On the Measurement of Gross Ecosystem Product (GEP) and Inclusive Wealth

Steve Polasky

University of Minnesota

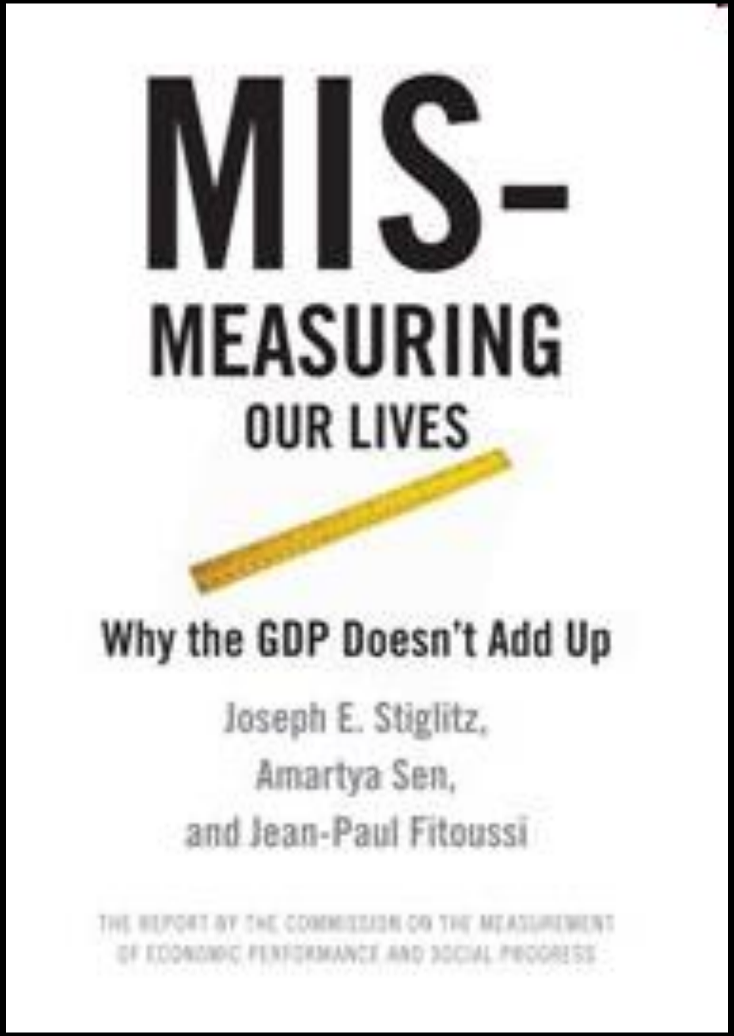
January 22, 2026

List of co-authors (in alphabetical order)

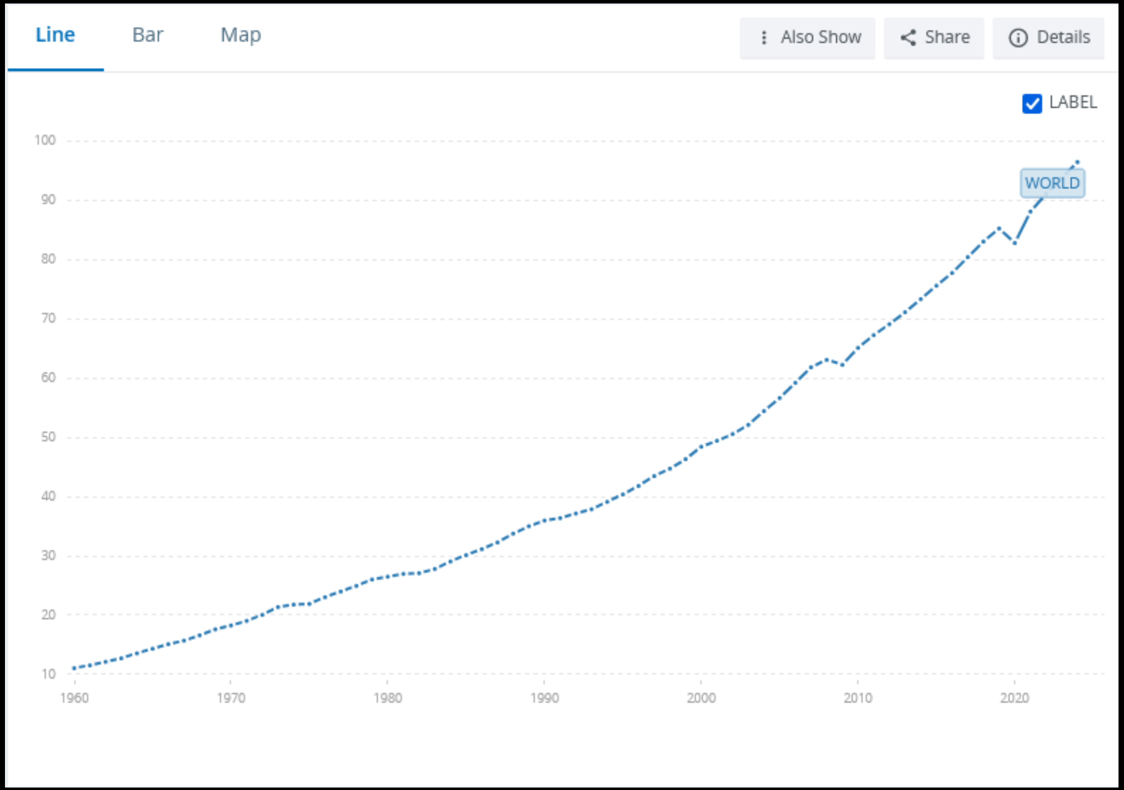
- Philip Adalikwu, Ken Bagstad, Lucie Bakels, Haku Bo, Matt Braaksma, Zhengwu Cai, Adriana Castillo-Castillo, Nfamara Dampha, Chen Gong, Baolong Han, Jacob Harris, William Sidemo Holm, Justin Johnson, Shunkei Kakimoto, Libby Kula, Yingjie Li, Xiaodan Lin, Lingling Liu, Heman Lohano, Yanxu Long, Raahil Madhok, Saleh Mamun, Ryan McWay, Colleen Miller, Natalie Narvaez, Zhiyun Ouyang, Prayash Pathak Chalise, Stephen Polasky, Subin Poudel, Christine Prissel, Sam Reed, Enming Rao, Lifeng Ren, Yinqin Ren, Varun Sethi, Marta Sylla, Liaila Tajibaeva, Sumil Thakar, Lan Wang Erlandsson, Lijing Wang, Spencer Wood, Tong Wu, Yue Xu, Yunong Yao, Yu Zhao

The need for better measures ("beyond GDP")

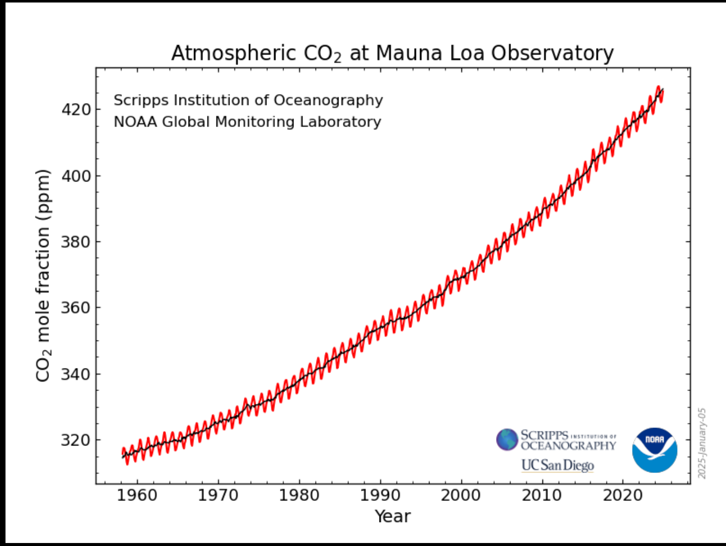
- GDP provides clear and easily understood signal of market-based economic performance
- There is no current widely available summary measure of the contribution of nature to the economy or human well-being
- Without measures (and incentives) we risk further degradation of natural capital and the decline of valuable ecosystem services



