Natural Capital Accounting and Measuring Ecosystem Services: The Next Wave

Interagency Collaborative on Environmental Modeling and Monitoring (ICEMM)
Annual Public Meeting
March 17-18, 2020
USGS Headquarters, Reston, VA

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Some content directly from Ken Bagstad, PhD, USGS

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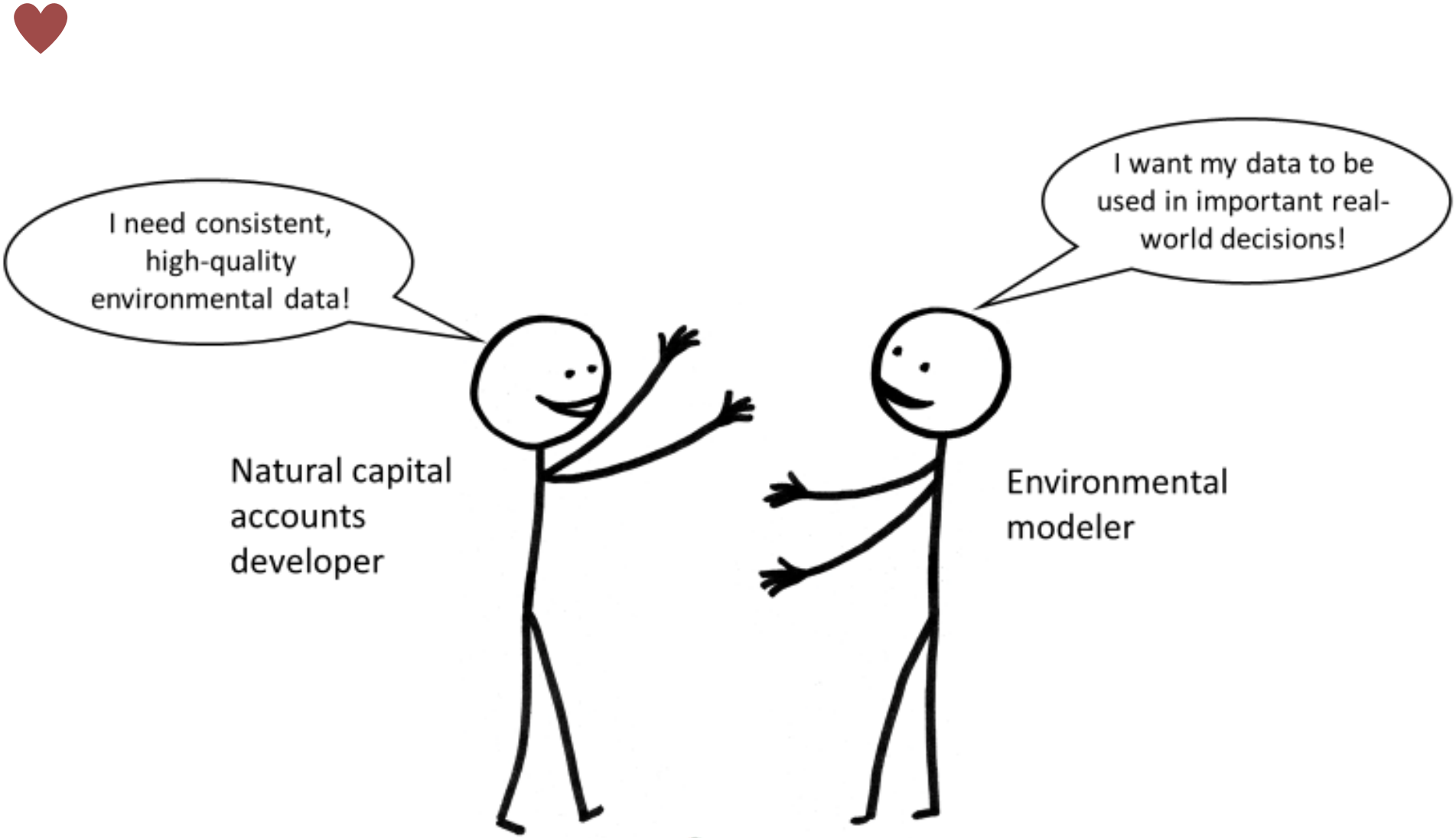
Natural Capital Accounting (**NCA**):

- shares ICEEM 2020 Meeting Objectives and more!
- includes a hard pairing of Environmental Modeling and Monitoring (**EMM**) outputs to human processes and behaviors
- is a critical and expanding user of EMM!

- The resolve to embrace and develop NCA is real Beyond GDP
- Deeper wider understanding and measurement, to inform urgently needed adaptive management strategies
- Each field working alone won't cut it any more



Jeremy Havens and Ken Bagstad of USGS made cartoon

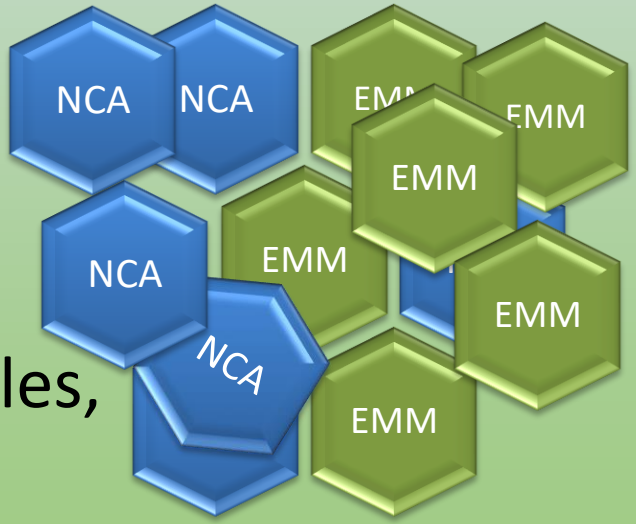
Many who assume NCA can use their research products directly have learned:

1st – it is not as easy or as obvious as they thought

2nd – a common organizing framework and vocabulary helps

3rd – their own definitions and concepts can fit (with some alterations) into NCA framing

So…how to coordinate efforts across fields that are not close partners?



1st – *Communicate*

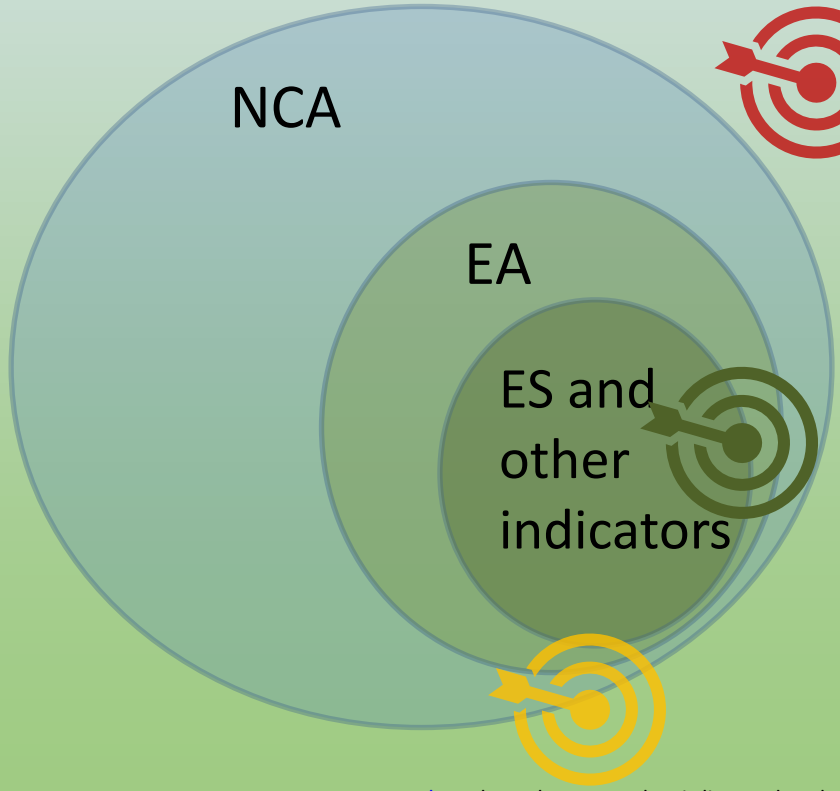
2nd – *Invest* in: shared organizing principles, common definitions, and common goals for model & data sharing

Interactive Modeling and Data – Can NCA easily apply *your* work?

- passing the baton – moving toward cleaner passes

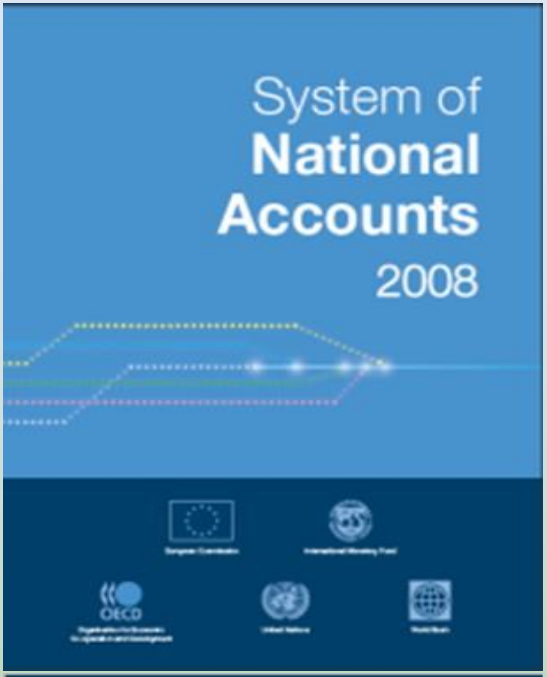
This presentation:

- **explains** basics of NCA frame, Ecosystem Accounting frame within NCA, and place of Ecosystem Services (**ES**) and other key indicators in Ecosystem Accounting
- **discusses** how different attempts to conduct or match modeling and data to NCA have stumbled and succeeded, and lessons from these attempts

