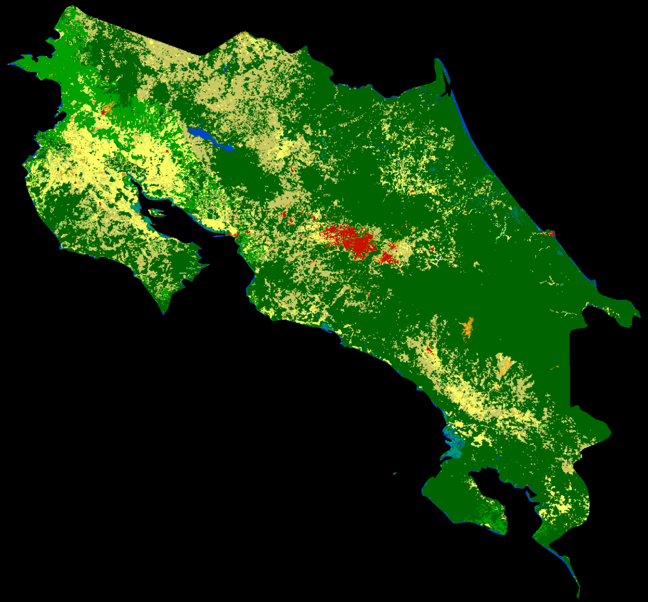
Summary of Qinghai Province case study

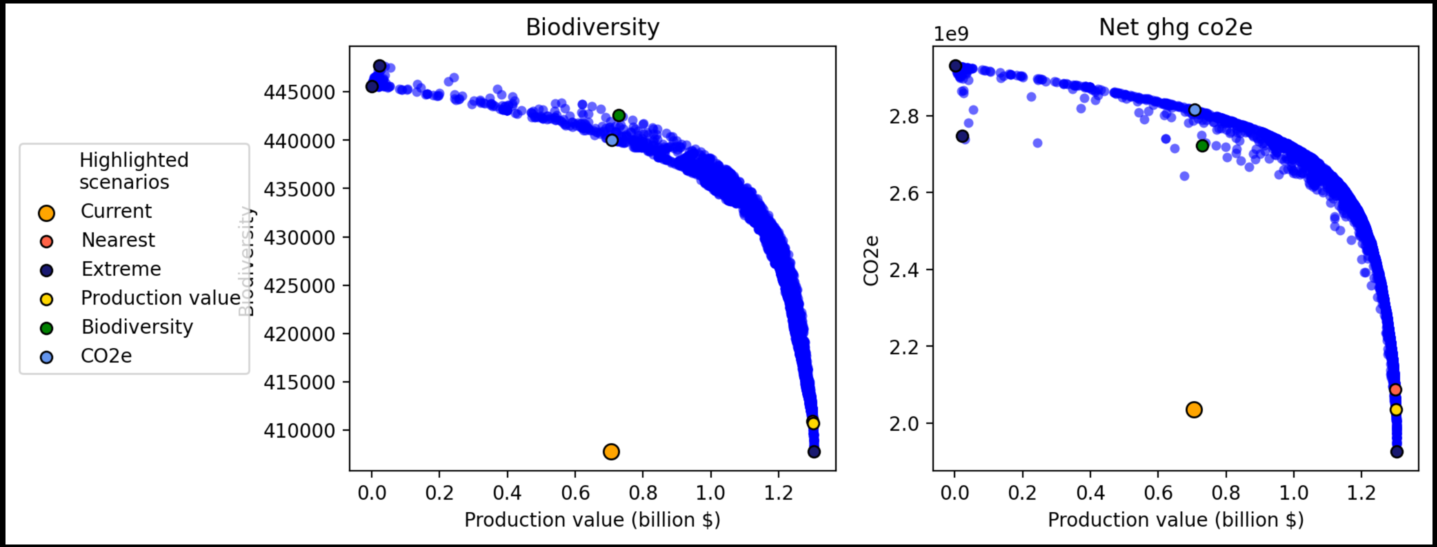
- GEP rivals GDP in value
- Importance of water supply services:
  - Close to 60% of value of GEP in Qinghai
- Other important services
  - Sandstorm prevention 17.1% (all regulatory services 23.7%)
  - Ecotourism: 11.7%
  - All material goods: 7.1%
- Important provider of downstream (downwind) services to other provinces

Conclusion

- 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

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





Natural Capital Index (NCI) overview

- Goal: to provide national-scale indicators on the efficiency of sustainable natural capital management that can inform policy and strategic decisions
- NCI is really a set of metrics rather than one index
- The metrics assess the contribution of natural capital in terms of the value of the sustainable provision of multiple ecosystem services relative to the maximum combinations of these service values that could be achieved given the endowment of the country
- Set of NCI metrics
  - Efficiency index: how close does the country come to operating on the Pareto frontier (production possibility frontier)
  - Percent maximum: how close to the maximum possible score does the country come in any particular dimension of performance

Motivation

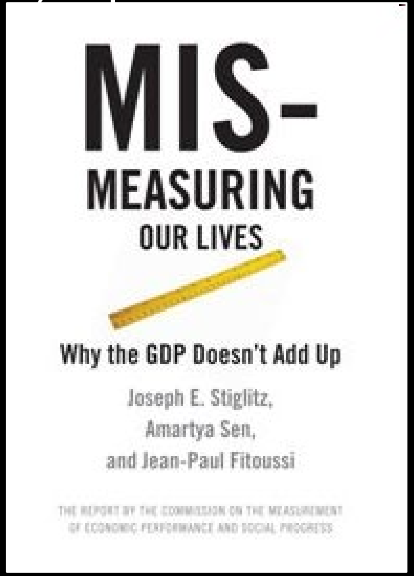
- Having a consistent set of natural capital statistics allows:
  - Benchmarking country performance against peers
  - Evaluating policy alternatives
  - Diagnosing inefficient practices
  - Promoting reforms to improve efficiency and sustainability
- The NCI could also provide data and information to guide analytical work within the World Bank for efforts such as
  - Systematic Country Diagnostics and Country Partnership Frameworks
  - Lending operations
  - Analysis of infrastructure with a large environmental footprint

What to report: Metrics

- Some natural capital that generates ecosystem services with market values can be aggregated into a monetary measure of value (agricultural crops, animal products, timber)

- Other forms of natural capital that generate ecosystem services that either do not have market values, or for which estimating market value is possible but highly uncertain (e.g., converting health impacts into a monetary value using value of statistical life

- Follow the spirit of Stiglitz et al. (2010) hybrid approach: monetize where it makes sense, report in biophysical or other non-monetary terms when that is more informative
  - Dashboard analogy



Basics of the NCI approach: Output metrics

- Monetary returns
  - Agricultural crop
  - Grazing
  - Forestry
- Greenhouse gas emissions
  - CO_2
  - Methane
- Biodiversity
  - Potential species richness
  - Threatened and endangered species
  - Endemic species
  - Rare ecoregions
  - Key biodiversity areas
- Water quality
  - Colorectal cancer reductions [not included in current set of results]

Basics of NCI approach: Management options

- Current sustainable land management: current land management EXCEPT for unsustainable use of groundwater for irrigation, or unsustainable timber harvest, stocking rate
- Restoration to potential natural habitat
- Expanded forestry
- Expanded grazing
- Crop production (9 options)
  - Current management with no changes (1 option)
  - Combinations of (8 options)
    - Irrigated or rainfed
    - Current crop footprint or expanded footprint
    - Best management practices or no best management practices

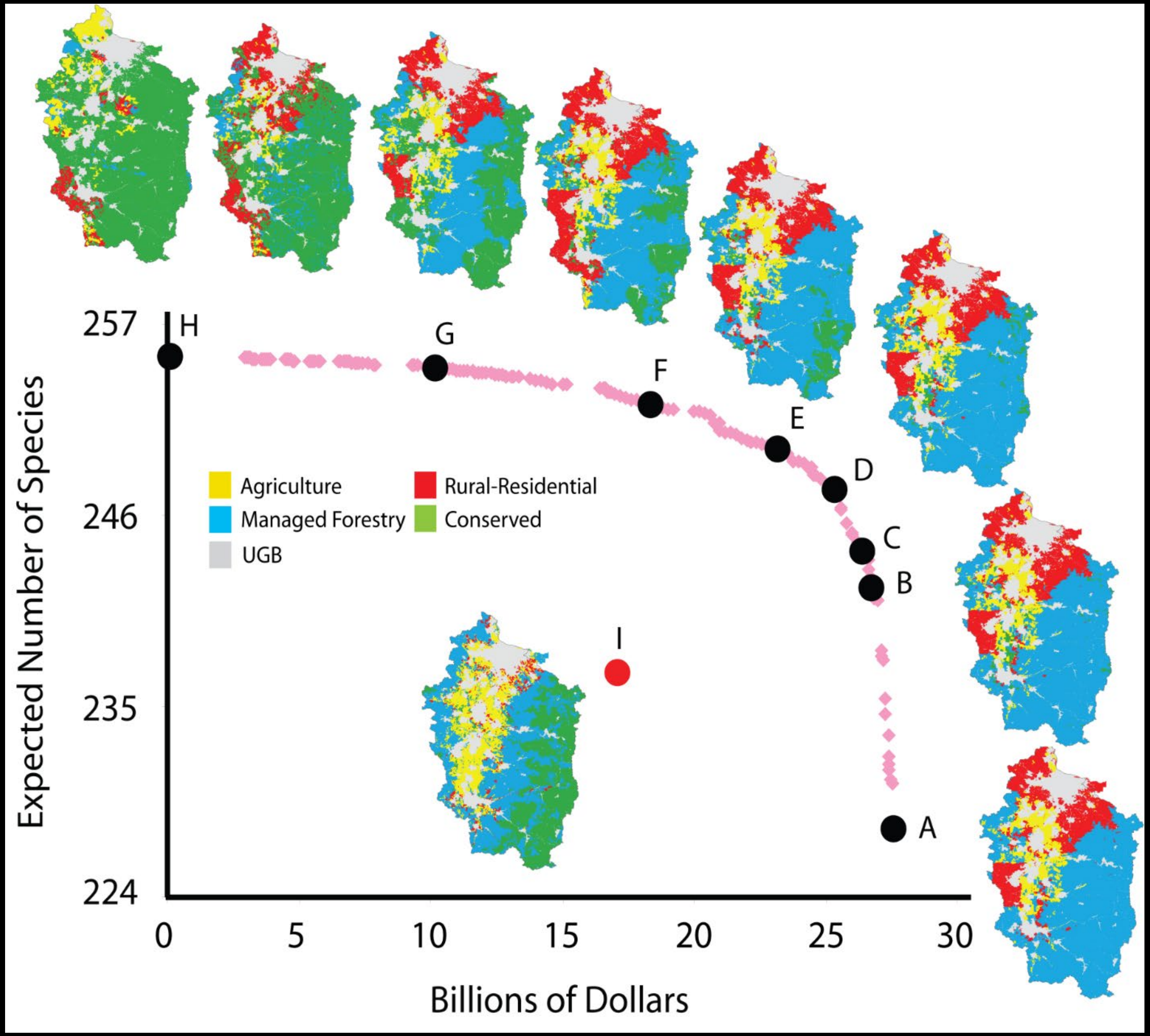
Basics of the NCI approach: From management options to output metrics