The consequences of measuring and providing incentives for GDP growth but not for sustainability

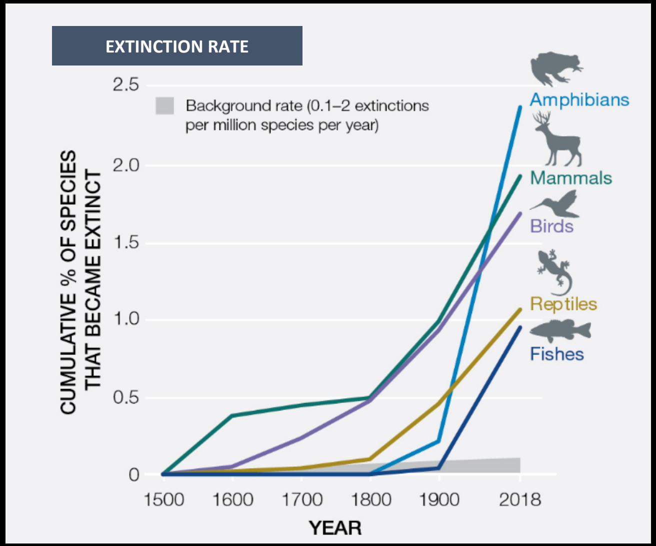


1960 11.07 trillion – 2024 96.49 trillion 2015$
Global GDP 1960-2024 (World Bank)
data.worldbank.org/indicator/NY.GDP.MKTP.KD



https://gml.noaa.gov/ccgg/trends/

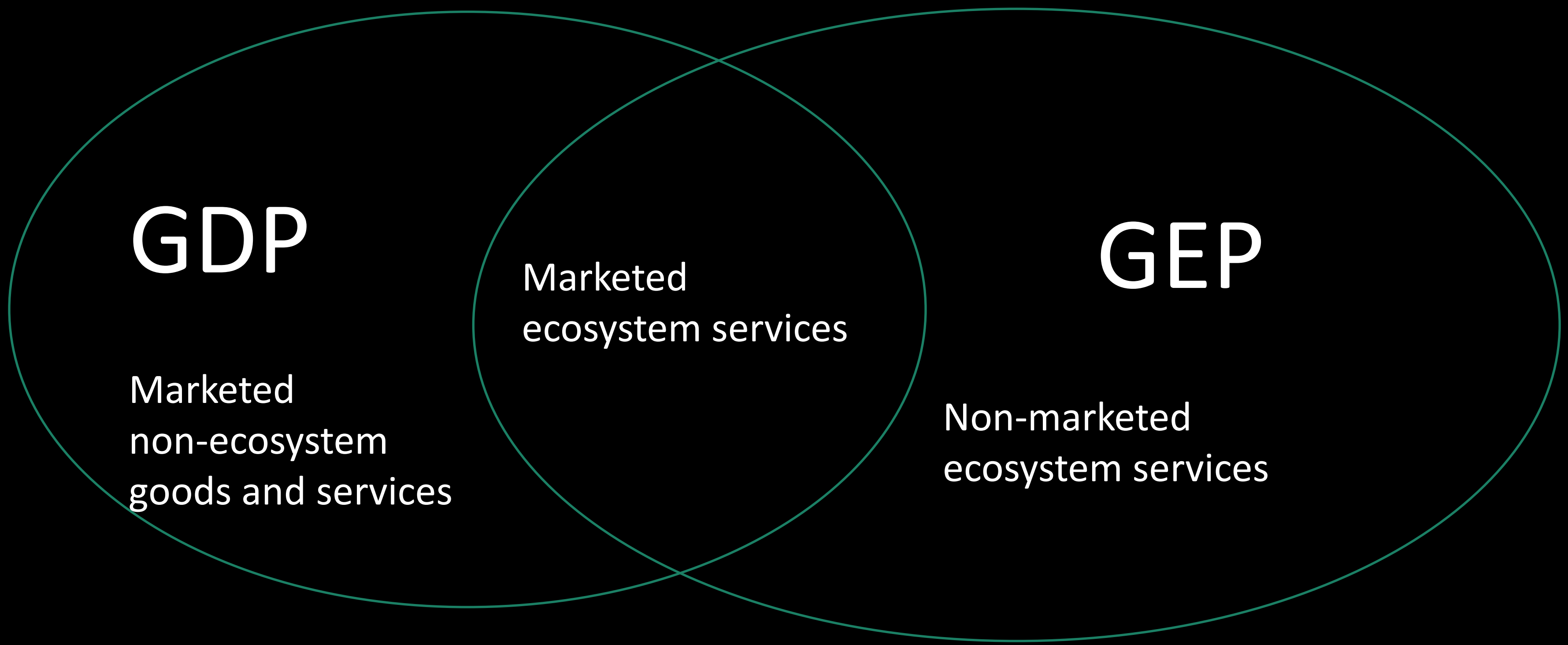
Not all rising trends
are good news



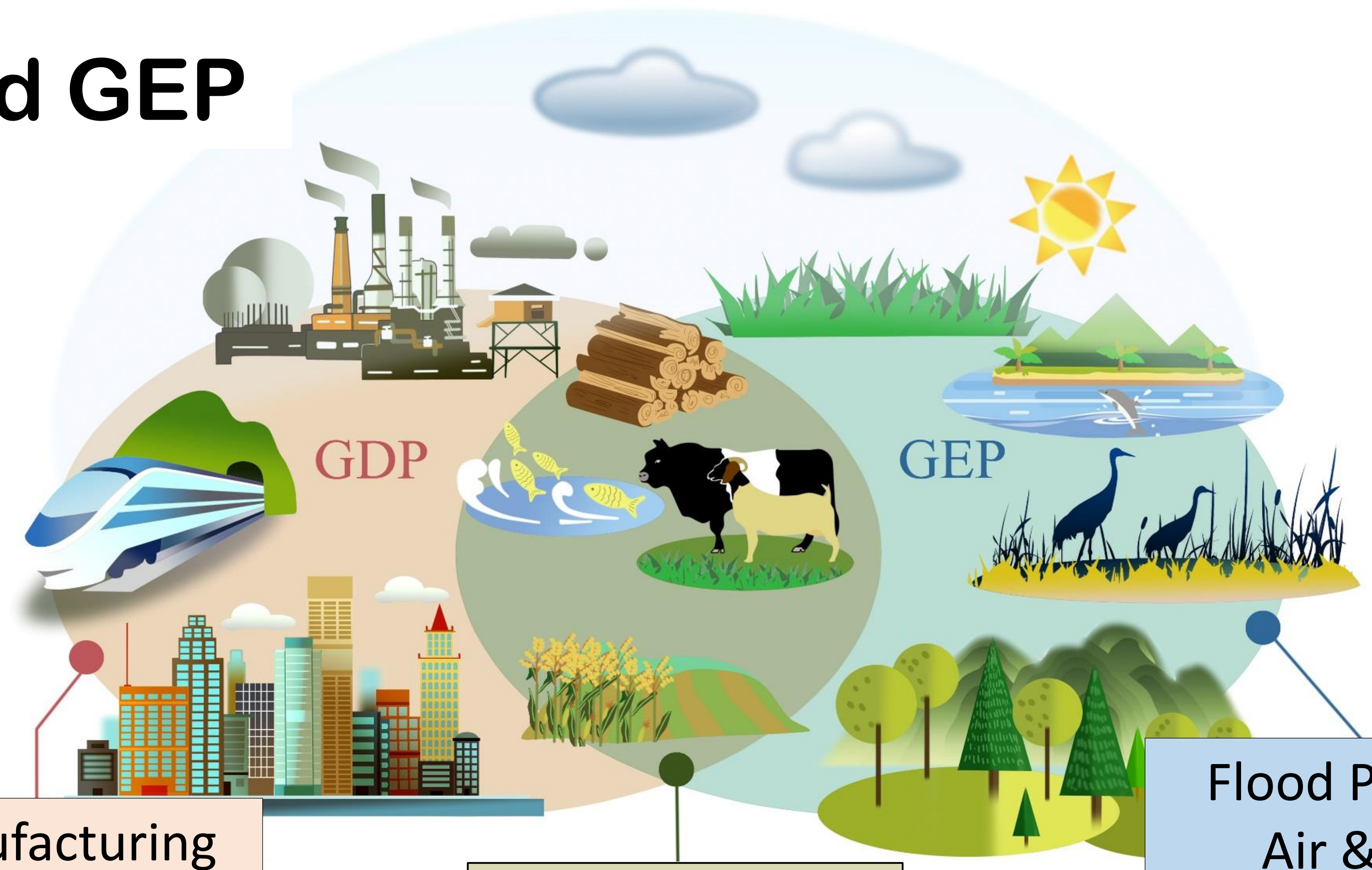
IPBES Global Assessment

Gross Ecosystem Product (GEP)