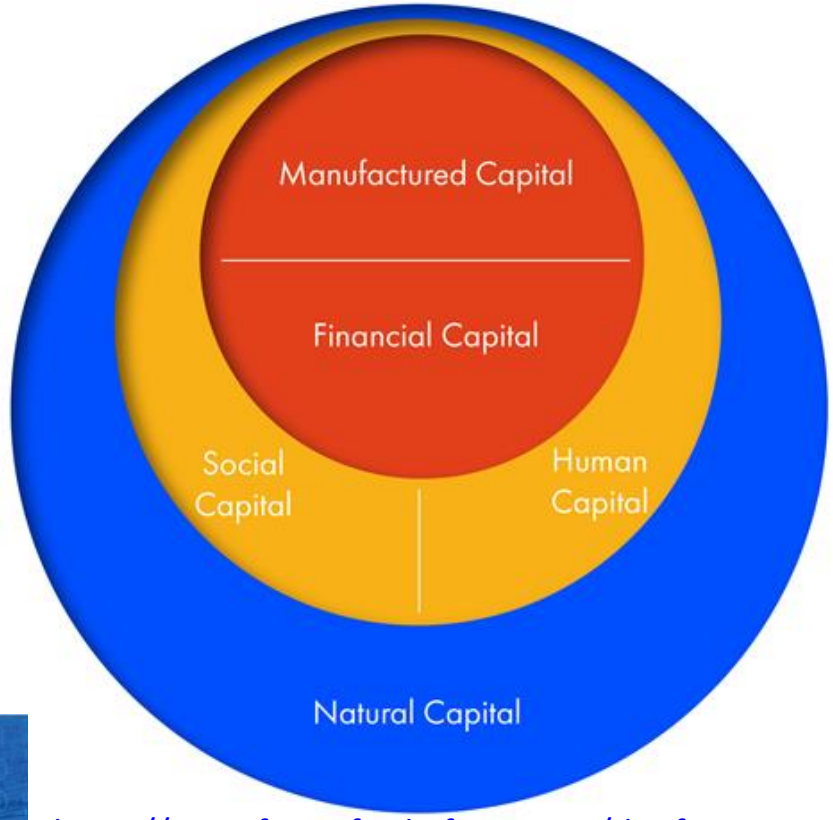


What is NCA?

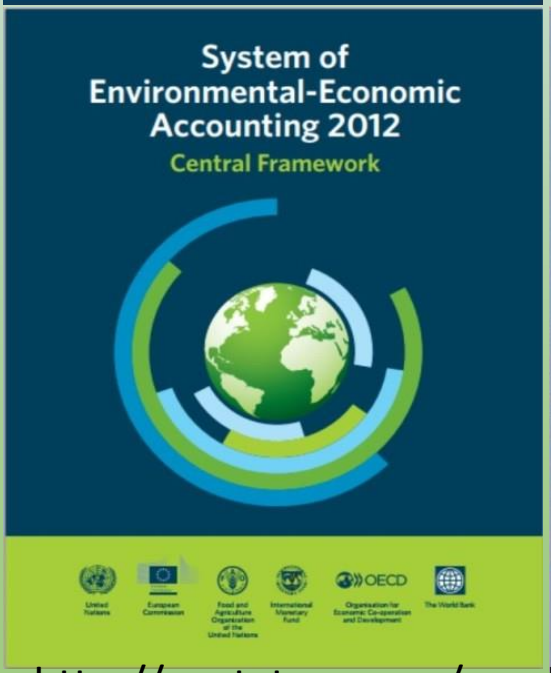
UN Statistics Division (UNSD)

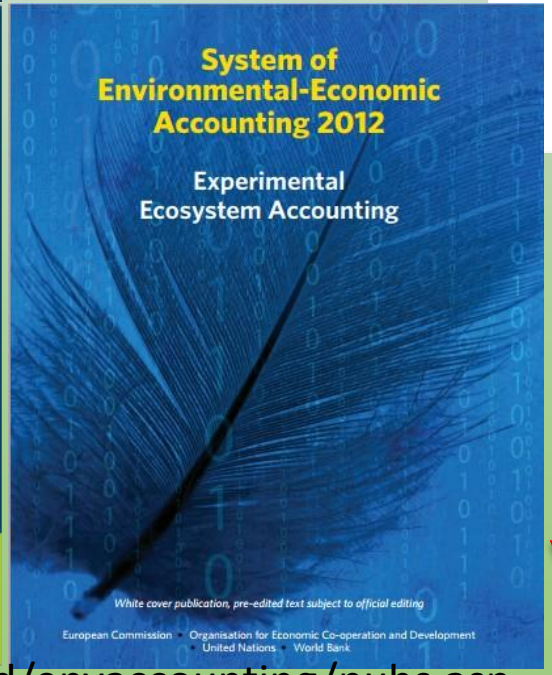


Does SNA +
SEEA-CF +
SEEA-EEA =
NCA ??



https://www.forumforthefuture.org/the-five-capitals



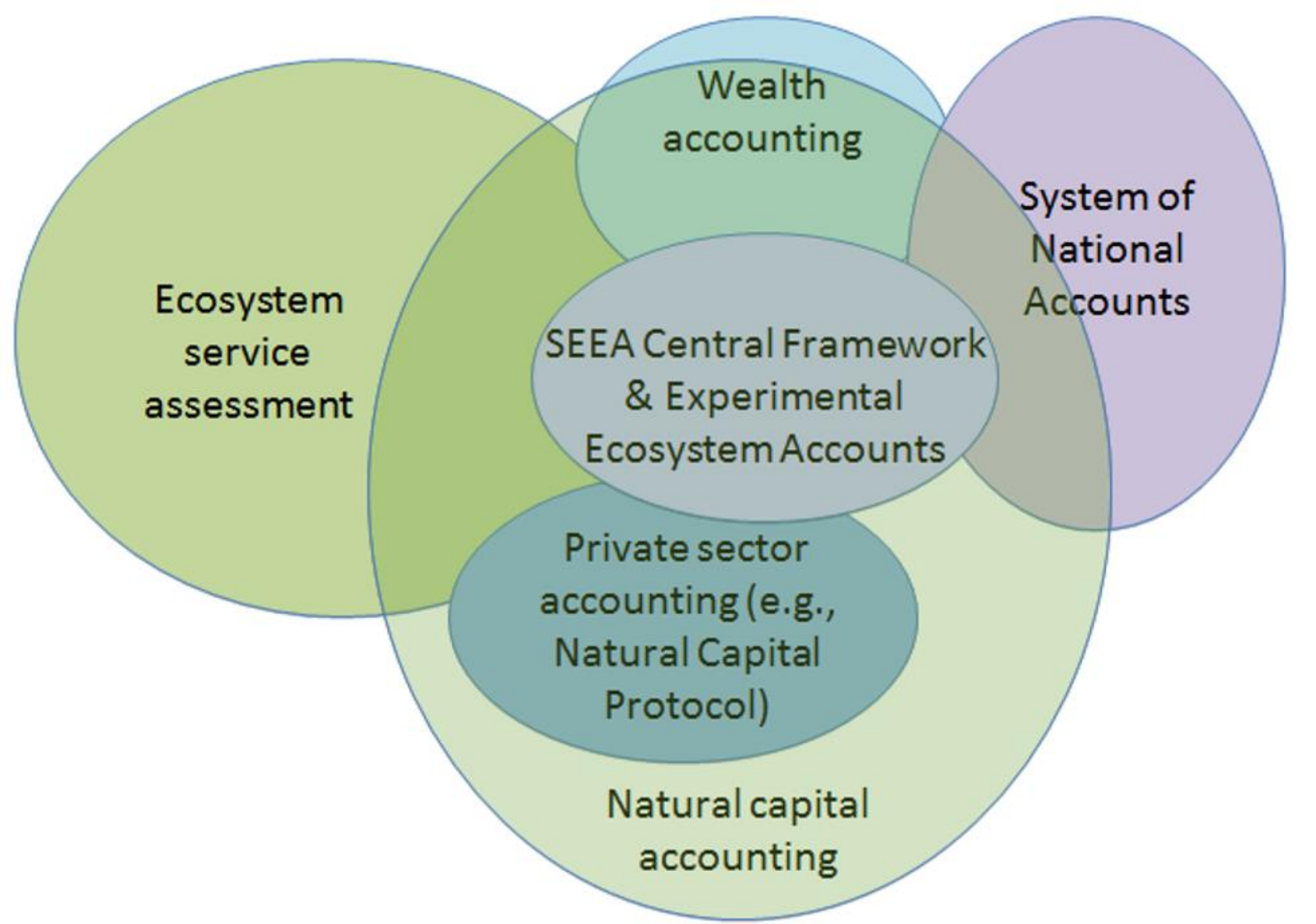


http://unstats.un.org/unsd/envaccounting/pubs.asp

No, the term NCA is not tightly defined. US NCA working group had to grapple with this. We created the Venn diagram and locking hexagon figures below to explore and explain…

Not yet standard

Relationship of natural capital accounts to economic accounts & ecosystem services