- InVEST (Integrated Valuation of Ecosytem Services and Tradeoffs) models plus biodiversity, grazing, forestry models
- These models
  - Inputs:
    - Biophysical data
    - Economic data
    - Map of land use and land management
  - Output: monetary returns, greenhouse gas, biodiversity, water quality
- Example: Crop production
  - Biophysical data (soil, climate) and land management (intensive cropping/irrigation) predict yield
  - Combine with price to get gross monetary returns
  - Use GTAP factor shares to subtract off labor, capital, input costs to get net returns

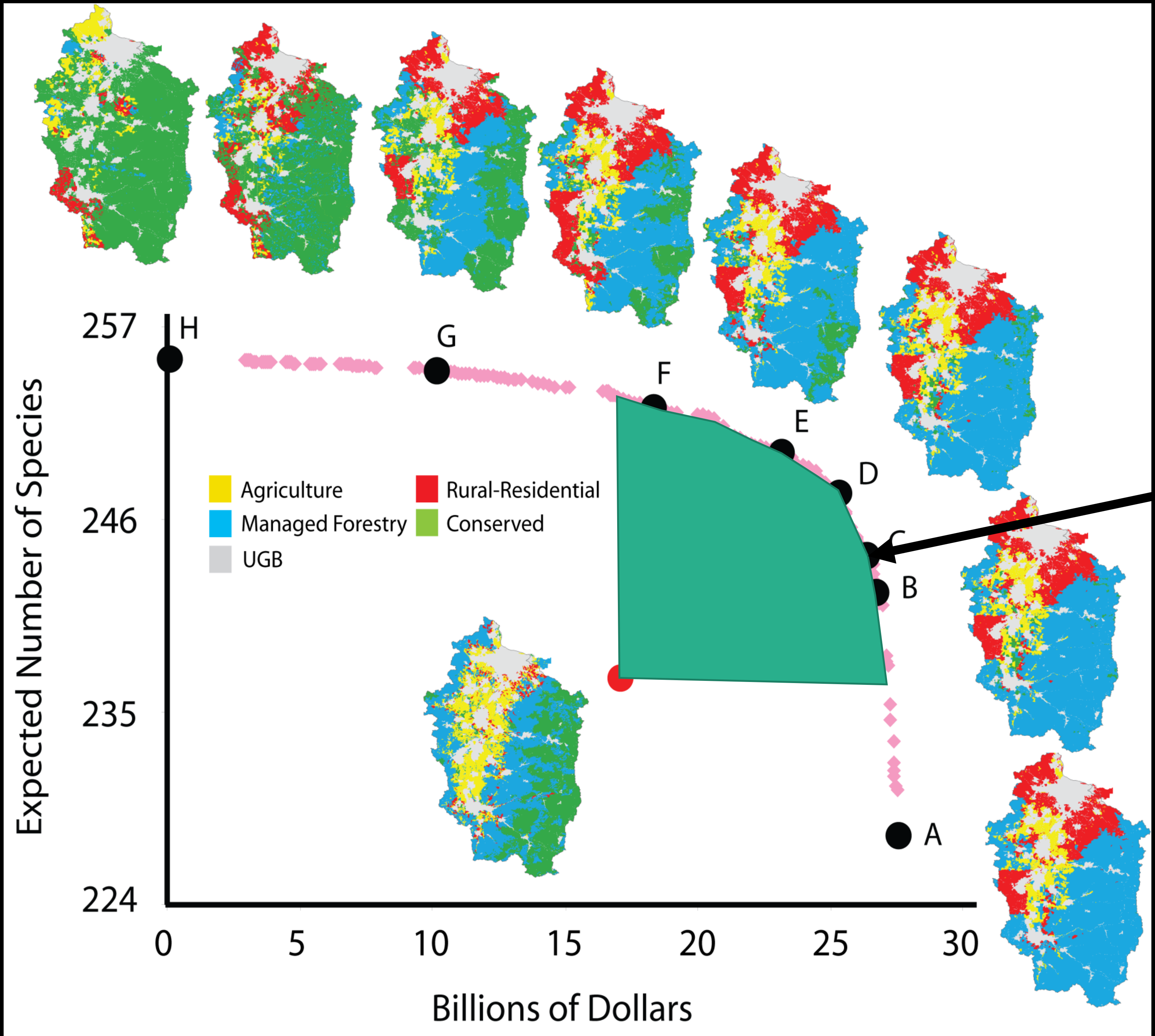
Basics of the NCI approach: Efficiency frontier

- Find the efficiency frontier (and the minimum frontier) for each country and compare it to the current outcome (baseline)
- Optimization routine: choose a land management option for each grid cell that maximizes the objective, which is a weighted sum of the four dimensions. By varying the weights we trace out the efficiency frontier.

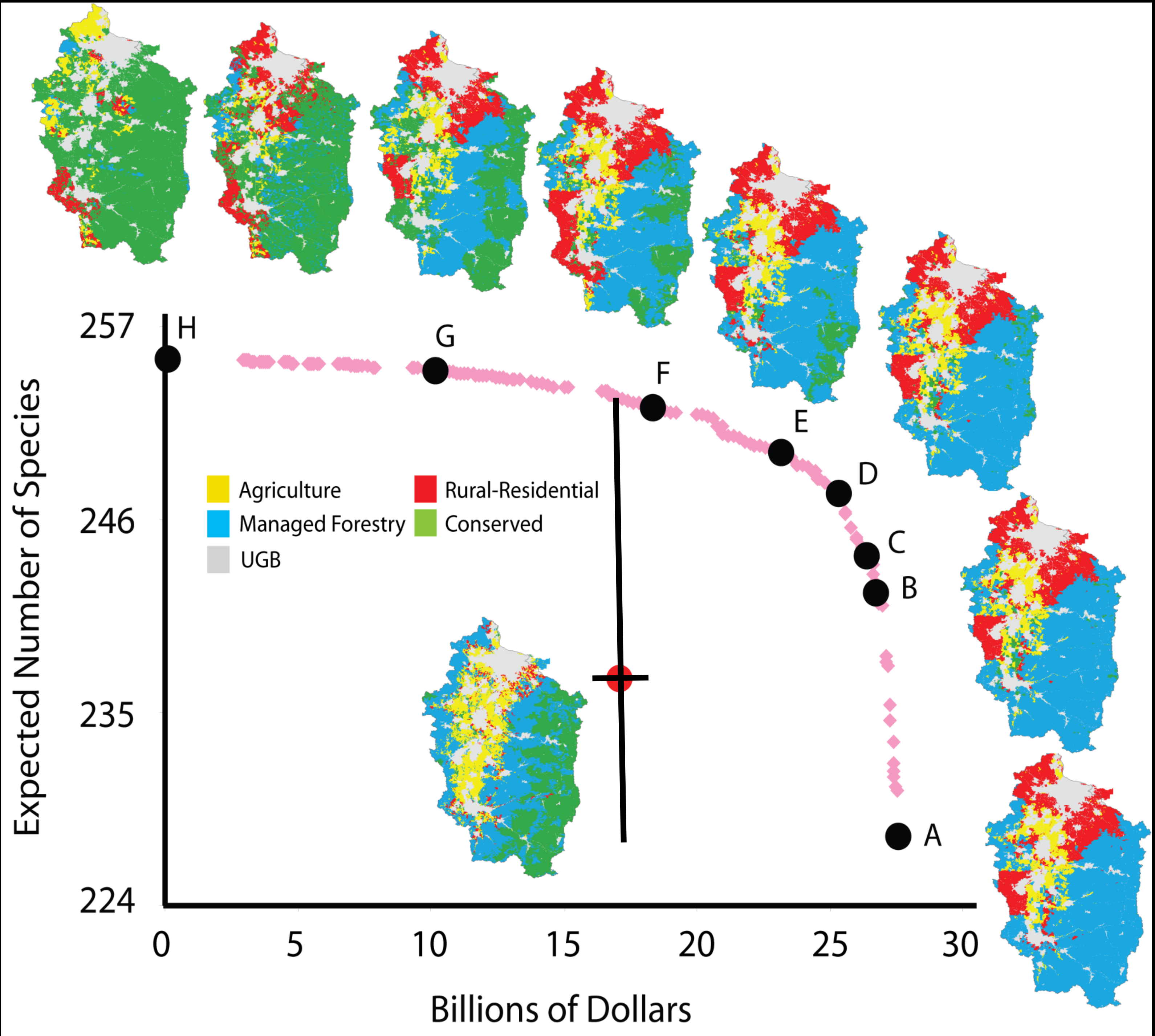
Example efficiency frontier: Willamette Basin, Oregon, US