- GDP: summary statistic that measures the flow of income from marketed goods and services in a region in an accounting period (e.g. measured annually for a country)
- GEP: summary statistic that measures the flow of monetary value from final market and non-market ecosystem goods and services in a region in an accounting period



GDP and GEP



Manufacturing
Construction
Transportation
Communication

Agriculture
Forestry
Tourism

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

(Zheng et al. *Ambio* 2023)

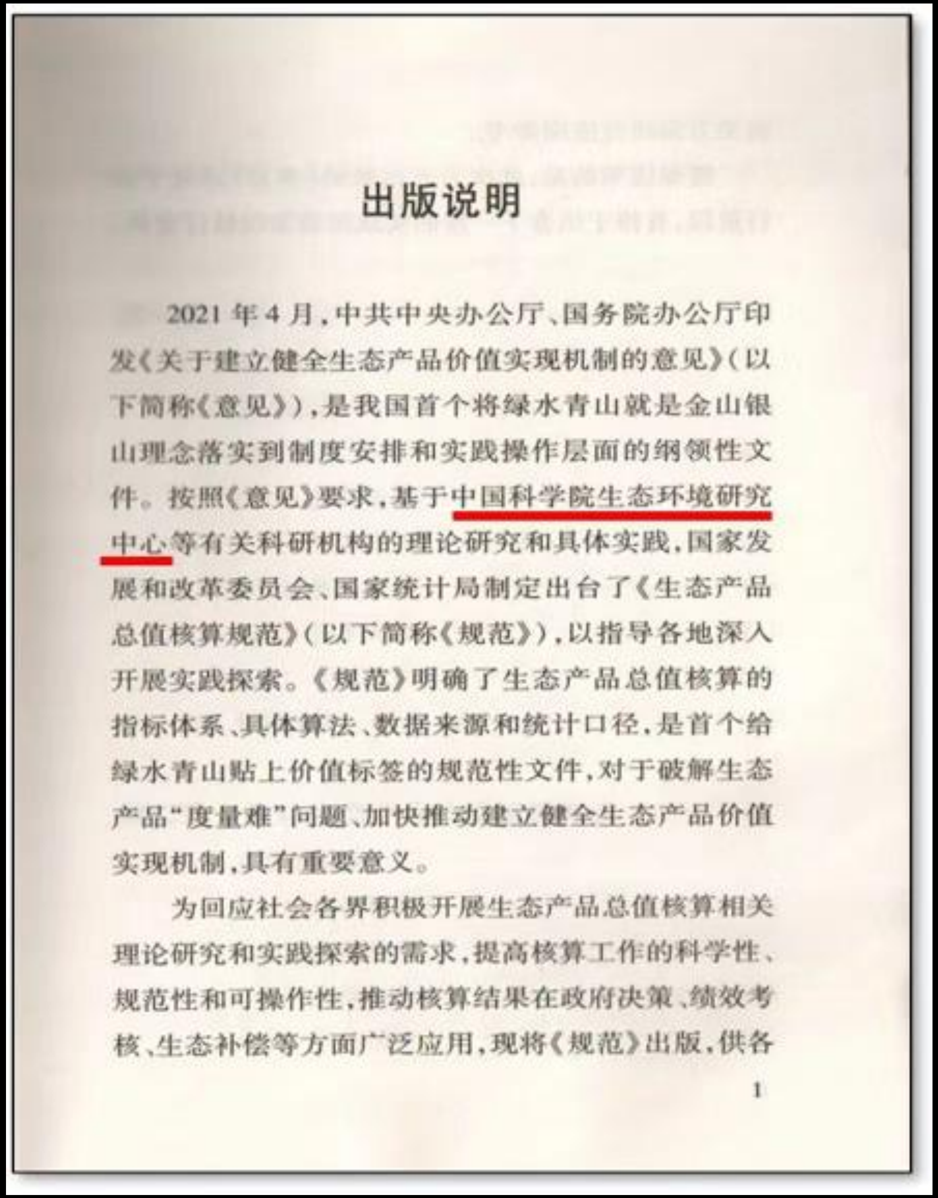
Some prior work on GEP

- Prior work on GEP: almost all prior work on GEP is based in China
- Ouyang, Z.Y., et al. 2013. Gross ecosystem product: Concept, accounting framework and case study." *Acta Ecologica Sinica* 33: 6747–61.
- Ouyang, Z.Y. and L.S. Jin. 2017. *Developing Gross Ecosystem Product and Ecological Asset Accounting for Eco-Compensation*. Science Press.
- 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): 14593–601.
- Zheng, H., T. Wu., Z. Ouyang, S. Polasky, M. Ruckelshuas, L. Wang, Y. Xiao, X. Gao, C. Li, G.C. Daily. 2023. Gross Ecosystem Product (GEP): Quantifying nature for environmental and economic policy innovation. *Ambio* 52 (12): 1952–67.

生态产品总值核算规范

国家发展和改革委员会
国 家 统 计 局

人 民 出 版 社



出版说明

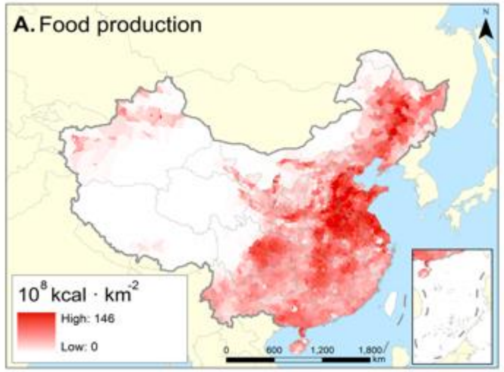
2021年4月，中共中央办公厅、国务院办公厅印发《关于建立健全生态产品价值实现机制的意见》（以下简称《意见》），是我国首个将绿水青山就是金山银山理念落实到制度安排和实践操作层面的纲领性文件。按照《意见》要求，基于中国科学院生态环境研究中心等有关科研机构的理论研究和具体实践，国家发展和改革委员会、国家统计局制定出台了《生态产品总值核算规范》（以下简称《规范》），以指导各地深入开展实践探索。《规范》明确了生态产品总值核算的指标体系、具体算法、数据来源和统计口径，是首个给绿水青山贴上价值标签的规范性文件，对于破解生态产品"度量难"问题、加快推动建立健全生态产品价值实现机制，具有重要意义。

为回应社会各界积极开展生态产品总值核算相关理论研究和实践探索的需求，提高核算工作的科学性、规范性和可操作性，推动核算结果在政府决策、绩效考核、生态补偿等方面广泛应用，现将《规范》出版，供各