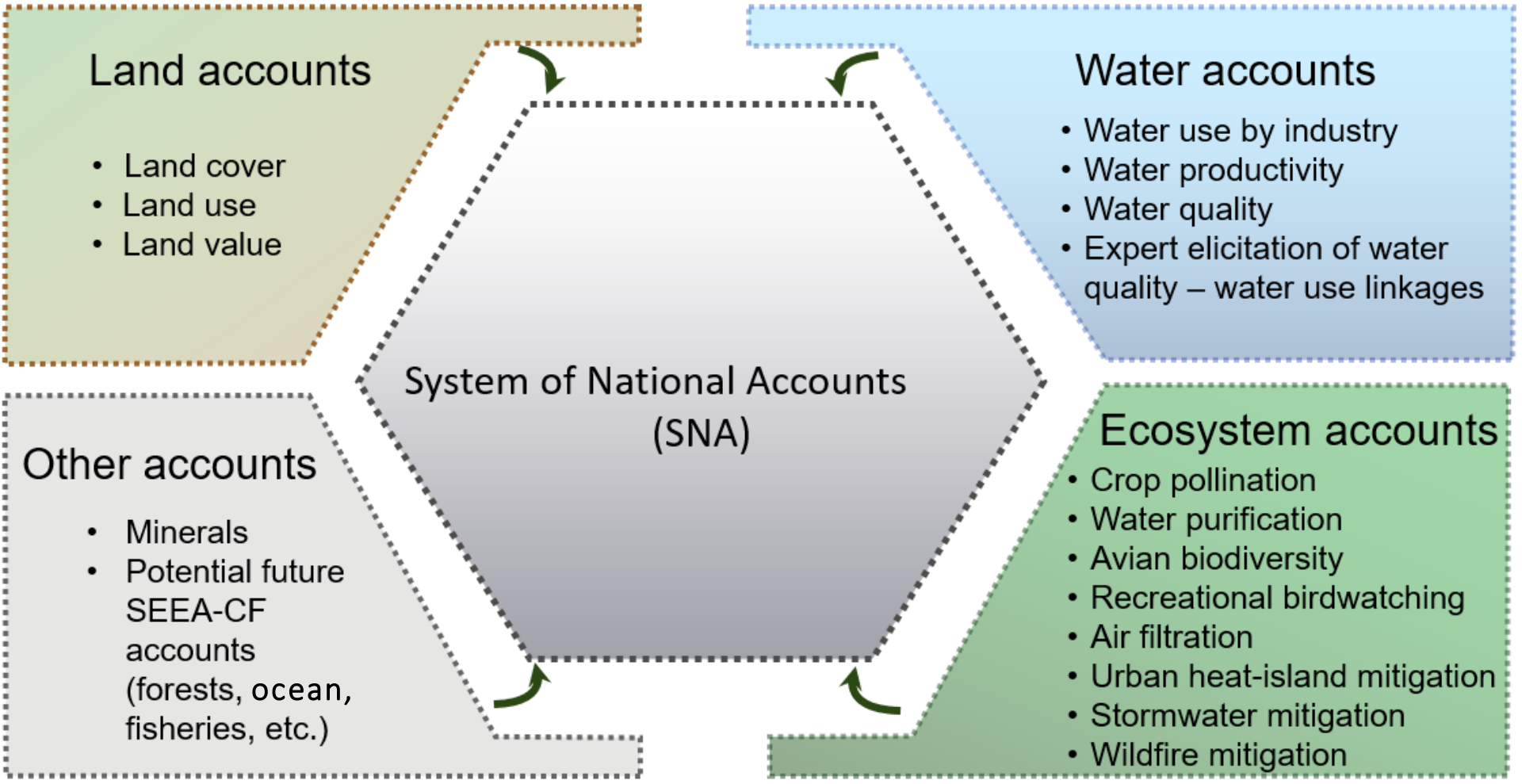


Countries that have compiled SEEA EEA accounts

Some countries have published all accounts that they have compiled, and others have published only some. China, Japan, and the United States have compiled accounts but not published them (see supplementary materials, section 1). The scope and resolution of the accounts vary between countries. The figure presents a snapshot—countries continue to compile and publish accounts. SEEA, System of Environmental-Economic Accounting; EEA, Experimental Ecosystem Accounting.

Hein et al., *Science*, Policy Forum: Progress in natural capital accounting for ecosystems, 31Jan20, vol. 367 iss.6477, 514-515.

Natural capital accounts for the U.S.



US NCA working group includes people from: USGS, NOAA, BEA, EPA, State Dept., World Bank, National Ecosystem Services Partnership, Basque Center for Climate Change, UMN, UVM, U CO, U HI, STATCAN, Australian National U, Resources for the Future/SESYNC, Ernst & Young, COMPASS, et alia

US NCA objectives, results, and discussion follow, starting with Ecosystem Accounts

US NCA Working Group Objectives:

How much can we populate without major data or model investments?

Can we suggest a structure that attracts institutional investment and momentum in building time-series accounts?

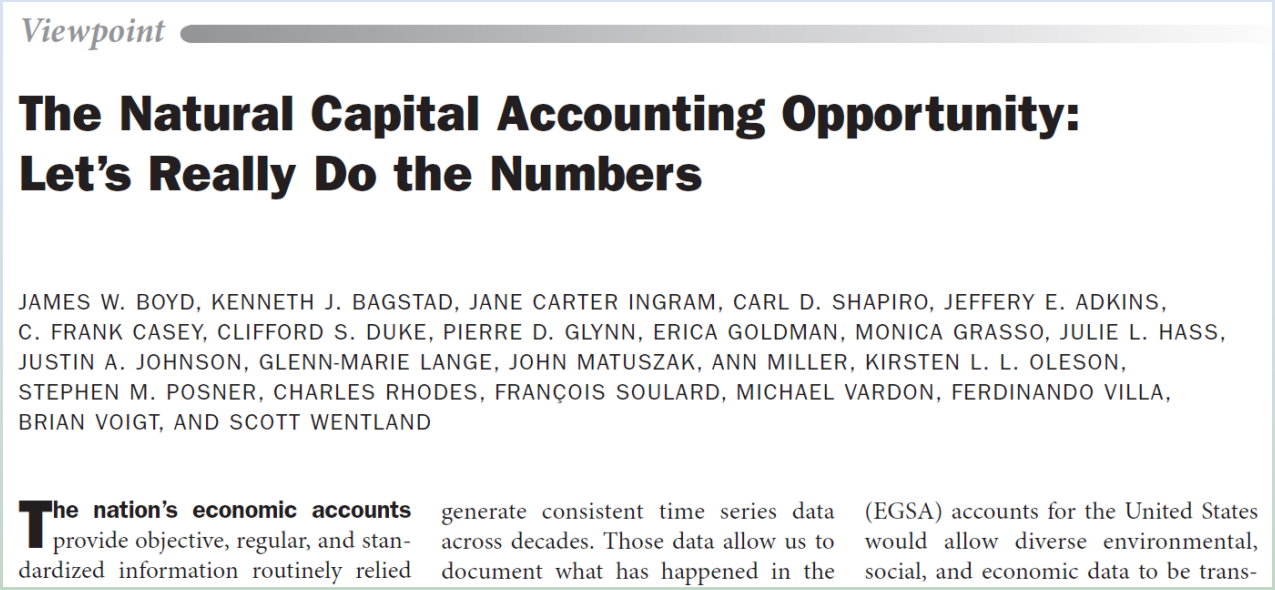
1) Build pilot accounts with little US institutional investment
2) Use existing structures and data wherever possible
3) Want results to be reproducible, and often
4) Key considerations:
    a. Data should be *publicly available* on a *national* scale
    b. Accounts summarized *geographically* and by *ecosystem type*
    c. Analyses should be *updateable* – tracking *over time* is essential
    d. A*void proprietary* tools and models

US NCA Working Group

1) Make the case to the community:

- Get the word out
- Stoke coalition building

2) Proceed with building accounts



Viewpoint

The Natural Capital Accounting Opportunity: Let's Really Do the Numbers

JAMES W. BOYD, KENNETH J. BAGSTAD, JANE CARTER INGRAM, CARL D. SHAPIRO, JEFFERY E. ADKINS, C. FRANK CASEY, CLIFFORD S. DUKE, PIERRE D. GLYNN, ERICA GOLDMAN, MONICA GRASSO, JULIE L. HASS, JUSTIN A. JOHNSON, GLENN-MARIE LANGE, JOHN MATUSZAK, ANN MILLER, KIRSTEN L. L. OLESON, STEPHEN M. POSNER, CHARLES RHODES, FRANÇOIS SOULARD, MICHAEL VARDON, FERDINANDO VILLA, BRIAN VOIGT, AND SCOTT WENTLAND

The nation's economic accounts provide objective, regular, and standardized information routinely relied generate consistent time series data across decades. Those data allow us to document what has happened in the (EGSA) accounts for the United States would allow diverse environmental, social, and economic data to be trans-

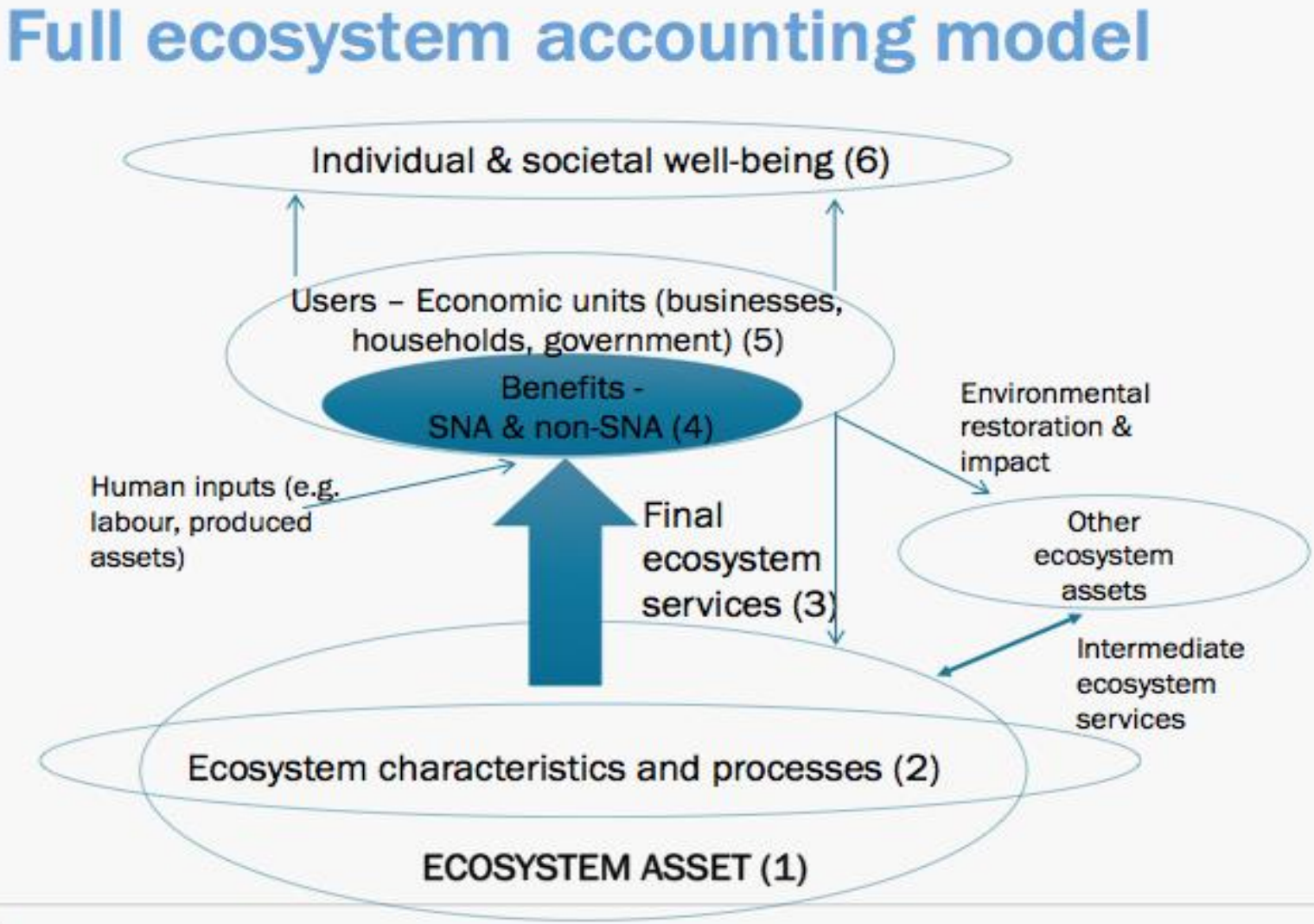
For Ecosystem Accounts, US NCA Working Group agrees to:

1) use/adapt UN SEEA EEA accounting model and account structure
2) use/adapt a US ES classification system (NESCS) that SEEA EEA is discussing

1st – What do these structures look like?

2nd – How did that agreement work in practice?

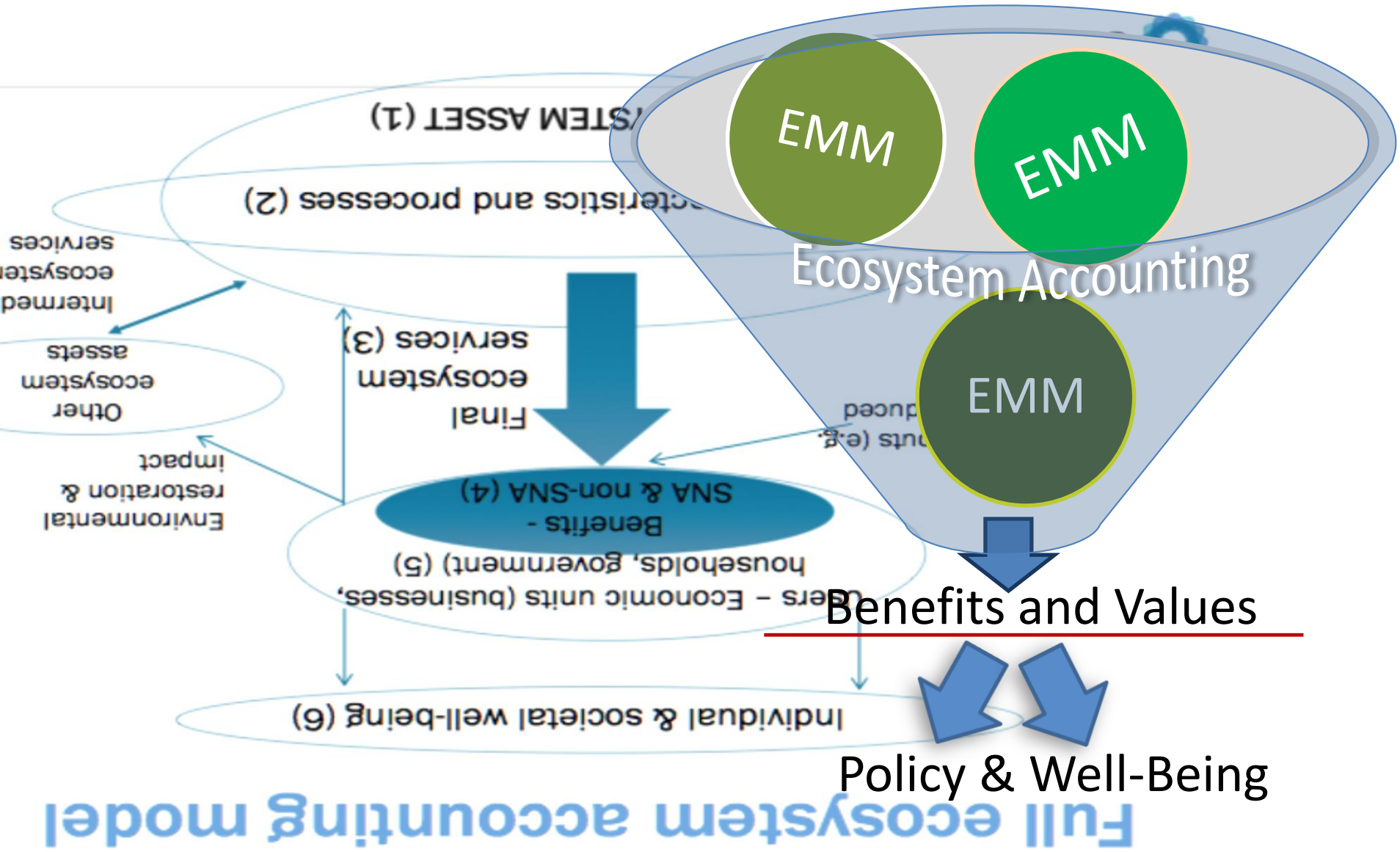
SEEA Experimental Ecosystem Accounting



(Figure 1, December 2015 draft of U.N. et al., 2017 "SEEA EEA Technical Recommendations")

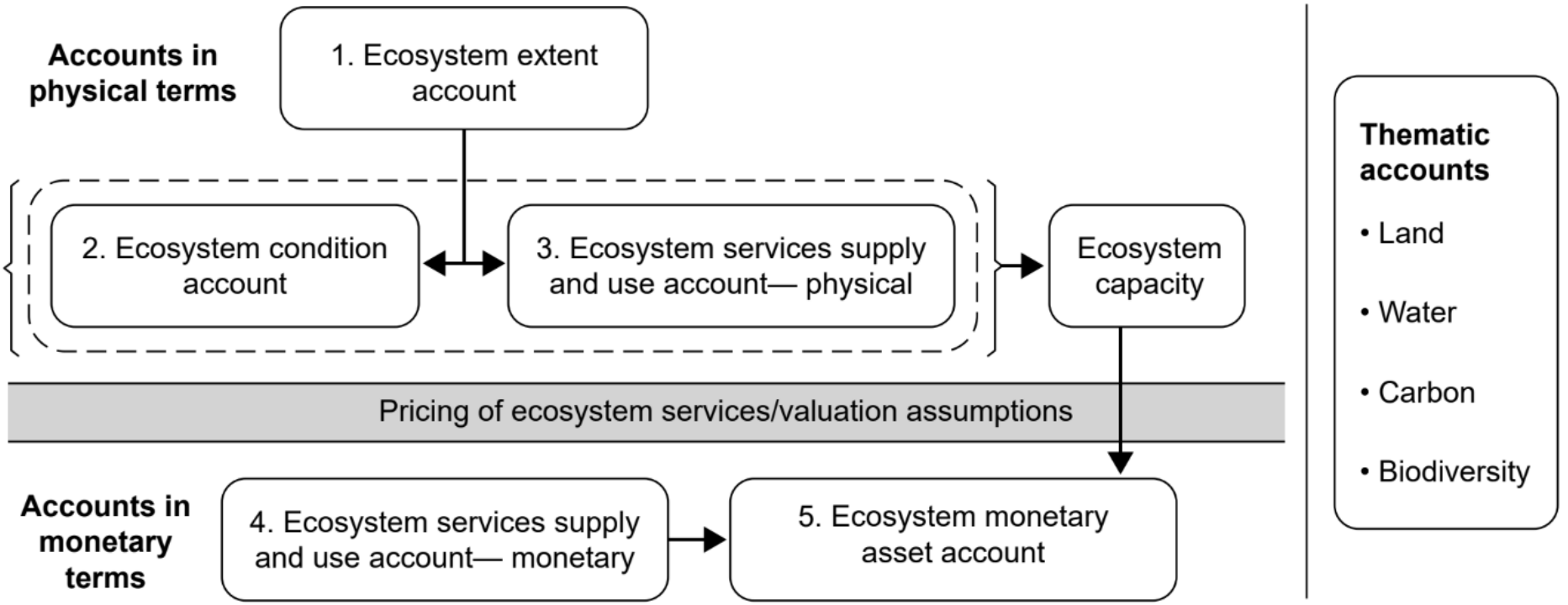
PICTORIAL EXPERIMENT

SEEA Experimental Ecosystem Accounting



(Figure 1, December 2015 draft of U.N. et al., 2017 "SEEA EEA Technical Recommendations")

SEEA Experimental Ecosystem Accounting (detail)



- *Ecosystem extent* begins with spatial areas, "ecosystem assets"
- *Ecosystem assets* hold biotic and abiotic components that in their *condition* produce things that when used/appreciated/transacted by *economic units* record as *ecosystem services*
- Physical flows and monetary flows are separate accounts
- Thematic accounts cover critical factors that span ecosystem assets
- Integration: SEEA-EEA entries should minimize overlap with SNA entries

SEEA EEA – Supply and Use Tables (SUTs)

3. Ecosystem services supply and use account – physical

ECOSYSTEM SERVICES SUPPLY TABLE

		Type of economic unit	Type of Ecosystem Unit
Ecosystem services Provisioning services Regulating services Cultural services		A	B
Products		C	D