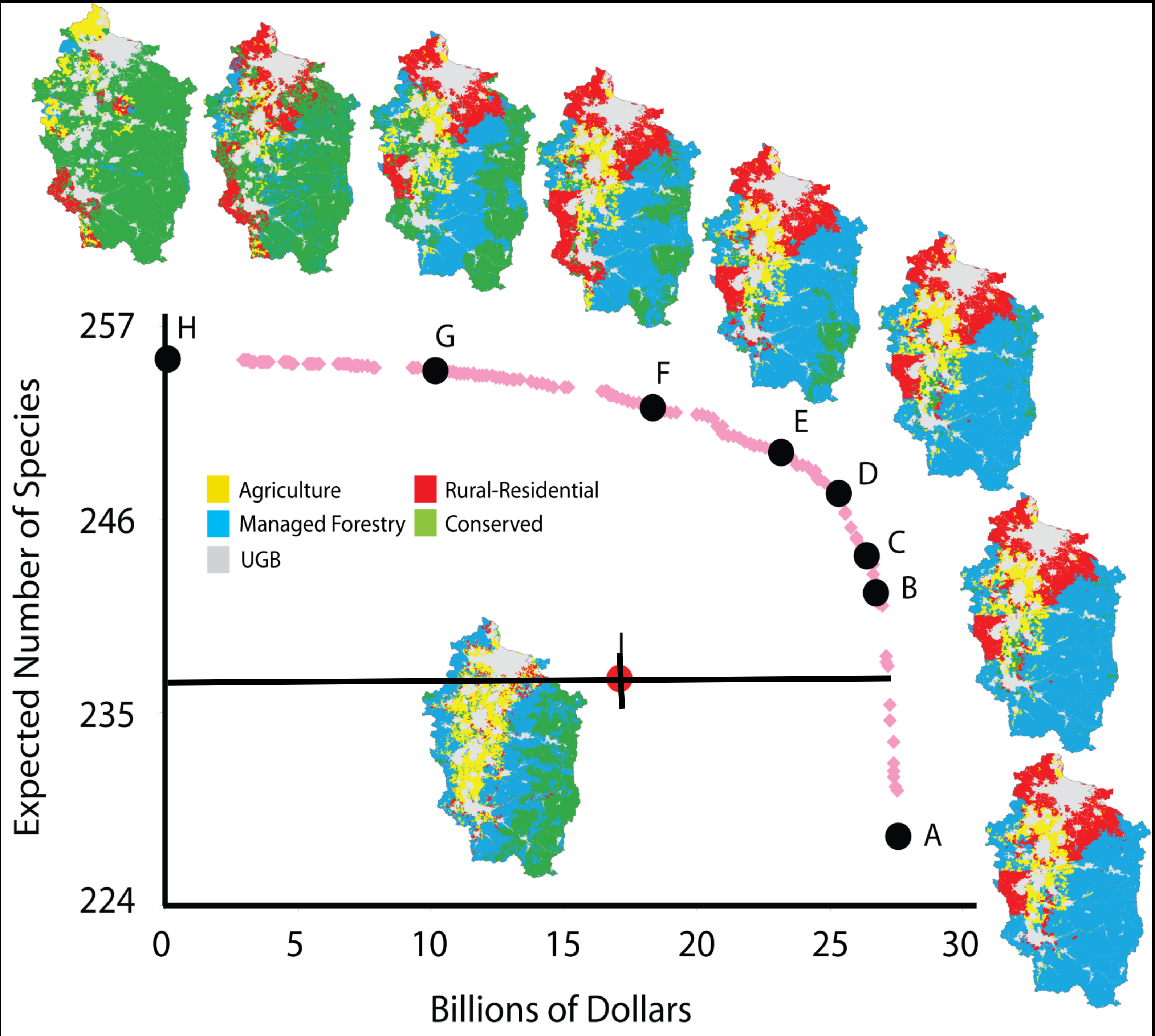
Polasky et al. 2008



Pareto Improving Space



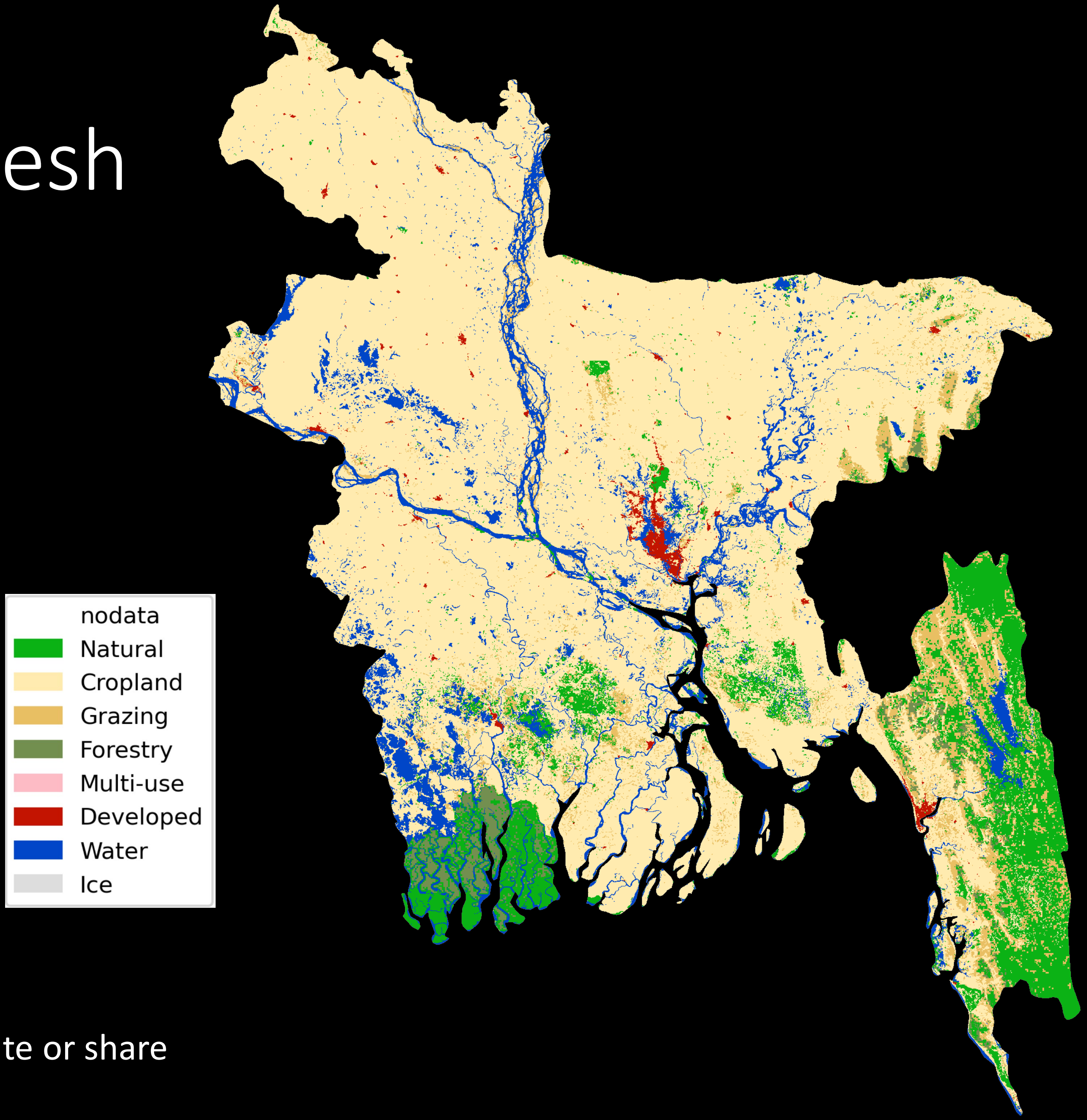
Expected Number of Species
257
246
235
224
0
5
10
15
20
25
30
Billions of Dollars
H
G
F
E
D
C
B
A
Agriculture
Managed Forestry
UGB
Rural-Residential
Conserved



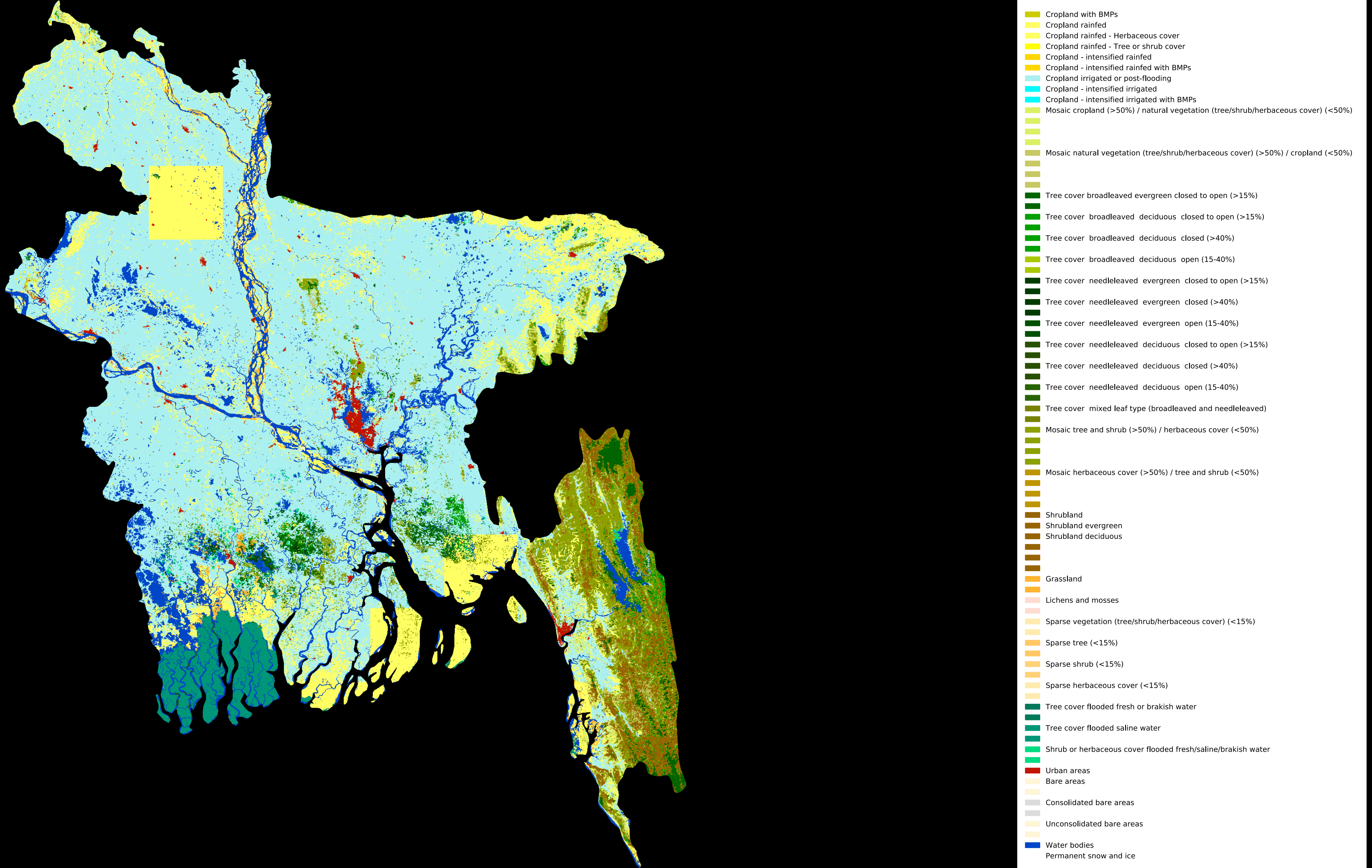
257
246
235
224
Expected Number of Species
H
G
F
E
D
C
B
A
Agriculture
Managed Forestry
UGB
Rural-Residential
Conserved
0
5
10
15
20
25
30
Billions of Dollars