1

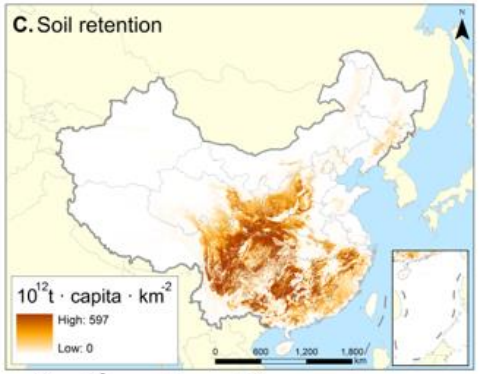
China’s National Development and Reform Commission: Guidelines for calculating GEP

Ouyang et al. 2016. Improvements in ecosystem services from investments in natural capital. *Science* 352: 1455-59

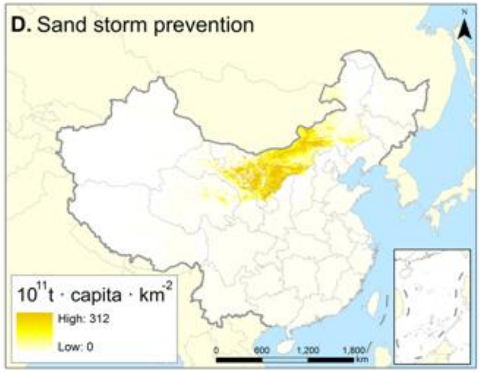


Food production

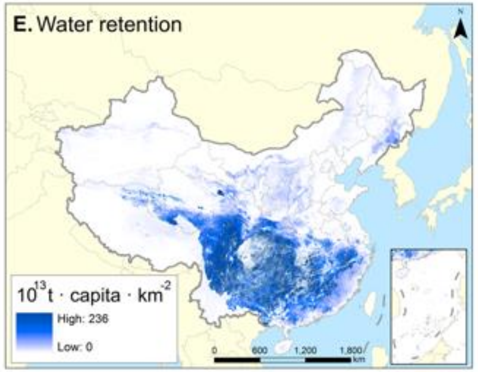
Carbon sequestration



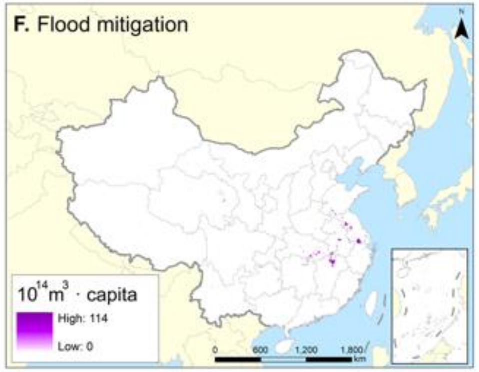
Soil retention



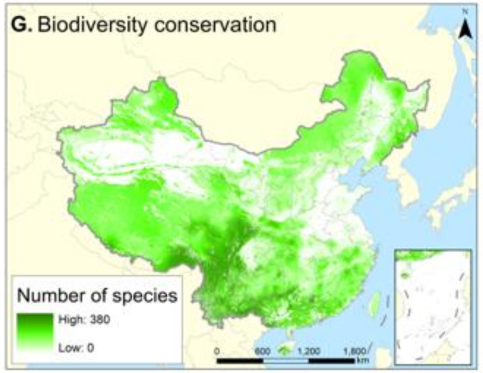
Sand storm prevention



Water retention by forests



Flood mitigation by wetlands



Biodiversity conservation

InVEST

integrated valuation of ecosystem services and tradeoffs

Example: GEP Accounting in Qinghai (2000 – 2015)

Types of services	Category of ecosystem services	Ecosystem service	2000			2015		
			Bio-physical quantity	Monetary value (Billion Yuan)	% of total value	Bio-physical quantity	Monetary value (Billion Yuan)	% of total value
Material services	Production of ecosystem goods	Agricultural crop production ($x10^3$t)	1652.1	1.0	1.2	3091.2	5.6	3.0
		Animal husbandry production ($x10^3$t)	458.7	1.1	1.4	724	5.8	3.1
		Fishery production ($x10^3$t)	1.2	0.01	0.01	10.6	0.3	0.1
		Forestry production ($x10^3m^3$)	1800	0.2	0.2	825	0.7	0.4
		Plant nursery production ($x10^9$)	0.3	0.2	0.2	11	0.7	0.4
		Total		2.5	3.0		13.1	7.1
	Water supply	Water use in downstream agricultural irrigation ($x10^9$ m^3)		11.8	14.5		15.0	8.1
		Water use in households ($x10^9m^3$)		5.3	6.5		13.8	7.4
		Water use in industry ($x10^9m^3$)		19.4	23.8		29.2	15.8
		Hydropower production ($x10^9$ kwh)	21.3	11.3	13.9	92	48.8	26.3
		Total		47.8	58.7		106.7	57.6
Regulating services	Flood mitigation	Flood mitigation ($x10^9m^3$)	0.07	0.02	0.03	0.07	0.03	0.02
	Soil retention and non-point pollution prevention	Retained soil ($x10^9$ t)	0.4	4.8	5.9	0.4	7.0	3.8
		Retained N ($x10^3$ t)	9.8	0.01	0.01	10	0.02	0.01
		Retained P ($x10^3$t)	0.7	0.002	0.002	0.7	0.002	0.001
	Water purification (wetland)	COD purification ($x10^3$ t)	33.2	0.02	0.03	104.3	0.1	0.1
		NH-N purification ($x10^3$ t)	3.5	0.00	0.004	10	0.02	0.01
		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
		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
	Sandstorm prevention	Sand retention ($x10^9$t)	0.3	21.4	26.2	0.5	31.7	17.1
	Carbon sequestration	Carbon sequestration ($x10^9$ t)	0.01	2.0	2.4	0.02	4.7	2.5
		Total		28.3	34.7		43.9	23.7
Non-material services	Eco-tourism	Tourists（$x10^6$ persons）	3.2	3.0	3.7	23.2	21.6	11.7
Grand Total				81.5	100.0		185.4	100.0

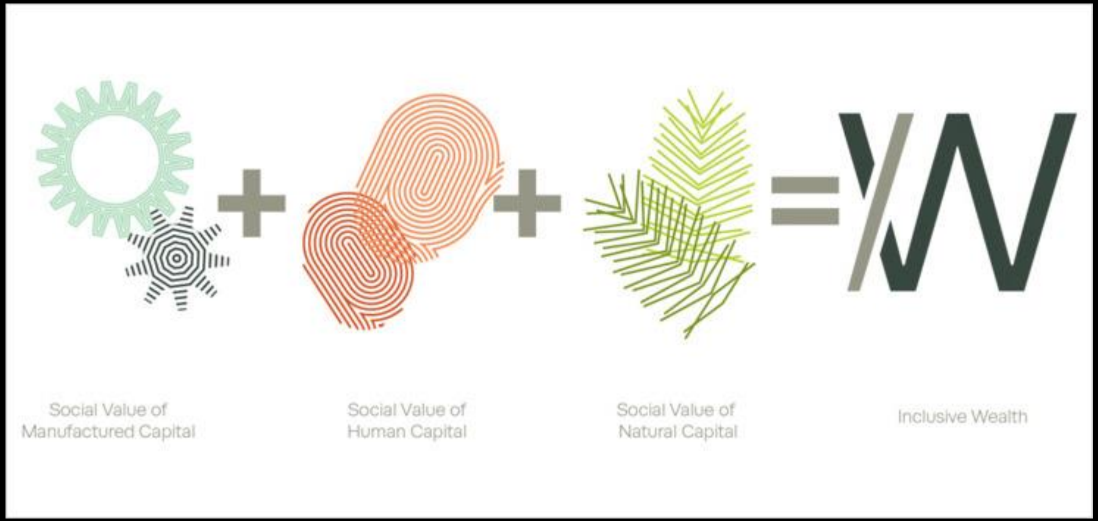
Source: Ouyang et al. 2020

The need for inclusive wealth (“beyond GDP/GEP”)

- Income measures (GDP, GEP) describe current flows that contribute to wellbeing but do not say anything about future wellbeing
- Sustainability (sustainable development) is about current and future wellbeing
- Value of wealth (capital assets) measures capacity for future flows: value of an asset = present value of the flow of benefits it generates

Inclusive wealth defined

- Inclusive wealth: aggregate value of ALL capital assets (human capital, manufactured capital, natural capital, social capital) in a common (monetary) metric



Some prior work on inclusive wealth

- Hartwick. 1990. Natural resources, national accounting and economic depreciation. Journal of Public Economics 43: 291–304.
- Pearce and Atkinson. 1993. Capital theory and the measurement of sustainable development: an indicator of “weak” sustainability. Ecological Economics 8(2): 103–108.
- Hamilton and Clemons. 1999. Genuine saving rates in developing countries. World Bank Economic Review 13: 333–356.
- Dasgupta and Mäler. 2000. Net national product, wealth and social well-being. Environment and Development Economics 5: 69–93.
- Arrow et al. 2004. Are we consuming too much? Journal of Economic Perspectives 18(3): 147-172.