ECOSYSTEM SERVICES USE TABLE

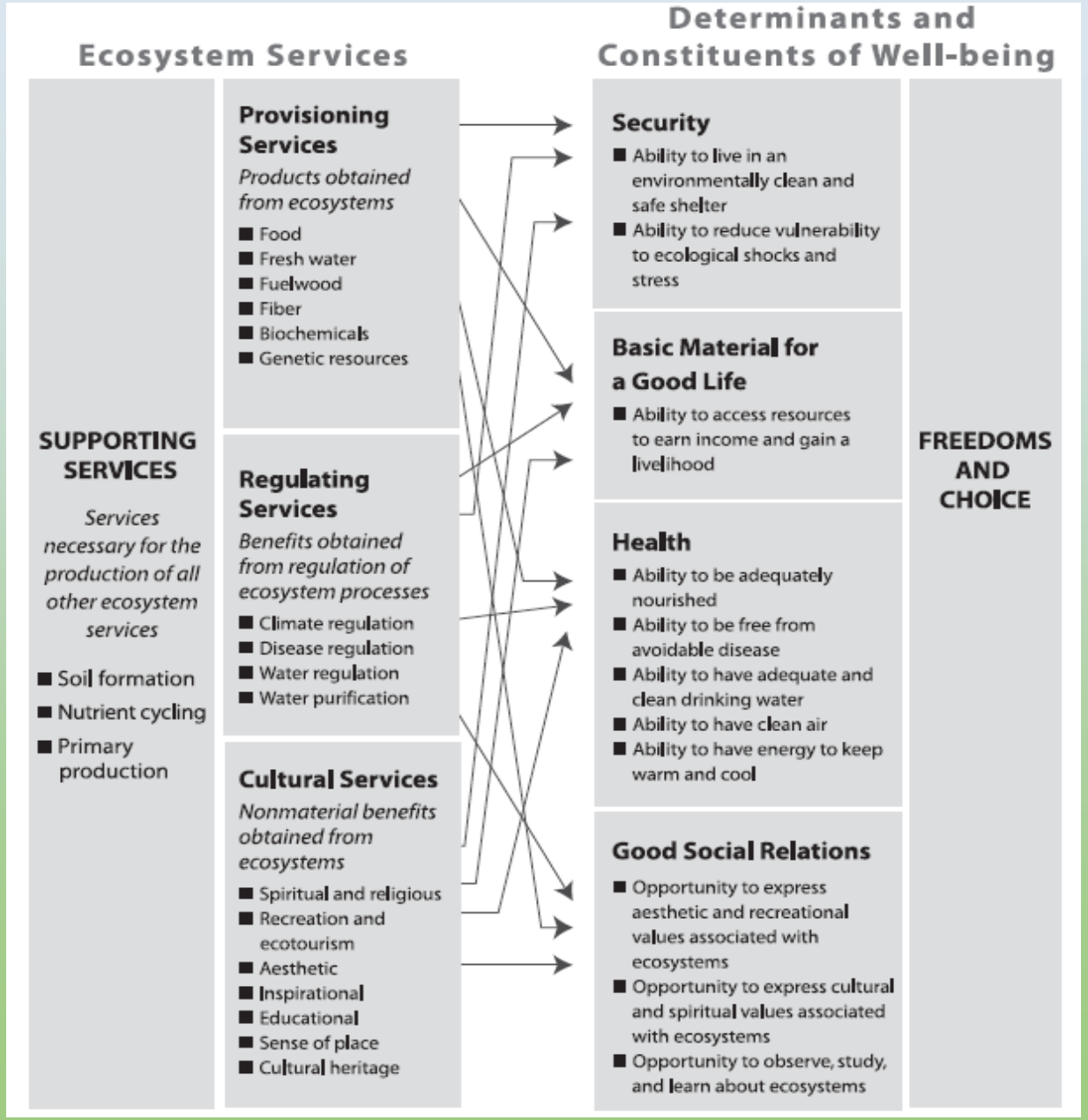
		Type of economic unit	Type of Ecosystem Unit
Ecosystem services Provisioning services Regulating services Cultural services		E	F
Products		G	H

SEEA EEA ecosystem services supply and use table structure (reduced from December 2015 draft of U.N. et al., 2017)

- Only Ecosystem Units(/assets) can supply ES, never Economic Units
- Only "final" ES; must be *used/appreciated/transacted* in area and year
- Quadrants B & E are equal in total, and by row

Millennium Ecosystem Assessment Categorization of Ecosystem Services and their Links to Human Well-Being

Source: Millennium Ecosystem Assessment. 2003. Ecosystems and human well-being: a framework for assessment, 266p.



"These categories overlap extensively, and the purpose is not to establish a taxonomy but rather to ensure that the analysis addresses the entire range of services"

(p. 38).

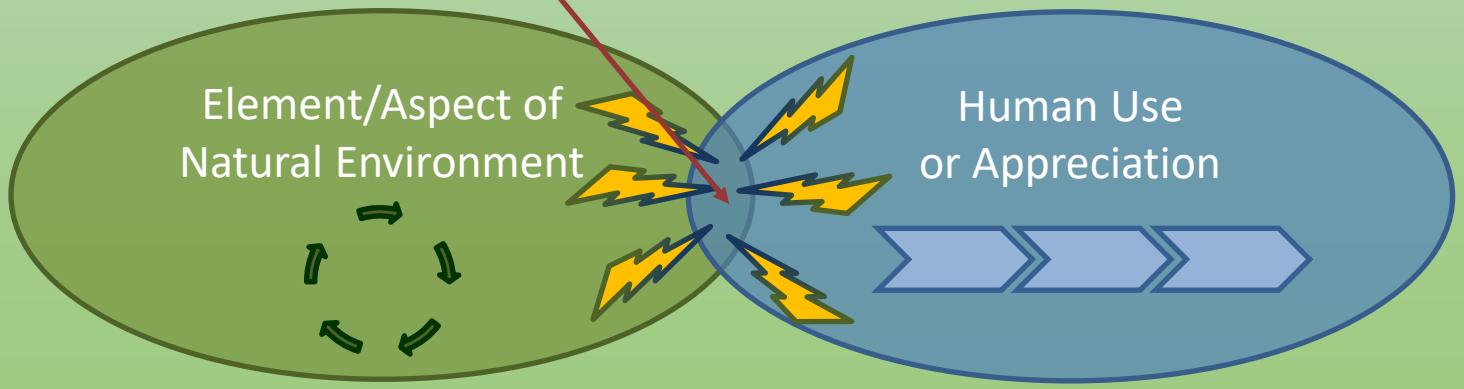
- **Porous categories**
- **Double Counting**

Ecosystem Services (ES) – Definitions Matter!

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. *Daily et al. 1997*

Ecosystem services are the benefits people obtain from ecosystems.
Millennium Ecosystem Assessment, 2005

Colloquially, ecosystem services are "the benefits of nature to households, communities, and economies." …(H)owever, ecology and economics have failed to standardize the definition and measurement of ecosystem services.
… *Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being.*
Boyd and Banzhaf, 2007



Relationship
Service
Transaction
Exchange

Why a National Ecosystem Services Classification (**NESCS**)?

Approaches to definition and identification of ES split between:

Those seeking formalization and standardization of ES definitions and identification

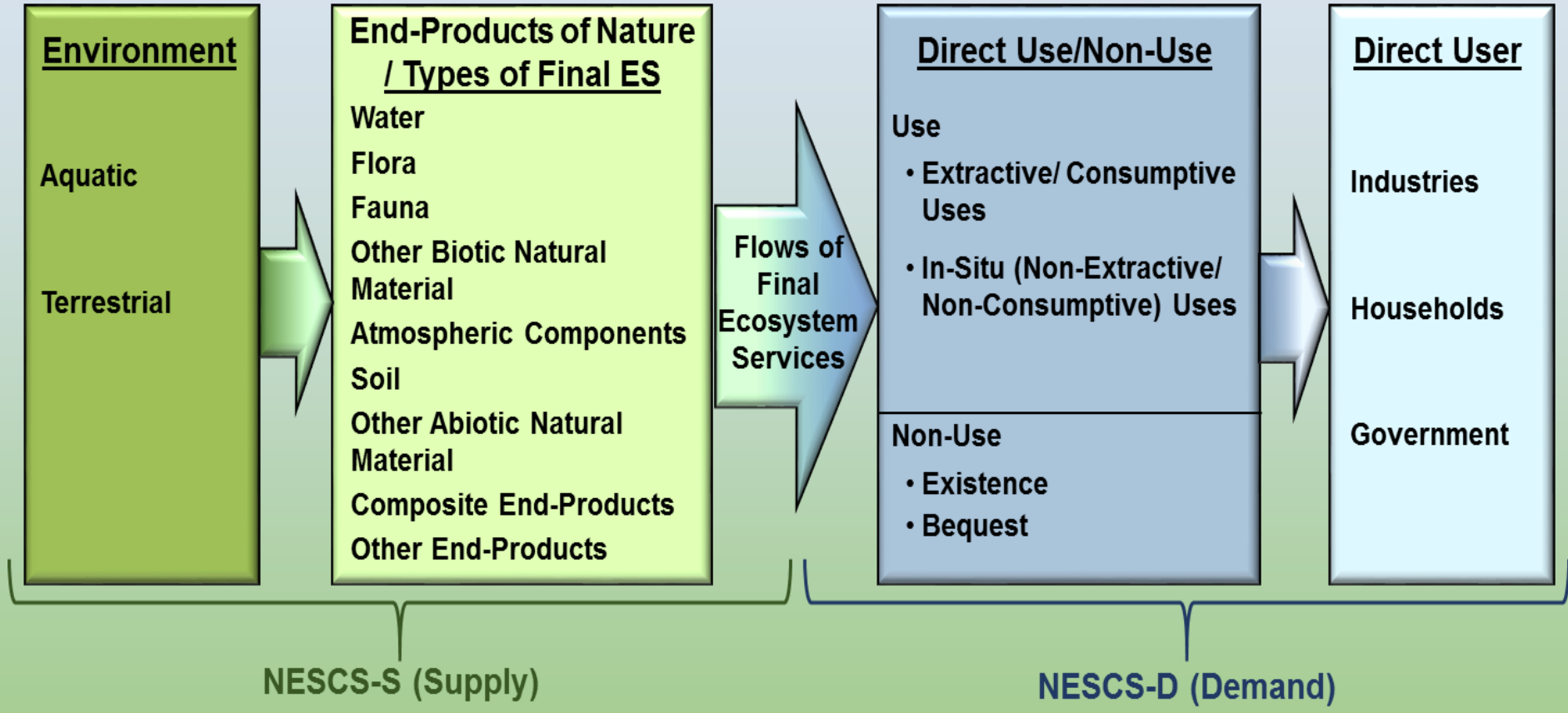
- bound to formal analysis
  - marginal/scenario/cost-benefit analyses
- seek long-term tool development
  - "full-spectrum" *identification*
  - precise, reproducible, and specific field *metrics*
  - precise final ES for known users/beneficiaries to *value*
  - common tracking of relevant ES metrics with the *goal* of "allowable" benefits transfer