Results for Bangladesh

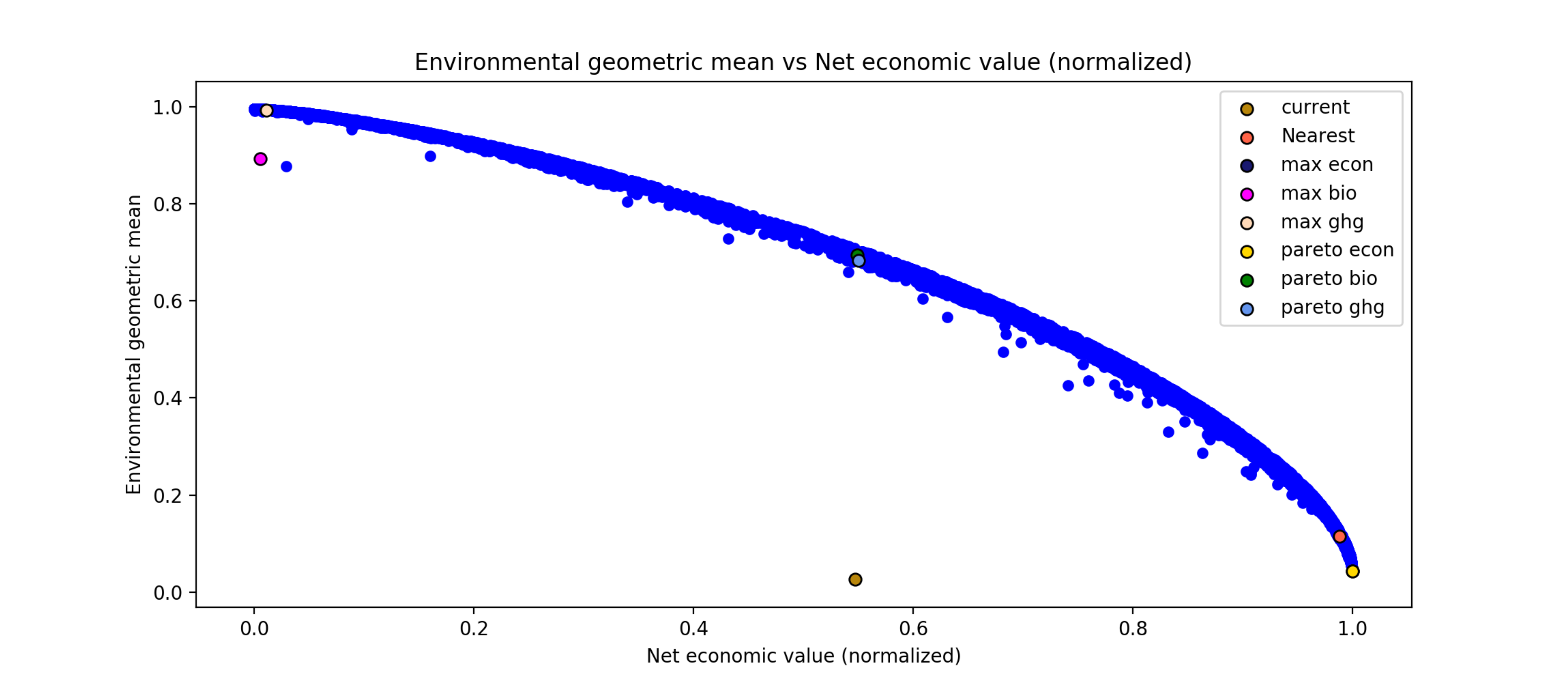
- Current landscape



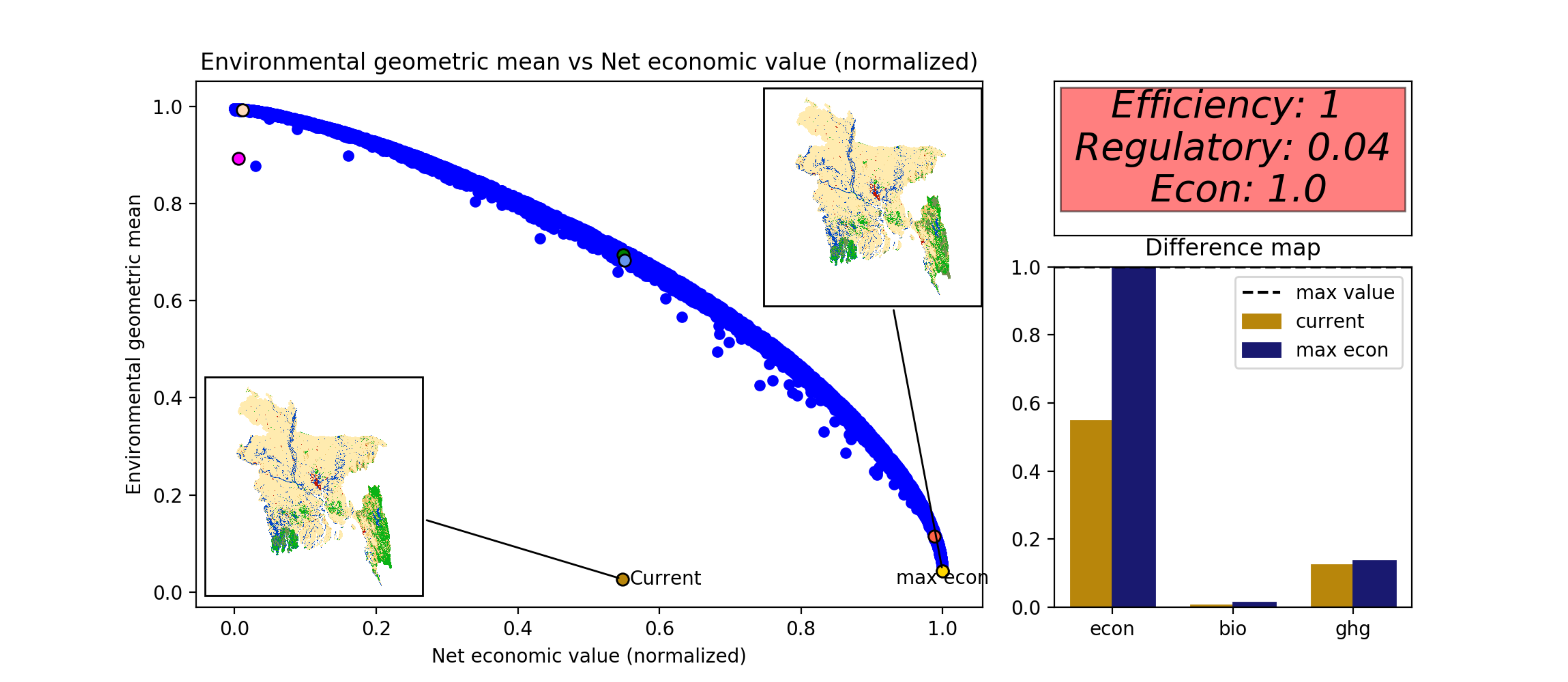
Note: Results are preliminary – do not distribute or share


Cropland with BMPs
Cropland rainfed
Cropland rainfed - Herbaceous cover
Cropland rainfed - Tree or shrub cover
Cropland - intensified rainfed
Cropland - intensified rainfed with BMPs
Cropland irrigated or post-flooding
Cropland - intensified irrigated
Cropland - intensified irrigated with BMPs
Mosaic cropland (>50%) / natural vegetation (tree/shrub/herbaceous cover) (<50%)
Mosaic natural vegetation (tree/shrub/herbaceous cover) (>50%) / cropland (<50%)
Tree cover broadleaved evergreen closed to open (>15%)
Tree cover broadleaved deciduous closed to open (>15%)
Tree cover broadleaved deciduous closed (>40%)
Tree cover broadleaved deciduous open (15-40%)
Tree cover needleleaved evergreen closed to open (>15%)
Tree cover needleleaved evergreen closed (>40%)
Tree cover needleleaved evergreen open (15-40%)
Tree cover needleleaved deciduous closed to open (>15%)
Tree cover needleleaved deciduous closed (>40%)
Tree cover needleleaved deciduous open (15-40%)
Tree cover mixed leaf type (broadleaved and needleleaved)
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
Shrubland
Shrubland evergreen
Shrubland deciduous
Grassland
Lichens and mosses
Sparse vegetation (tree/shrub/herbaceous cover) (<15%)
Sparse tree (<15%)
Sparse shrub (<15%)
Sparse herbaceous cover (<15%)
Tree cover flooded fresh or brakish water
Tree cover flooded saline water
Shrub or herbaceous cover flooded fresh/saline/brakish water
Urban areas
Bare areas
Consolidated bare areas
Unconsolidated bare areas
Water bodies
Permanent snow and ice