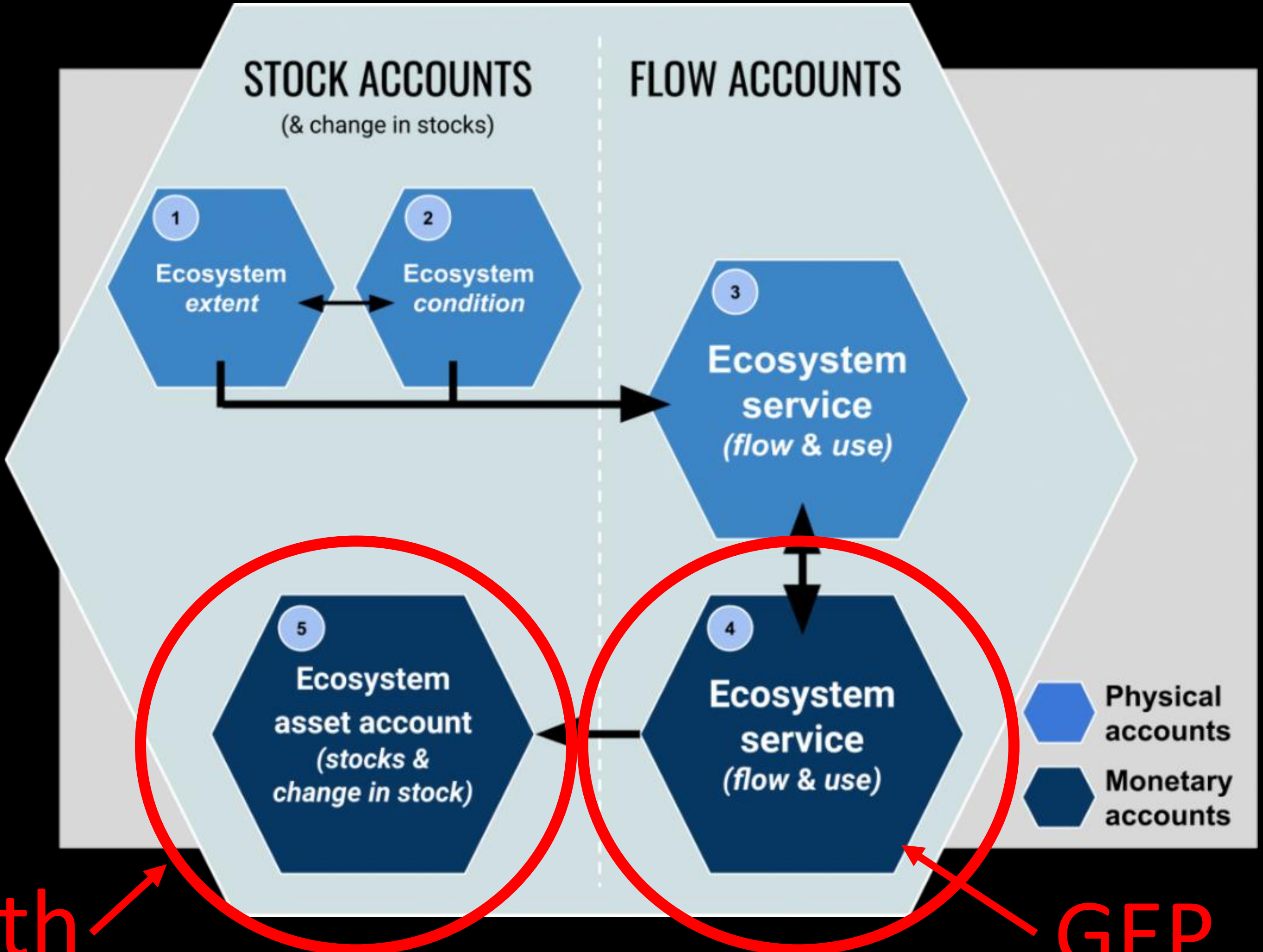
Some prior work on inclusive wealth

- Arrow et al. 2012. Sustainability and the measurement of wealth. Environment and Development Economics 17: 317-353.
- Hamilton and Hartwick. 2014. Wealth and sustainability. Oxford Review of Economics and Policy 30(1): 170–189.
- Polasky et al. 2015. Inclusive wealth as a metric of sustainable development. Annual Reviews of Environment and Resources 40: 445–466
- UN Inclusive Wealth Reports: 2012, 2014, 2018, 2023, 2024.
- World Bank. Changing Wealth of Nations. 2006, 2011, 2018, 2021, 2024.
- Muller et al. 2025. Measuring and accounting for environmental public goods: A national accounts perspective. NBER.

Other related efforts

- Nordhaus and Tobin. 1972. Is growth obsolete? NBER
- Nordhaus, William D., and Edward C. Kokkelenberg. 1999. *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. National Academies Press
- Costanza et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260
  - Toman 1998: "serious underestimate of infinity"
- System of Environmental Economic Accounting (SEEA) – 1993
  - SEEA Central Framework (SEEA CF) 2012
  - SEEA Ecosystem Accounts (SEEA EA) 2021 officially recognized statistical reporting standards
  - GEP mentioned in SEEA EA

Relationship of GEP, inclusive wealth, and SEEA EA (2021)



Inclusive wealth

GEP

https://seea.un.org/ecosystem-accounting

Relationship between inclusive wealth and sustainability

- Present value of flow of well-being:

$$V(K_t) = \int_{\tau=t}^{T} U\,(C_\tau) e^{-\delta(\tau - t)} dt$$

$$\frac{dK_t}{dt} = F(K_t, L_t) - C_t - \beta K_t$$

where K_t is capital stock at time t, C_t is consumption at time t, L_t is labor at time t, δ is the discount rate, β is the depreciation rate of capital

Inclusive wealth and sustainable development

- Non-declining human well-being:

$$d\,V(K_t)/dt \geq 0$$

- Very clear and simple definition of sustainable development

- Note: maintaining capital is essential to maintain ability to produce flows of well-being

Inclusive wealth

- Non-declining present value of well-being is simple rule but not practical
  - Cannot directly observe well-being so cannot directly measure *V*(.)
- Switch to using value of “wealth” rather than present value of well-being
- Advantage of wealth is that we ***may*** be able to observe the value of assets that comprise wealth

Inclusive wealth as a measure of sustainable development

- Non-declining well-being:

$$dV(K_t)/dt \geq 0$$

- Expand this expression:

$$\frac{dV(K_{1t}, K_{2t}, \ldots, K_{Jt})}{dt} = \sum_{j=1}^{J} \frac{\partial V(K_t)}{\partial K_{jt}} \frac{dK_{jt}}{dt}$$

Inclusive wealth as a measure of sustainable development

- $\frac{\partial V(K_t)}{\partial K_{jt}} = p_{jt}(K_t)$
  - Value of capital asset *j* is the contribution of asset *j* to the present value of well-being ("shadow price")