Ad-hoc pragmatists

- frustrated with slowness of adoption of ES perspective
- focused on limitations of full-scale ES assessment for very few ES
  - 1 to 6 "ecosystem services"
- question the efficacy of formalizing classification *(didn't see SEEA-EEA coming)*

Early adopters of MA 4-types of ES, and to some extent WAVES get stuck here. "Walking path."

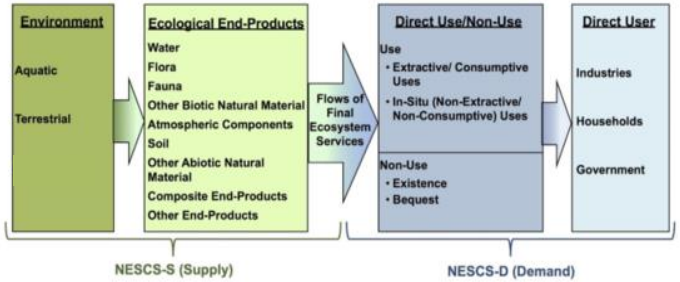
NESCS Four-Group Classification Structure (condensed)



ES Defns test to SEEA EEA SUTs

US NCA for Ecosystem Accounting chooses SEEA EEA framework, and tests NESCS framework for ES supply and use tables

NESCS Four-Part Classification Structure (condensed)



ECOSYSTEM SERVICES SUPPLY TABLE

	UNITS	Type of economic unit: Agriculture, forestry and fisheries	Electricity, gas supply	Direct User: Wa	Oth	Hou	Accumulation	Rest of the world - Imports	Type of Ecosystem Unit: Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Environment: Tr	M	St	Rt	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL SUPPLY
Ecological End-Products: Water, Flora, Fauna, Other Biotic Natural Material, Atmospheric Components, Soil, Other Abiotic Natural Material, Composite End-Products, Other End-Products																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15								
Ecosystem services: Provisioning services, Regulating services, Cultural services		A							B															
Products		C							D															

ECOSYSTEM SERVICES USE TABLE

	UNITS	Type of economic unit: Agriculture, forestry and fisheries	Electricity, gas supply	Water collection, treatment and supply	Other industries	Households	Accumulation	Rest of the world - Exports	Type of Ecosystem Unit: Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL USE
Ecological End-Products: Water, Flora, Fauna, Other Biotic Natural Material, Atmospheric Components, Soil, Other Abiotic Natural Material, Composite End-Products, Other End-Products																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15								
Ecosystem services: Provisioning services, Regulating services, Cultural services		E							F															
Products		G							H															

US NCA EA sub-group: Let's start filling rows and columns!

US NCA EA paper Case Study notes

Ecosystem Accounting paper sub-group: first draft from outline to text breaks from SEEA EEA account structure and NESCS ES definition structure!!

Is this even a problem?

NO

- researchers re-frame questions all the time
- Working Group stated goal to use existing measures where possible
- team members were using own vocabulary and measures from previous publications as starting point (who wouldn't do that?)
- very tempting to settle "what to measure?" quickly, knowing most effort will be on "how to measure?" and "how to report?" (our quantitative training first, baton pass 2nd!)
- team members split between ad-hoc and formal approaches to ES definition, why should one be favored?

YES

- US NCA EA work publishable, but compatible with SEEA EEA? Could replicating it fuel a schism in approaches to EEA?
- Re-tasking SEEA EEA terms and account structure not disrespectful, just unfamiliar with framework, rigor of its development, and with basic constraints imposed by SEEA goal of integrating with SNA and becoming a standard
- Following SEEA EEA structure and rigorous ES definition signals US cooperation with proposed international standards and signals leadership in NCA development
  - breaking in key ways from European attempts
  - anchoring methods, measures, and place in accounts for US NCA EA time-series products

How did we work through the problem? A few case specifics and lessons…

Resolving conflicting project objectives, and differences in approach by team members:

- Communication
- Leadership
- Finding role/place in accounts for what can be measured
  - whether or not past "ES" are "ES" in final placement…

Carefully determine, including people familiar with ES classification and EEA (NCA):

- what you already model and monitor
- *ideal* measure
- *actual* measure (with uncertainty, error, etc.)
- what measures *don't work* for SEEA, what SEEA *needs*, what SEEA *prefers*
- where in *framework*, from environment to economy, does actual measure fit?
- where in *accounts*, from environment to economy, does actual measure fit?

Pollination

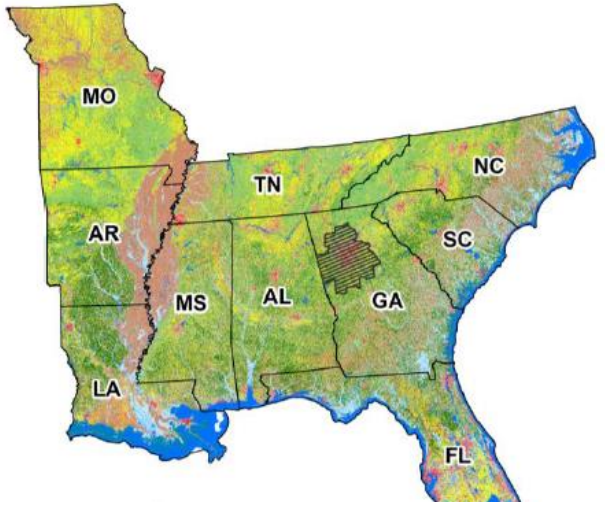
1. pollinator habitat vs. pollination
2. pollination vs. wild pollination
3. actual measure and call to science

Biodiversity

1. orgs and literature vs. EEA and ES classification
   - coalition building vs. rigors of SEEA
2. open questions and continuing debate

Carbon

Ecosystem accounts for the SE U.S. (Warnell et al., accepted)



			Ecosystem Types (Land Cover)																	
			Offshore	Open Water - non-freshwater	Open Water - freshwater	Developed - Open	Developed - Low	Developed - Medium	Developed - High	Barren	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands
Wild pollination*	Area of pollinator habitat in flight range of pollinator-dependent crops (sq km)	2001									5,471	2,516	1,336	1,290	165			7,061	172
		2006									4,152	2,125	1,459	2,191	423			11,539	371
		2011									53,679	30,441	6,670	18,388	9,314			43,104	3,354
	Area of pollinator-dependent crops in flight range of pollinator habitat (sq km)	2001															11,182		
		2006															21,581		
		2011															65,818		
	Ratio of pollinator habitat to pollinator dependent crops	2001															1.66		
		2006															1.05		
		2011															2.55		
Water purification	Area of purifying land cover types between NPS sources and waterways (sq km)	2001									31,542	20,238	6,959		5,385			25,463	3,379
		2006									31,453	19,780	6,678		5,997			25,427	3,504
		2011									31,005	19,330	6,353		6,192			25,151	3,789
	% of flowpath between NPS sources and waterways in purifying land cover types	2001			30.6%														
		2006			30.4%														
		2011			29.9%														

			Ecosystem Types (Land Cover)														
			Offshore	Open Water	Developed - Open	Developed - Low	Developed - Medium	Developed - High	Barren	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands	Total
Recreational birding (thousands of birding days)		2001	2,015	8,471	6,935	5,897	1,850	978	416	6,586	3,441	365	1,075	1,498	2,285	4,614	7,106	3,343	56,874
		2006	518	4,418	8,552	9,451	4,368	1,129	780	6,273	3,433	531	2,208	2,808	2,833	3,658	6,196	2,204	59,360
		2011	1,236	5,207	10,022	7,420	3,553	1,046	1,408	7,173	3,816	692	1,966	1,833	4,050	2,634	4,964	3,695	60,715
Air pollutant concentrations (annual mean, ppb except for PM (µg/m3))	CO	2010	314.6																314.6
		2015	290.1																290.1
	NO_2	2010	7.3																7.3
		2015	7.0																7.0
	O_3	2010	30.6																30.6
		2015	27.9																27.9
	PM_{10}	2010	9.5																9.5
		2015	9.5																9.5
	$PM_{2.5}$	2010	10.9																10.9
		2015	10.4																10.4
	SO_2	2010	2.0																2.0
		2015	1.0																1.0
Carbon storage* (kilotons of C)		2001	0	0	307,170				0	11,039,035		1,211,205	601,250	4,941,118			3,276,189	741,315	22,117,283
		2006	0	0	361,629				0	11,074,236		1,282,818	713,026	4,897,046			3,260,913	748,974	22,338,642
		2010	0	0	384,934				0	10,935,461		1,464,086	740,303	4,887,533			3,225,475	782,570	22,420,361

160	160	158	148	
160	160	159	150	
160	160	159	147	

Ecosystem *Condition* accounts for the SE U.S.