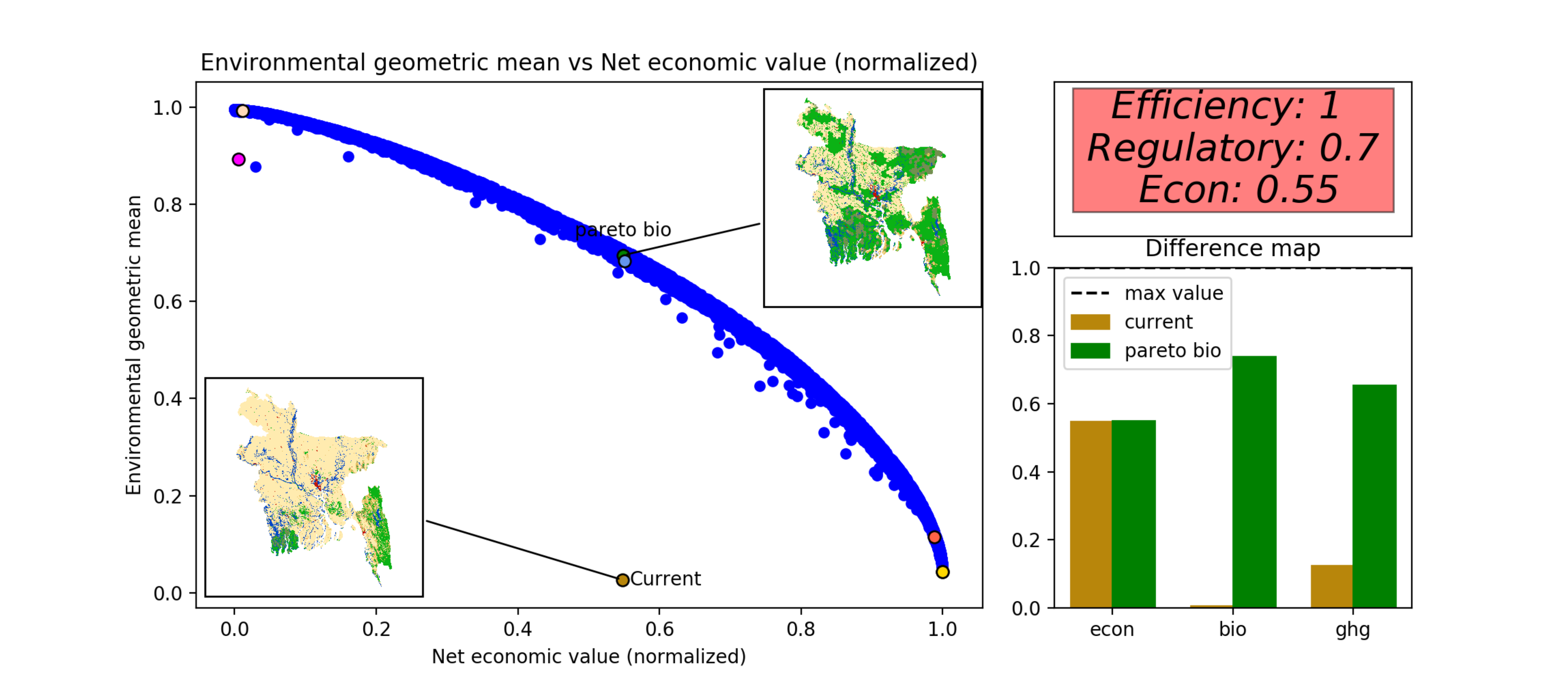
Efficiency frontier



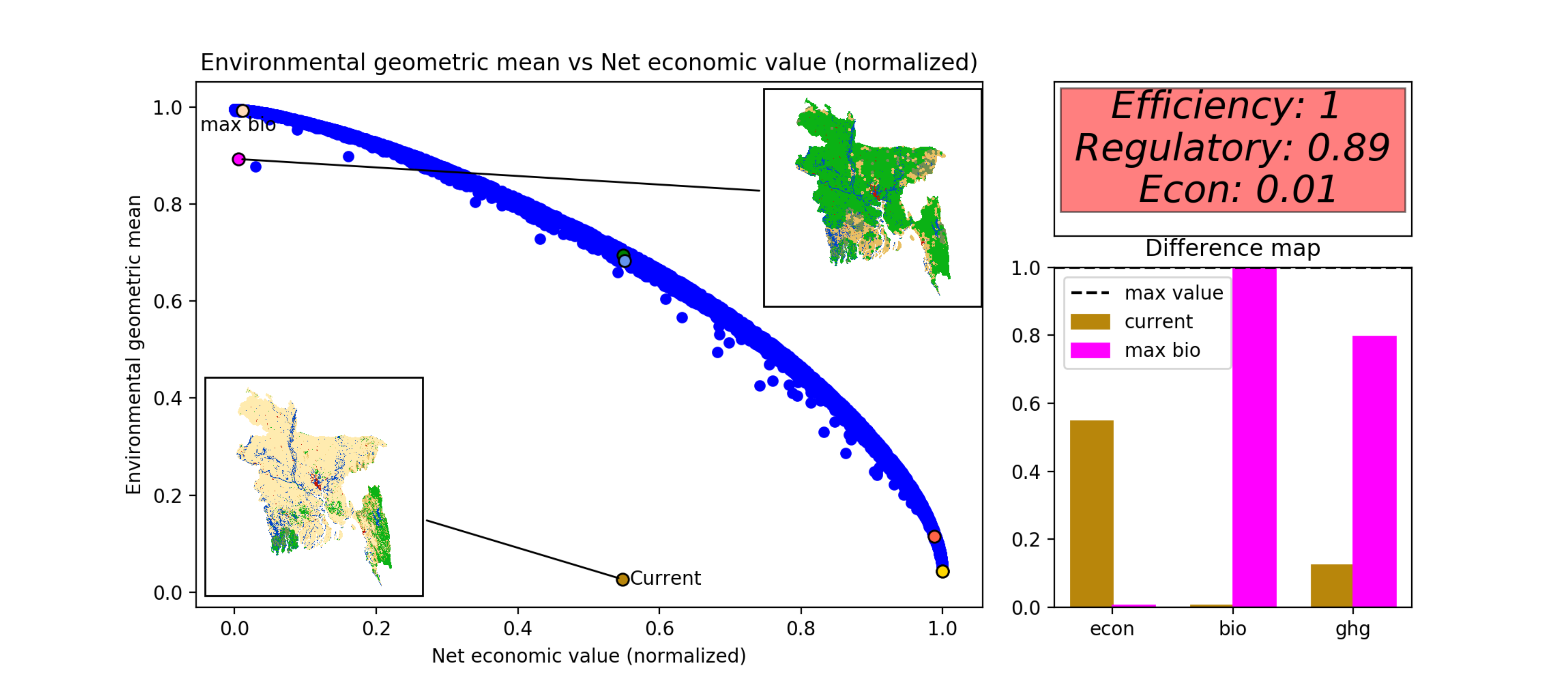
Maximum Net Economic Value



Pareto Maximum Biodiversity



Maximum Biodiversity



Summary

- Calculated ecosystem services, biodiversity flows under current landscape
- Computed an efficiency frontier to show how efficient or inefficient a country is in its use of land and resources
- Currently finishing analysis for all 163 countries > 10,000 sq km recognized by World Bank
- Hope to publicly release analysis and data in 2022

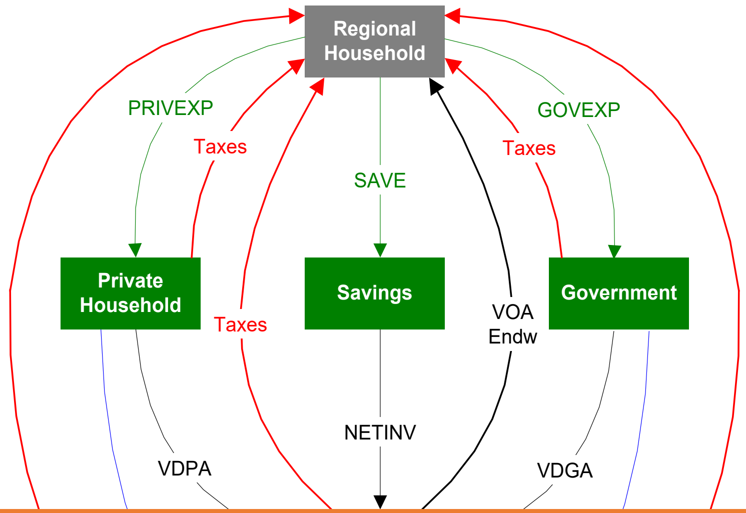
Global Earth-Economy Modeling

A new model linking the Global Trade Analysis Project (GTAP) model with the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) toolkit

Biodiversity and ecosystem services need to inform macroeconomic planning

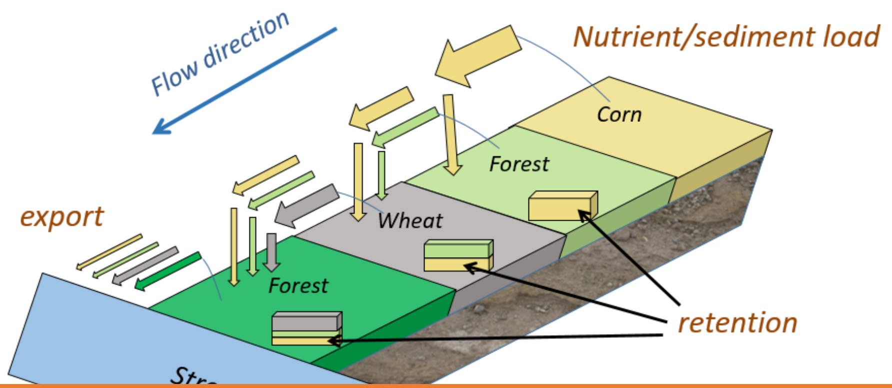
Economic models connect firms, households and governments

e.g., General Equilibrium



Ecosystem models connect natural assets and their services

e.g., Hydrological Routing of Sediment Retention



But they rarely connect to each other…

… and we need to know the **extent to which our economies depend on nature** and **how nature is affected by our decisions**

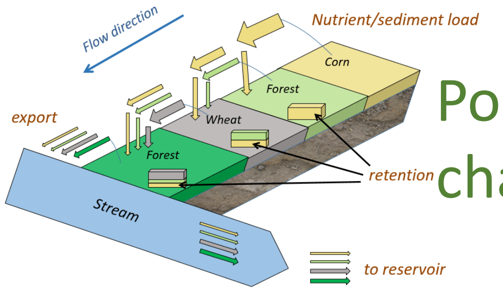
A novel approach: the integrated Global Earth-economy Model in a nutshell

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

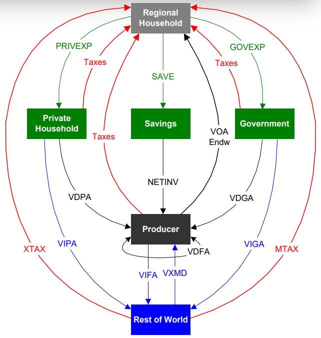
- **GDP**
- **Welfare**
- **Factor use**

Ecosystem Services Model

CGE Economic Model



Policy changes



The Global Earth-Economy Model in a nutshell

Policy changes

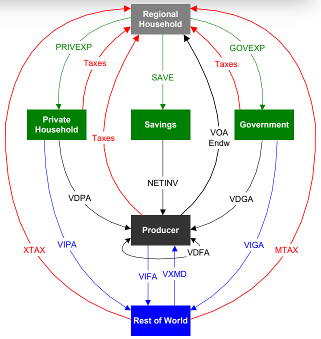
- Fiscal reform
- Expansion of PES
- Intensification of agriculture
- Trade policies

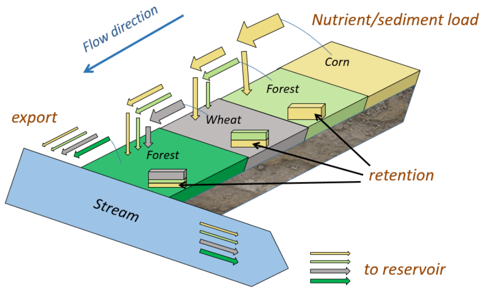
Change in land use

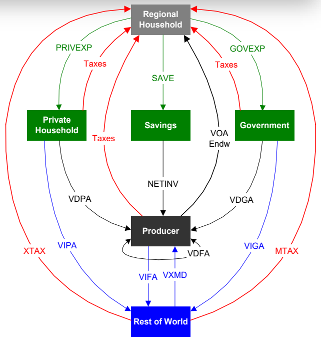
1. *Pollination*
2. *Timber*
3. *Fisheries*
4. *Carbon*