- $\frac{dK_{jt}}{dt} = I_{jt}$
  - Net investment in capital asset *j*
  - Positive if capital asset is increasing
  - Negative if capital asset is decreasing

Inclusive wealth as a measure of sustainable development

- Non-declining well-being:

$$dV(K_t)/dt \geq 0$$

- Is equivalent to:

$$\frac{dV(K_t)}{dt} = \sum_{j=1}^{J} \frac{\partial V(K_t)}{\partial K_{jt}} \frac{dK_{jt}}{dt} = \sum_{j=1}^{J} p_{jt}(K_t) I_{jt} \geq 0$$

Inclusive wealth and sustainable development

- Condition for sustainable development:
  - Non-declining well-being = non-declining inclusive wealth

$$\sum_{j=1}^{J} p_{jt}(K_t) I_{jt} \geq 0$$

- Two components:
  - Shadow price: $p_{jt}(K_t)$
  - Net investment: I_{jt}

Extensions

- Population growth rate: non-declining per capita well-being
- Technological change: total factor productivity growth rate, γ

$$\sum_{j=1}^{J} P_j(K_{jt}) I_{jt} - Pop_t + \gamma \geq 0$$

Measuring inclusive wealth: Arrow et al. (2012)

- Ambitious attempt to measure change in inclusive wealth for five countries (US, China, India, Brazil, Venezuela) from 1995 to 2000
- Natural capital measures: what's in:
  - Value of energy and mineral resources
  - Value of timber stock
  - Value of carbon emissions (negative value) – use "social cost of carbon" estimates
- What's not:
  - No ecological processes
  - No non-market ecosystem services other than carbon sequestration
  - No accounting for resilience, thresholds, or other dynamics (except as capitalized into prices)
- Note: the authors are quite candid about methodological shortcomings and data gaps

Results: components of natural capital (table 1)

Table 1. *Natural capital stocks: quantities, prices and values, 1995–2000 (prices in 2000 US$, stock values in 2000 US$ billions)*

	Oil	*Natural gas*	*Bauxite*	*Copper*	*Iron*	*Gold*	*Lead*	*Nickel*	*Phosphate*	*Zinc*	*Timber*	*Forest benefits*	*Land*	*TOTAL natural capital*
United States														
Capital stock 1995	54.91	10.22		0.10			0.02		4.20		26.105	0.300		
Capital stock 2000	40.28	7.50		0.09			0.02		4.00		26.976	0.302		
Change in stock	−14.63	−2.73		−0.01			0.00		−0.20		0.871	0.002		
Average price	20.21	102		2,231			823		42		129			
Extraction cost	17.73	88		1,513			634		35		30			
Accounting price	2.48	14.55		718			189		7		99	3,149		
1995 stock value	136.15	148.69		70.89			4.23		30.83		2578.18	946.05	1779.70	**5694.73**
Value of change	−36.27	−39.66		−6.29			−0.45		−1.47		86.07	5.74		7.68
China														
Capital stock 1995	27.88	2.48	2.04	0.04	15.39	0.00	0.03	0.01			11.753	0.167		
Capital stock 2000	22.02	2.37	2.00	0.04	15.00	0.00	0.03	0.01			12.450	0.177		
Change in stock	−5.87	−0.12	−0.04	0.00	−0.39	0.00	0.00	0.00			0.698	0.010		
Average price	20.21	102	25	2,231	46	10.9m	823	7,394			61			
Extraction cost	14.18	44	17	989	10	10.7m	696	7,038			19			
Accounting price	6.03	58.28	8	1,242	35	20.7m	126	356			42	2,432		
1995 stock value	168.02	144.67	16.64	49.08	545.9	1.03	4.19	2.90			487.97	406.31	2027.81	**3854.52**
Value of change	−35.36	−6.76	−0.32	−3.14	−13.77	−0.18	−0.40	−0.09			28.96	24.15		−6.90

Results: components of inclusive wealth and change in wealth

Table 2. *Components of comprehensive investment (in 2000 US$ billions)*

	Natural capital	*Human capital*	*Reproducible capital*	*Oil net capital gains*	*Carbon damages*	*TOTAL*
United States						
1995 capital stock	5,694.73	60,086.93	13,430.66			79,212.320
2000 capital stock	5,702.41	64,802.68	15,923.83			84,889.968
Change 1995–2000	7.68	4,715.75	2,493.17	−1,367.38	−171.572	5,677.648
Percentage change	0.13%	7.85%	18.56%			7.17%
Growth rate	0.03%	1.52%	3.46%			1.39%
China						
1995 capital stock	3,854.52	8,492.93	3,706.23			16,053.680
2000 capital stock	3,847.62	9,394.69	6,471.69			19,398.916
Change 1995–2000	−6.90	901.76	2,765.46	−305.80	−9.284	3,345.236
Percentage change	−0.18%	10.62%	74.62%			20.84%
Growth rate	−0.04%	2.04%	11.79%			3.86%

Results: summary measure of inclusive wealth vs. GDP growth

Table 3. *Growth rates (%) of per capita comprehensive wealth, adjusted for technological change*

	(1) Comprehensive wealth growth rate	*(2) Population growth rate*	*(3) Per capita comprehensive wealth growth rate, accounting for population growth [(1) − (2)]*	*(4) TFP growth rate*	*(5) Per capita comprehensive wealth growth rate, accounting for TFP growth [(3) + (4)]*	*(6) Per capita GDP growth rate*
United States	1.39	1.17	0.22	1.48	1.70	2.93
China	3.86	0.94	2.92	2.71	5.63	7.60
Brazil	1.49	1.50	−0.01	0.15	0.14	0.50
India	2.60	1.74	0.86	1.84	2.70	3.99
Venezuela	1.15	1.98	−0.79	−2.12	−2.94	−1.20

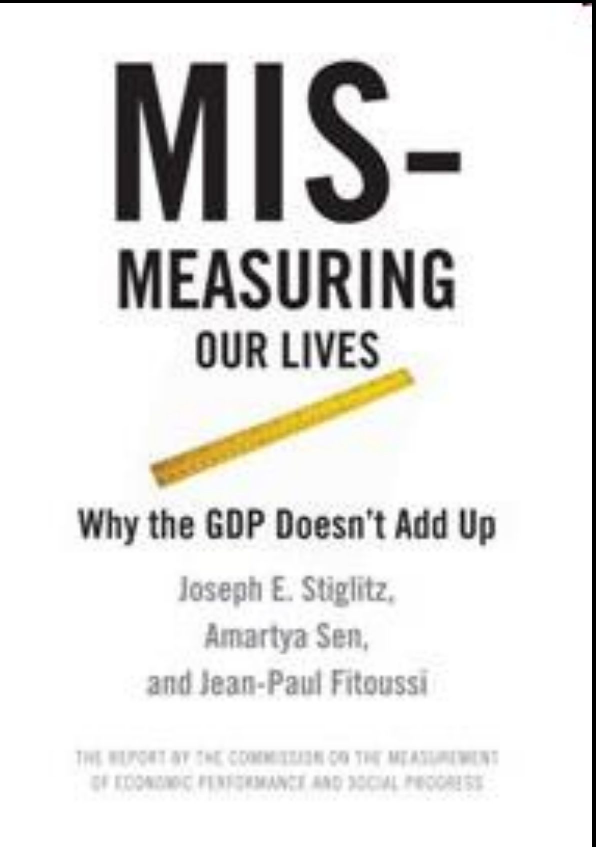
Note: The TFP growth rate reported in column (4) is obtained from Klenow and Rodriquez-Clare (2005).

Summary

- Exercise is informative
- But…
  - Large data gaps
  - Many important elements of capital are not included
  - Requires many assumptions that may not be accurate
- Stark contrast between elegance of theory and limited ability to measure capital stocks and shadow prices

Challenge of measurement

- "How can we measure whether enough of the assets will be left or accumulated for future generations….can we say that we are currently living above our means?
- Is there "reasonable hope of being able to characterize this with one simple number that could play the role for sustainability that GDP has long played for the measurement of economic performance?"