Includes metrics related to:

- Wild pollination
- Purification of runoff water
- Bird species richness
- Air pollutant removal

			Ecosystem Types (Land Cover)																
			Offshore	Open Water - non-freshwater	Open Water - freshwater	Developed - Open	Developed - Low	Developed - Medium	Developed - High	Barren	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands	TOTAL
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		2006									4,152	2,125	1,459	2,191	423			11,539	371	22,259
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		2006									31,453	19,780	6,678		5,997			25,427	3,504	92,840
		2011									31,005	19,330	6,353		6,192			25,151	3,789	91,820
	% of flowpath between NPS sources and waterways in purifying land cover types	2001			30.6%															
		2006			30.4%															
		2011			29.9%															

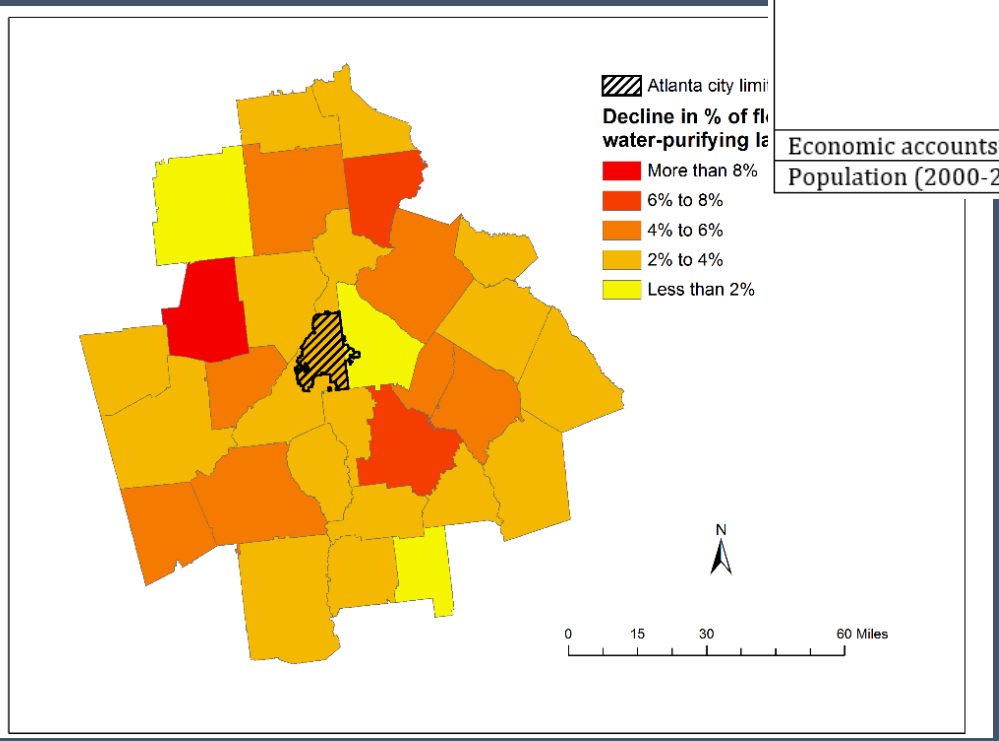
Warnell et al., accepted Ecosystem Services special issue

US NCA EA Results

Sub-state scale: from spatial data & models to accounts

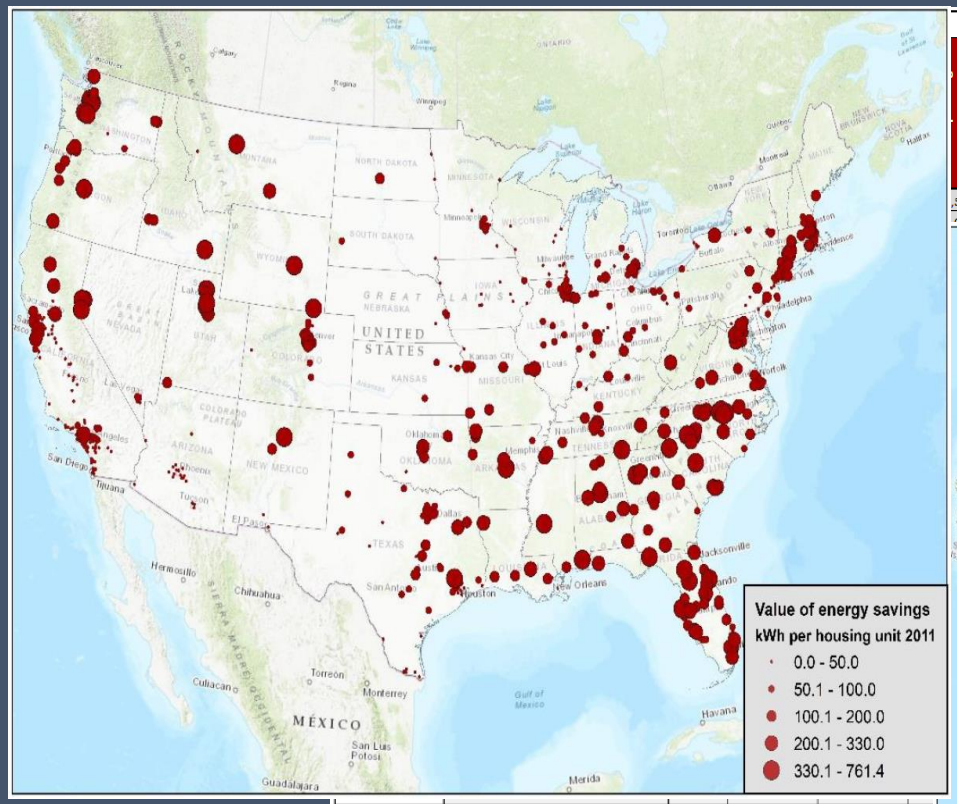
Ecosystem accounts support fine-grained analysis

Account	Metric	% change, 2001-2011
Land accounts[a]	Developed land cover	17.2%
	Agricultural land cover	-6.3%
	Other land cover	-4.0%
Water accounts	Total water use (million gallons/day, 2000-2010)[b]	-57.8%
	Water productivity ($/100 gallons water use, 2000-2010)[c]	153.3%
	Water-quality monitoring declines (% of sites monitored, 2002-2012)[d]	
Ecosystem accounts[e]	% of flowpath in purifying land cover	-18.2%
	Mean annual concentration, CO (2010-2015)	14.8%
	Mean annual concentration, NO_2 (2010-2015)	-25.0%
	Mean annual concentration, O_3 (2010-2015)	-3.8%
	Mean annual concentration, PM10 (2010-2015)	-32.5%
	Mean annual concentration, PM2.5 (2010-2015)	-1.8%
	Mean annual concentration, SO_2 (2010-2015)	-42.7%
	Mean annual removal rates, CO (2010-2015)	22.5%
	Mean annual removal rates, NO_2 (2010-2015)	18.9%
	Mean annual removal rates, O_3 (2010-2015)	3.4%
	Mean annual removal rates, PM10 (2010-2015)	-20.3%
	Mean annual removal rates, PM2.5 (2010-2015)	0.3%
	Mean annual removal rates, SO_2 (2010-2015)	-46.6%
	Total precipitation (mm/yr)	39%
	Recreational birding-days	209.6%
Economic accounts[f]	GDP, all industries	8.8%
Population (2000-2010)[g]		24.0%



- Atlanta MSA (left)
- New county-level GDP estimates from BEA enable finer scale analysis
- Ability to extract results for any geography e.g., watersheds, public lands

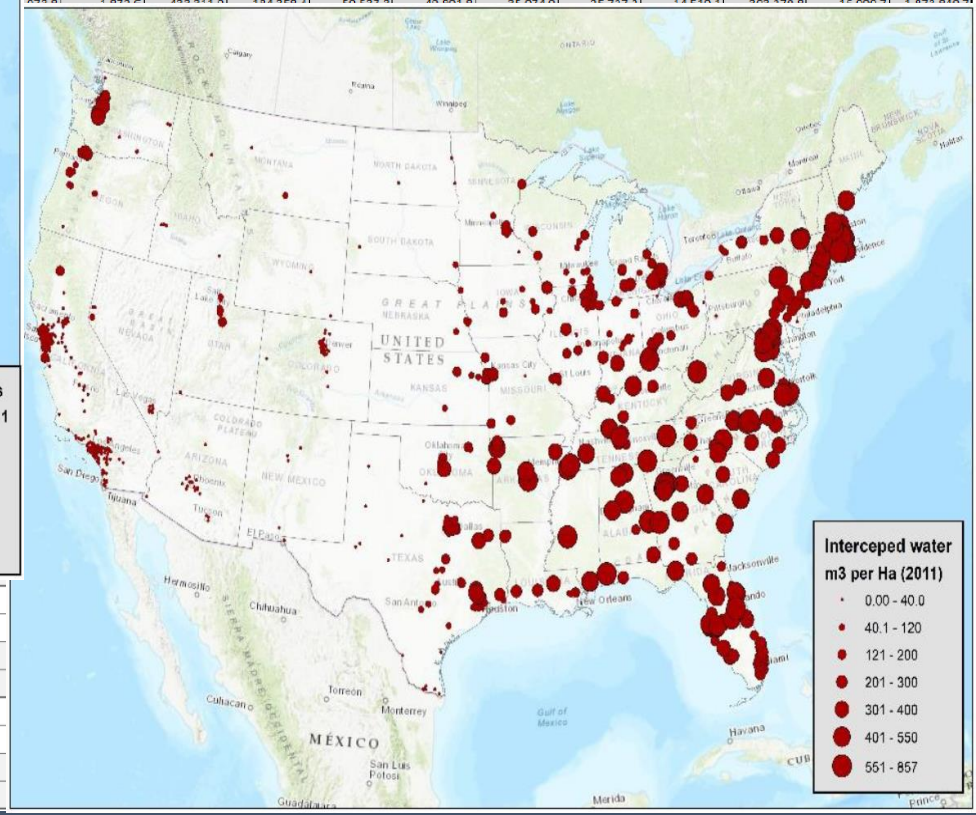
National-scale urban ecosystem accounts (Heris et al. in review)