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

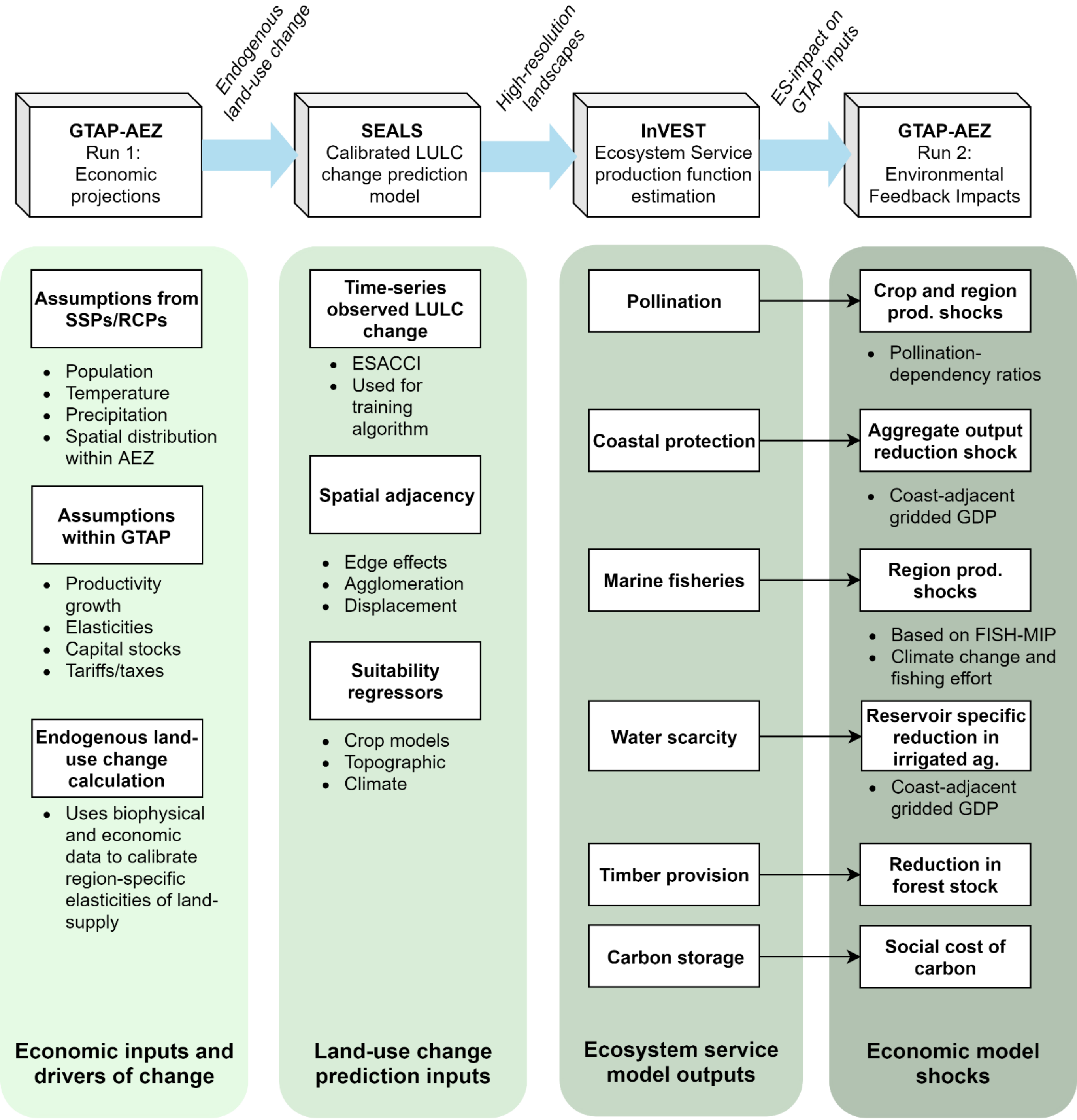
CGE Economic Model (without ES) → Natural Capital → Ecosystem Services Model → CGE Economic Model







Full diagram of model connections



Enabling Condition

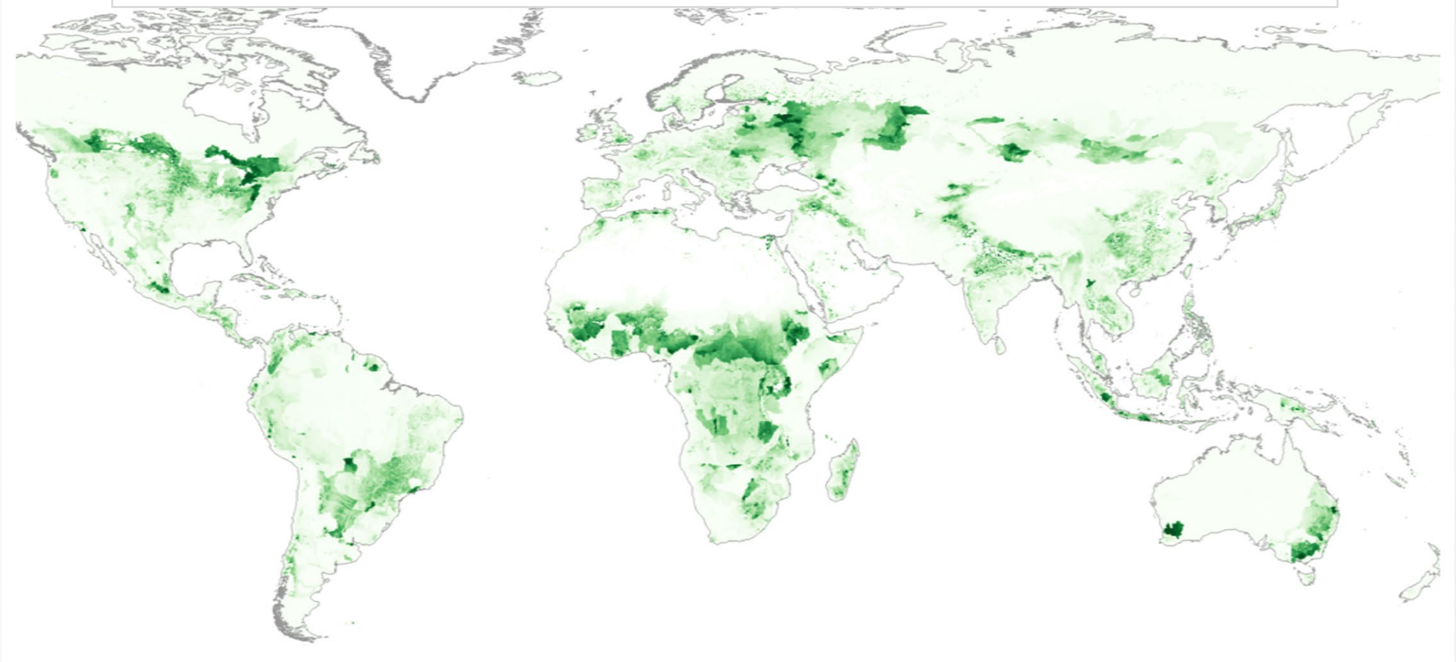
Global InVEST runs for 3 ecosystem services (Chaplin-Kramer et al. 2019, Science)

Ability to calculate high-resolution, global landscape dynamics

Science

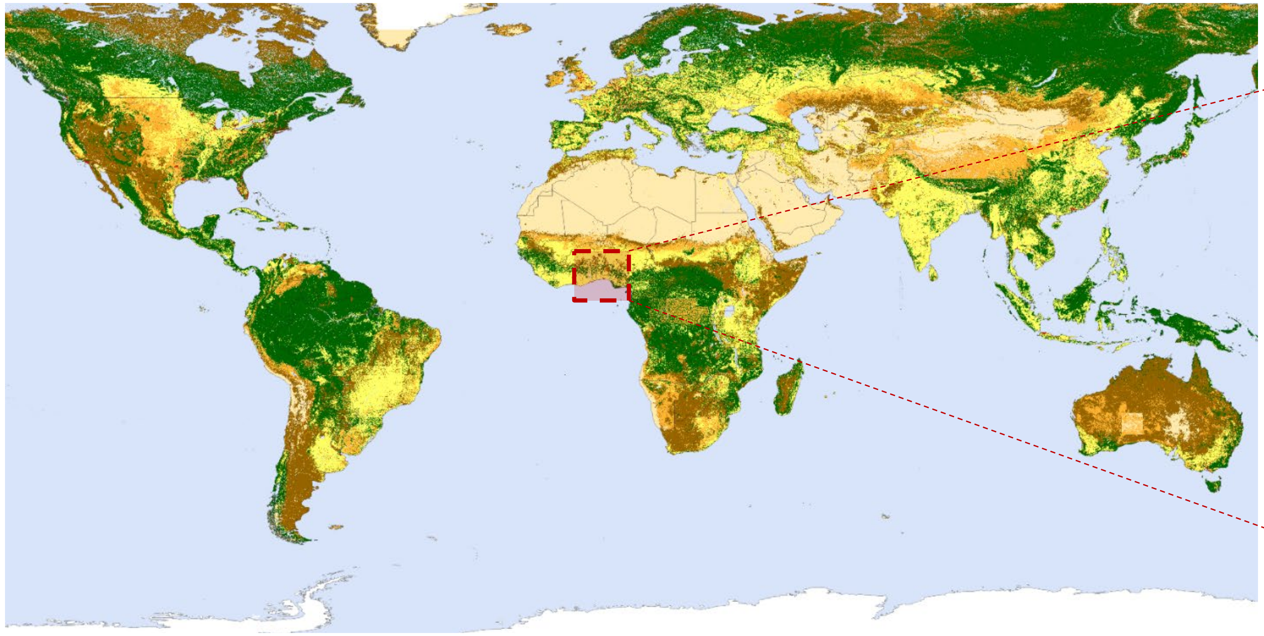
Global modeling of nature's contributions to people

Rebecca Chaplin-Kramer, Richard P. Sharp, Charlotte Weil, Elena M. Bennett, Unai Pascual, Katie K. Arkema, Kate A. Brauman, Benjamin P. Bryant, Anne D. Guerry, Nick M. Haddad, Maike Hamann, Perrine Hamel, Justin A. Johnson, Lisa Mandle, Henrique M. Pereira, Stephen Polasky, Mary Ruckelshaus, M. Rebecca Shaw, Jessica M. Silver, Adrian L. Vogl and Gretchen C. Daily