Challenge of measurement

- "…if we want to accomplish this, we need to convert all the stocks of resources passed on to future generations into a common metric, be it monetary or not…such a goal seems overly ambitious. The aggregation of heterogeneous items seems possible up to a point for physical and human capital or some natural resources that are traded on markets. But the task appears much more complicated for most natural assets, due to the lack of relevant market prices and to the many uncertainties concerning the way these natural assets will interact with other dimensions of sustainability in the future." (Mis-measuring our lives, pp. 98-99)

Semi-inclusive wealth

- Rather than attempt to come up with an all-inclusive measure
  - Use market prices to measure value of some capital assets (e.g., Arrow et al., Inclusive Wealth Report)
  - Track important non-market assets separately (biophysical accounts)

- Dashboard analogy

Another approach towards measuring inclusive wealth

- The value of capital assets is equal to the present value of the flow of benefits it generates
- To measure the value of natural capital, let’s value the flow of ecosystem services
- Start by measuring the current value of ecosystem services (GEP)
- Later combine this with predictions of future conditions to predict the future flow of ecosystem services

Data and methods for measuring GEP

Measuring GEP

- Value of ecosystem service *i*:

$$V_i = \lambda_i P_i Q_i$$

λ_i = share of value attributed to nature for service *i*

= P_i is the per unit price (or shadow price determined by non-market valuation) of service *i*

= Q_i is the quantity of service *i*

Ecosystem services with available market value by country (FAO or SNA data)

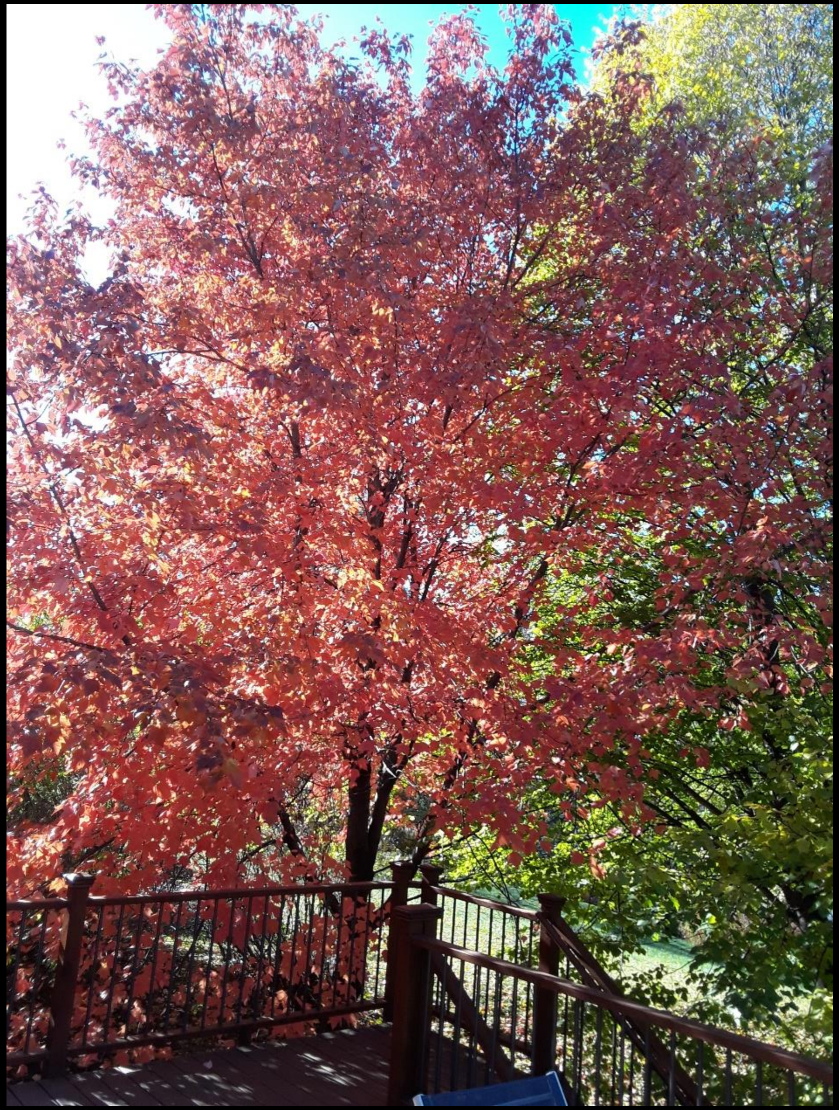
- Some ecosystem services provide marketed commodities with recorded market value (*P***Q*)
    - Agricultural crops
    - Livestock
    - Timber
    - Commercial fisheries
    - Energy (fossil fuels and renewables)
    - Mineral extraction

- For GEP, we then need the share attributable to nature: λ_i
- Input shares: deduct labor and human-made inputs to get input value from nature

Photo credits: Croplands Research Group (top)
National Geographic (bottom)

Non-market ecosystem services

- Virtually all regulatory and non-material services lack market price and quantity data
- Several approaches for calculating price and quantity
- Note: λ_i is equal to 1 in most cases



Calculating prices and quantities

- Use Natural Capital Project InVEST models or other models to calculate biophysical quantity
  - Pollination (change in quantity/quality of crops due to pollination)
  - Air pollution (emissions/filtration to exposure to health outcomes)
  - Carbon (tons of carbon stored)

- Use literature values for price
  - Pollination: crop price
  - Air pollution (health): value of statistical life
  - Carbon storage: annual rental price based on the social cost of carbon

Photo credit: Pixabay

Calculating prices and quantities

- Use literature (meta-analysis) for quantity
  - Access to nature and mental health (reduced depression, anxiety)
  - Access to nature and physical health
- Use literature values for price
  - Mental health: estimates of value of reduced depression, anxiety
  - Physical health: value of reduced disease, value of statistical life

Photo credit: Minneapolis Parks Foundation

Example: Air filtration

- Overview: causal pathway from nature to mortality outcomes: Emissions and deposition to effects on air quality, to exposure, to health outcomes
- Land use-related emissions that lead to $PM_{2.5}$ formation: soil NO_x, biogenic VOC, windblown $PM_{2.5}$ dust, and biomass burning
- Filtration: dry pollutant deposition on vegetation

Photo Credit: Nithya sai.c, Wikimedia Commons

Example: Air filtration

- Emissions and air pollution modeling: Global InMAP model
- Avoided health impacts by simulating the changes in $PM_{2.5}$ concentrations that would have occurred with and without nature
- Air pollution to health: Global Exposure Mortality Model
- Valuation: value of statistical life year by country: US Value of statistical life modified by income ratio, age distribution of population

Photo Credit: Nithya sai.c, Wikimedia Commons

Aggregating services for 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

Ecosystem services included: biotic and abiotic

Regulating ecosystem services	Material ecosystem services	Non-material ecosystem services
Global climate regulation (terrestrial, coastal, and marine carbon storage)	Agricultural crop provision (commercial and subsistence)	Recreation and tourism
Regional climate regulation (rainfall pattern regulation)	Livestock provision	Physical health benefits from nature exposure (hypertension reduction)
Local climate regulation (urban cooling)	Fish provision (commercial and subsistence)	Mental health benefits from nature exposure
Air filtration	Timber provision	
Erosion control	Fuelwood	
Landslide mitigation	Non-timber forest products provision	
Storm mitigation (sand and dust control)	Water supply	
Water filtration (nutrient retention)	Solar energy provision	
Groundwater recharge	Wind energy provision	
Coastal protection	Geothermal energy provision	
River flood mitigation	Hydropower provision	
Pollination	Fossil fuel provision (oil and natural gas)	
Pest control	Fossil fuel provision (coal)	
	Mineral extraction	