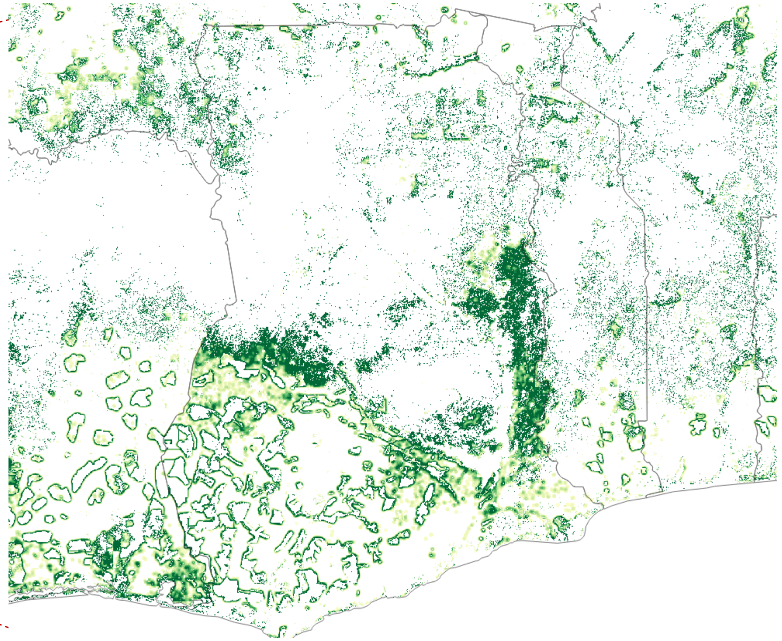


InVEST output	Pollination	Coastal protection	Water yield	Carbon storage		Marine fisheries
GTAP input	Lowered agricultural productivity	Reduced land-capital, productivity losses	Reduced water input to irrigated agriculture	Reduced extraction efficiency of forestry sector	Social cost of carbon	Lowered fisheries productivity

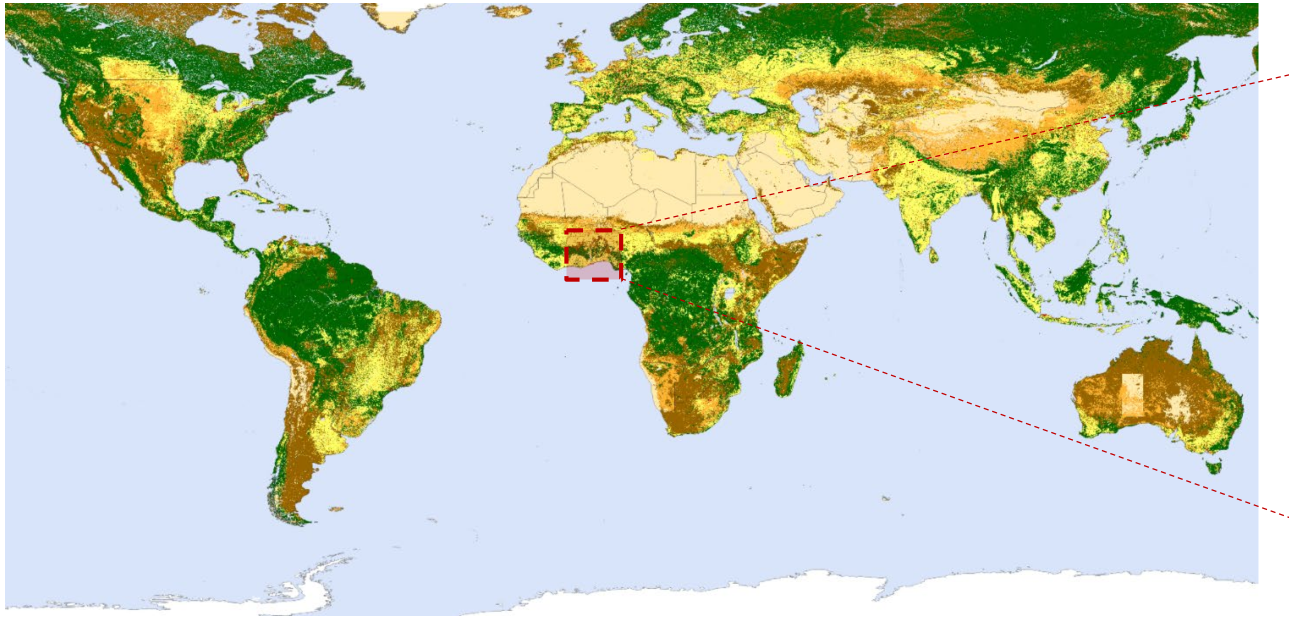
Land Cover Maps (300m) under BAU



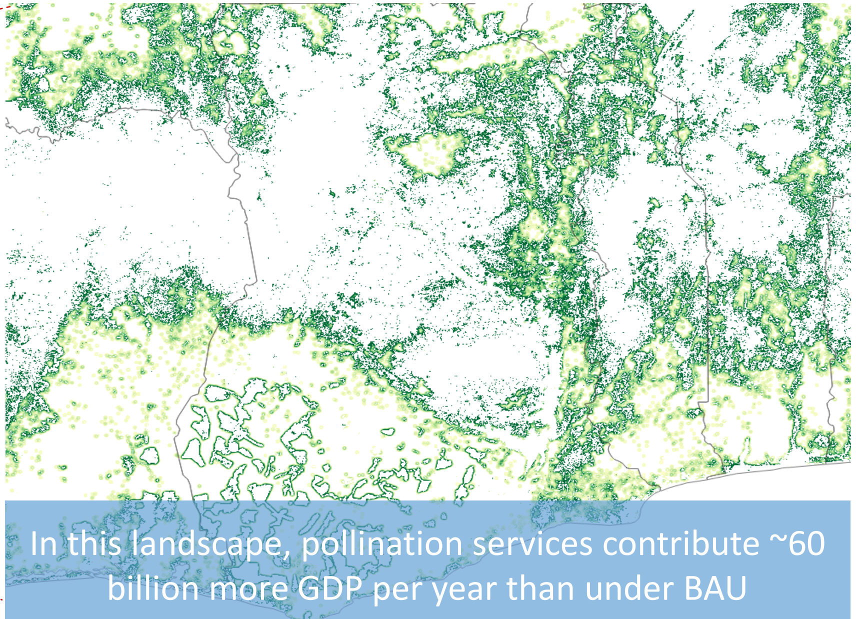
Pollination Service under BAU



Land Cover Maps under Conservation Scenario



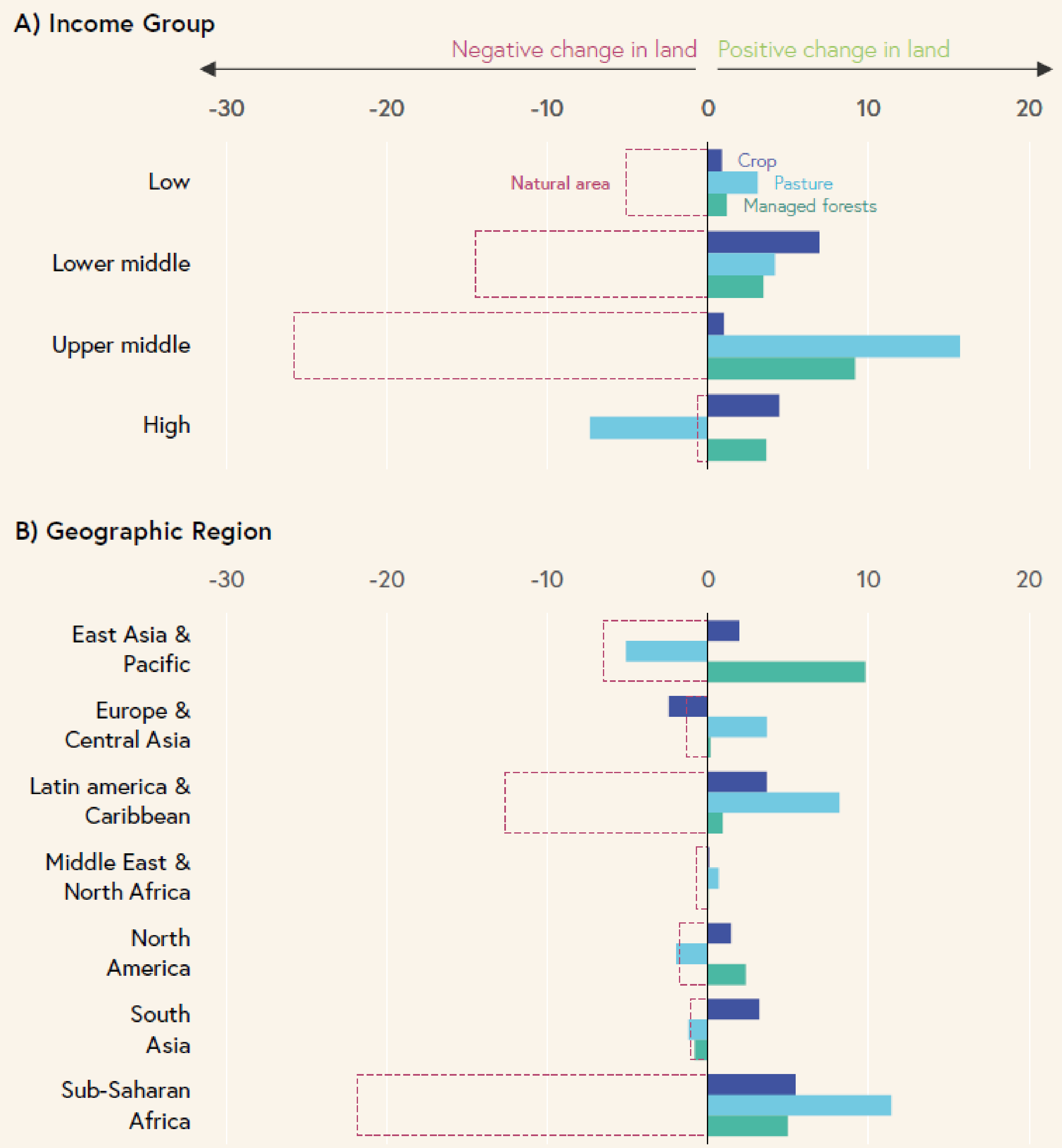
Pollination Service under Conservation Scenario



Results

How much natural land do we lose?

- Expansion of cropland, pasture and managed forests leads to large losses of natural land by 2030 in the BAU scenario.
  - A.) by income group
  - B.) by geographic region

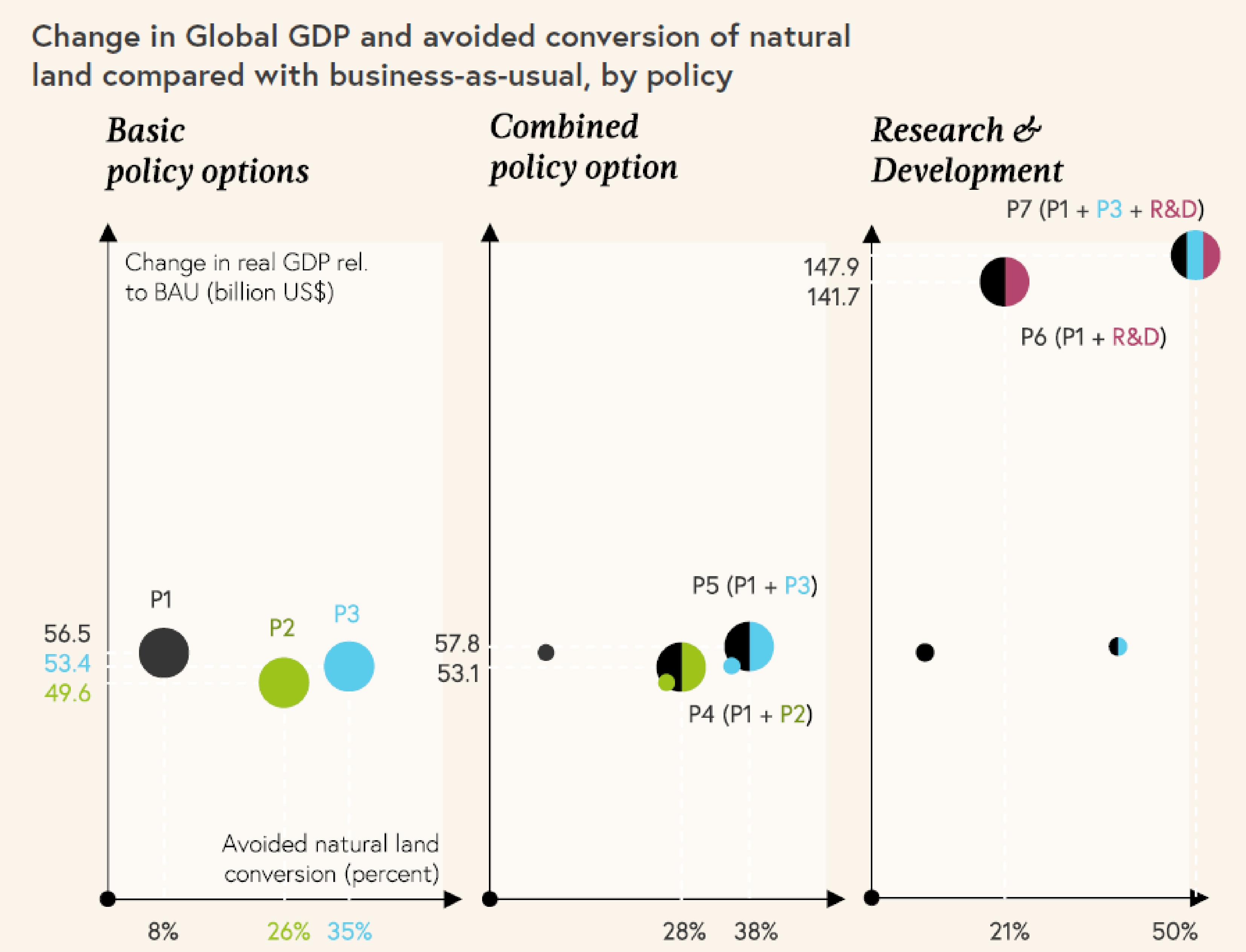


How can nature-smart policies improve this?

With the World Bank, we defined three nature-smart policy "building blocks" to be assessed with GTAP-InVEST

Repurpose Ag. Subsidies	Payments for Ecosystem Services	R&D to increase ag. yield
The first policy type is to repurpose public sector support to economic activities such as agriculture, so that such support is not linked to current or future production volume or value, thus removing incentives to maintain marginal land in production. This is an immediate opportunity for countries looking to realign support to agriculture with sustainable management of biodiversity and ecosystem services.	**The second policy type** is to create incentives for conservation, for example by paying landowners in exchange for the protection of forest carbon sinks. This can be done through domestic or global forest carbon payment schemes. The report looks at each of these modalities in separate policy scenarios.	**The third policy type**, which in the analysis is used in combination with the other two, is to increase public investment in agricultural research and development (R&D) as an incentive to increase output on existing agricultural areas, rather than expanding cultivated areas.

- **Nature-smart policies offer win-wins**, and they can be combined for greater impact



Note: P1: Decoupled Support to Farmers; P2: Domestic Forest-Carbon (FC) payment; P3: Global FC payment; P4: Decoupled Support to Farmers + Domestic FC payment; P5: Decoupled Support to Farmers + Global FC payment; P6: Decoupled Support to Farmers + agricultural R&D; P7: Decoupled Support to Farmers + agricultural R&D + Global FC payment

- Adding in the impacts of Climate change roughly double the benefits of each policy

Economic effects of the policies
(change in 2030 GDP relative to BAU, US$, billions)

	CHANGE IN 2030 GDP COMPARED WITH BAU ($, BILLIONS)	
Scenario	Excluding carbon emission reduction benefits	Adding carbon emission reduction benefits
P1: Decoupled support to farmers	29.4	56.5
P2: Domestic forest carbon payment	24.3	49.6
P3: Global forest carbon payment	19.0	53.4
P4: Decoupled support + Domestic forest carbon payment	26.0	53.1
P5: Decoupled support to farmers + Global forest carbon payment	21.7	57.8
P6: Decoupled support to farmers + R&D	109.1	141.7
P7: Decoupled support to farmers + R&D + Global forest carbon payment	100.7	147.9

Note: BAU = business as usual; GDP = gross domestic product; R&D = research and development.

Summary

- Central role for environmental/resource economists in analysis of sustainable development
- Rapid advances in data and methods – allows analysis to do what was impossible even a few years ago
- Large demand for integrated analysis that uses economics framework: way more than is currently being supplied!

Resources

- The Natural Capital Project (Invest Model)
  https://naturalcapitalproject.stanford.edu/
- Global Trade Analysis Project (GTAP)
  https://www.gtap.agecon.purdue.edu/
- GLASSNET: Global Local Analysis of Systems Sustainability Network
  https://mygeohub.org/groups/glassnet

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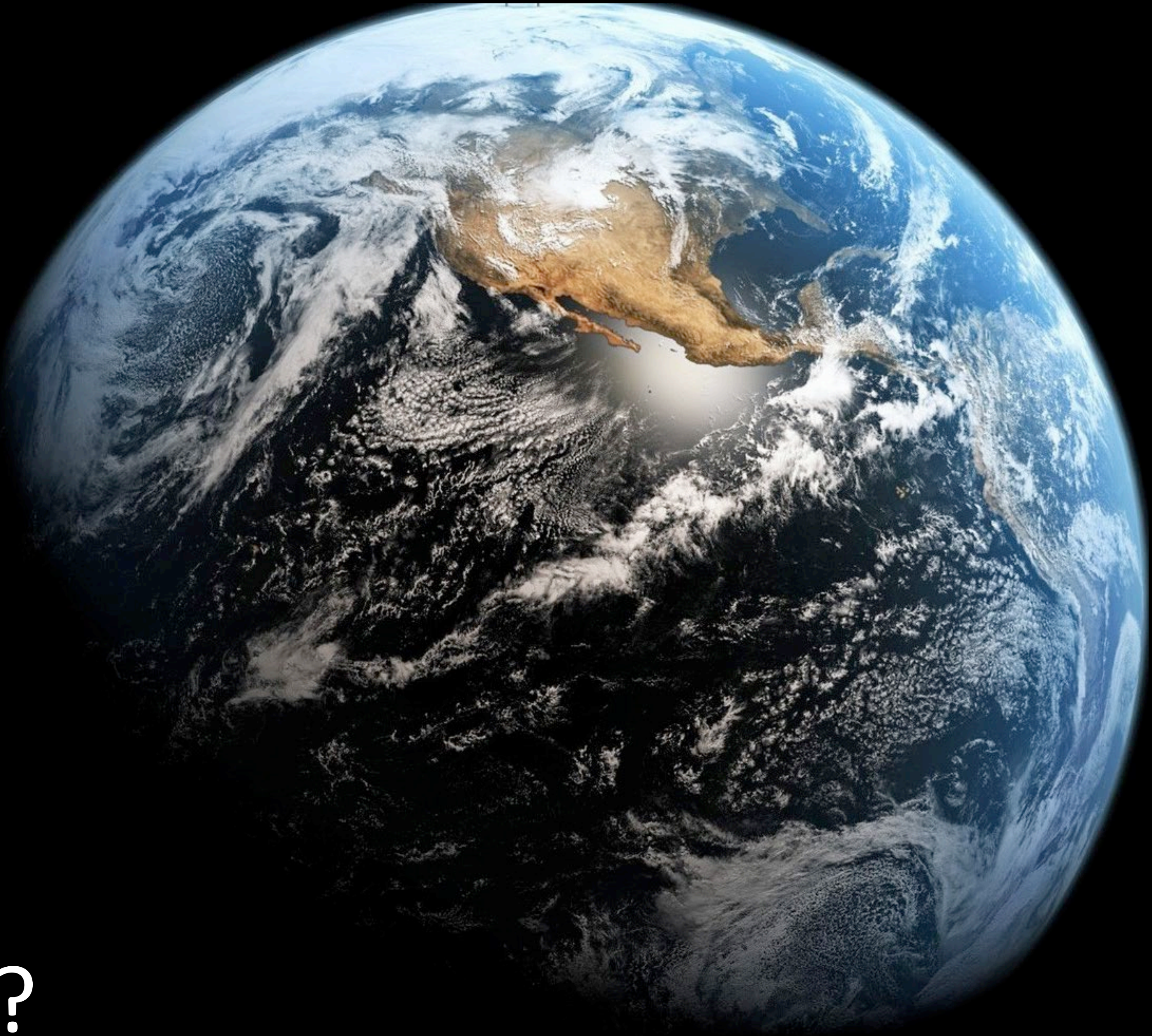
Thank you



Questions?