Accounting for double counting in GEP

Regulating ecosystem services	Material ecosystem services	Non-material ecosystem services
Global climate regulation (terrestrial, coastal, and marine carbon storage)	Agricultural crop provision (commercial and subsistence)	Recreation and tourism
Regional climate regulation (rainfall pattern regulation)	Livestock provision	Physical health benefits from nature exposure (hypertension reduction)
Local climate regulation (urban cooling)	Fish provision (commercial and subsistence)	Mental health benefits from nature exposure
Air filtration	Timber provision	
Erosion control	Fuelwood	
Landslide mitigation	Non-timber forest products provision	
Storm mitigation (sand and dust control)	Water supply (for agriculture)	
Water filtration (nutrient retention)	Solar energy provision	
Groundwater recharge	Wind energy provision	
Coastal protection	Geothermal energy provision	
River flood mitigation	Hydropower provision	
Pollination	Fossil fuel provision (oil and natural gas)	
Pest control	Fossil fuel provision (coal)	

Ecosystem service categories in SEEA not (yet) included in GEP

Ecosystem service
Genetic material (bioprospecting)
Solid waste remediation
Water purification (other pollutants besides nutrients)
Noise attenuation
Disease control
Nursery populations and habitat maintenance
Visual amenity
Education, scientific and research services
Spiritual, artistic, and symbolic services
Ecosystem and species appreciation

Conversion to 2019 USD

- Convert values for each ecosystem service and country from current values to 2019 constant values in national currencies using the World Bank GDP deflator
- Convert 2019 monetary units to 2019 international dollars using World Bank Purchasing Power Parity (PPP)-adjusted exchange rates

Partial Results: GEP by country 2019

Results

- Report results for three services (two regulating services and one material service)
  - Air filtration
  - Carbon storage
  - Hydropower production
- Other services still in the process of “sanity checking”
  - Reviewing all methods and data
  - Cross checking with other studies where possible
  - Expert review

Results for selected countries (top 5 in one of these services)

Country	Annual rental value of carbon storage (million USD 2019)	Air filtration (million USD 2019)	Hydropower production (million USD 2019)
Brazil	812,960	384	51,281
Canada	346,691	107	33,154
China	176,974	3,268	81,119
Democratic Republic of Congo	263,330	11	-
France	24,547	1,029	4,148
Germany	18,413	2,012	3,757
India	64,833	1,007	6,430
Japan	21,313	228	12,767
Russia	670,663	412	-
United States	352,743	1,418	20,785
Global total	5,365,469	17,809	287,732

Results

- Values are significant
  - \$5.4 trillion for annual rental value of terrestrial and coastal carbon storage
  - \$17.8 billion for air filtration
  - \$288 billion for hydropower* (partial coverage, and assuming $\lambda = 1$)
- Values are highly significant in some countries
  - Democratic Republic of Congo: in 2019, annual rental value of carbon storage \$263 billion; GDP \$37 billion

Discussion

- Provide first estimate of GEP broadly done – across countries, across multiple ecosystem services
- Provide tangible evidence of the value of nature in economic terms
- Development of standardized methods and use of globally available data for GEP accounting
  - Demonstrate that it is possible to calculate GEP with existing data and methods

Photo credit: Steve Polasky

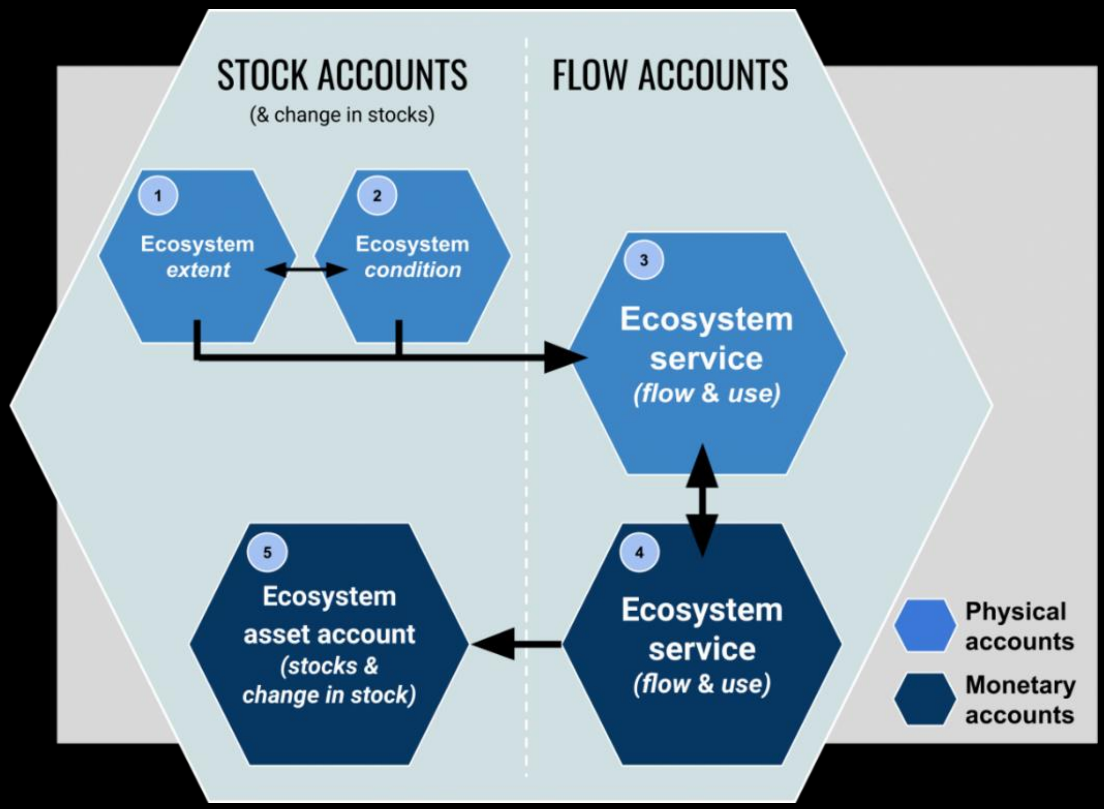
Discussion

- Emphasize that this is a first step to measuring GEP – not the last word
  - GDP and System of National Accounts took decades to mature – and is still being refined
- Stimulate the research community
  - Highlight knowledge gaps
  - Point out needs for additional data collection
  - Point out needs for additional methods development

Photo credit: Steve Polasky

Connecting GEP, inclusive wealth, and sustainable development

- System of environmental-economic accounts
  - Asset accounts (capital/wealth)
  - Flow accounts (ecosystem services/GEP)
- Non-declining inclusive wealth is a measure of sustainable development
- But must be able to measure inclusive wealth



An approach for measuring inclusive wealth

- Development rigorous measures of GEP
- Combine GEP analysis with scenarios of future conditions to develop trajectories of GEP
- Generate the present value of GEP to estimate the value of natural capital

Application of GEP and inclusive wealth to policy and decision-making

- GDP has influenced economic decision-making and powerfully influenced societal directions
- Can GEP and inclusive wealth be used to shift societal goals and perspectives?
- Examples of applications of GEP in China
  - Show the ecological connections among regions
  - Basis for compensation from beneficiaries to suppliers of ecosystem services
  - Serve as a performance metric for government officials
  - Beijing and Shenzhen use GEP for planning and evaluation
  - Two Mountains Banks: low-interest loans if improving ecosystem services

Applications of ecosystem services and natural capital to policy and decision-making

- Many uses of ecosystem services/natural capital information
- Social benefit-cost analysis
- Private sector investments, financial portfolio analysis (risks and opportunities)

Road ahead: Overcoming important challenges and limitations

- Complete coverage of all (important) services for all countries
- Using standardized rigorous methodology
- Ground-truthing and reliability
- Getting buy in from National Statistical Offices
- Creating time series (past and future)
- Dealing with uncertainty

Photo credit: Steve Polasky

Concluding thought

- 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 natural capital should lead society to realize the urgent need for better metrics of ecosystem services and natural capital, such as GEP, to help guide sustainable development