Colorado	Intercepted water (1000m^3)	2001	0.0	3,775.3
		2011	0.0	5,191.8
	Energy Savings (mWh)	2001	0.5	0.0
		2011	2.7	0.0
Denver	Intercepted water (1000m^3)	2001	0.0	649.4
		2011	0.0	886.8
	Energy Savings (mWh)	2001	0.0	0.0
		2011	0.8	0.0

Ecosystem Types

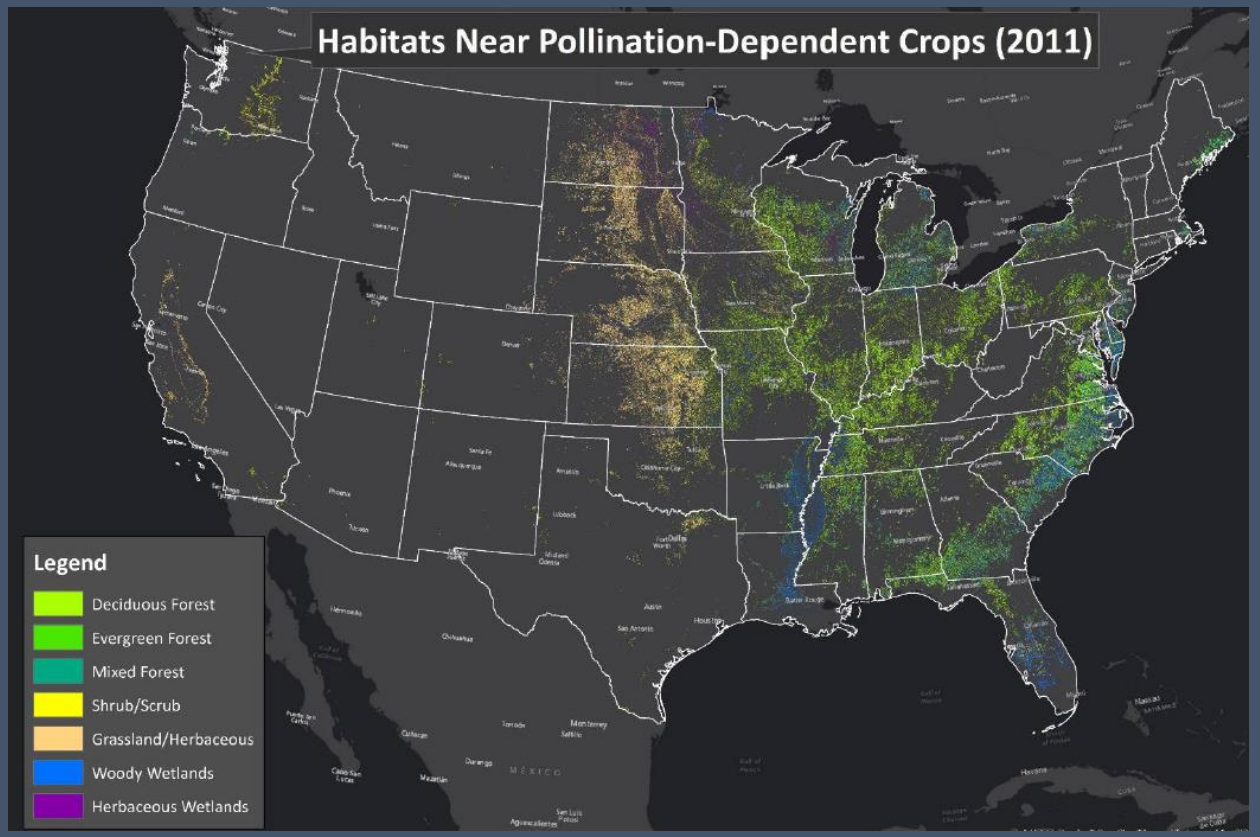
	Barren	Deciduous Forest	Evergreen Forest	Mixed Forest	Scrub/Shrub	Grassland/Herbaceous	Pasture/ Hay	Cultivated Crops	Woody Wetlands	Emergent Herbaceous Wetlands	Total
	1,199.0	422,914.2	260,253.1	69,532.0	37,858.4	22,132.8	18,067.9	10,728.6	300,915.5	15,339.8	1,755,508.2



- Urban ecosystem services (rainfall interception, urban heat island mitigation) for 768 cities >50,000 population
- Pollination in development, other ES to come
- New NLCD 2016 enables 2001 to 2016 time series

US NCA EA Results

National-scale ecosystem accounts



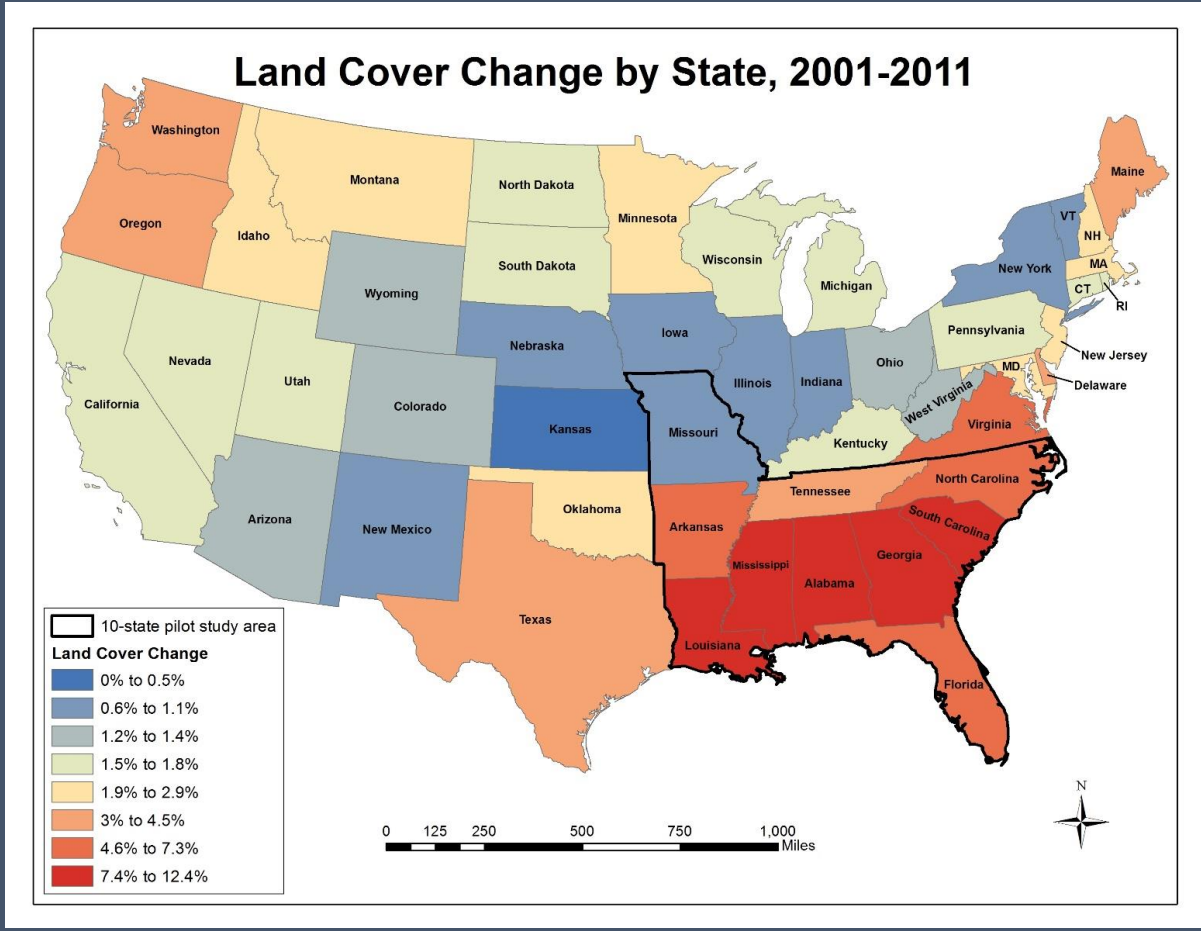
- Urban ecosystem services (rainfall interception, urban heat island mitigation)
- Pollination (in progress)
- Coastal storm protection (in progress)

Energy savings from urban trees, Atlanta MSA

Landcover	Sum Megawatt
Developed, Open Space	239.31
Developed, Low Intensity	1281.44
Developed, Medium Intensity	243.24
Developed, High Intensity	77.21
Barren Land (Rock/Sand/Clay)	-0.06
Deciduous Forest	0.48
Evergreen Forest	0.03
Mixed Forest	0.02
Shrub/Scrub	-0.26
Grassland/Herbaceous	0.16
Pasture/Hay	0.01
Cultivated Crops	0.08
Woody Wetlands	0.93
Emergent Herbaceous Wetlands	0.15
Sum	1688.32

Land accounts (Wentland et al. in review)

- Land cover (NLCD), land use (Theobald 2014) & land value (Zillow, through BEA)
- Value of land, excluding structures, its change over time
- *Potential uses:* Land-use planning, importance of public lands, multi-use planning



Land accounts – value

- National-scale hedonic model valuing land (price/ac) – incorporating aspects of its location, incl. value of ecosystem services
- State-level, aggregated to regions
- Census tract fixed effects allow location's influence to vary at fine scale

Table 4: Acreage, Total Value, and Average (Nominal) Price Per Acre by Census Division

		NLUD 2010	2002 - 2006		2007 - 2011		2012 – 2016	
		Total Acreage (000s)	Total Value ($Billions)	Average Price Per Acre ($)	Total Value ($Billions)	Average Price Per Acre ($)	Total Value ($Billions)	Average Price Per Acre ($)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
West Region	**Pacific**							
	Dense Urban Residential	237	1,101	4,649,537	702	2,965,103	939	3,966,882
	Urban Residential	2,415	2,890	1,196,770	1,599	662,202	2,577	1,067,320
	Suburban Residential	1,629	1,866	1,144,864	1,097	673,393	1,797	1,102,608
	Rural Residential	9,893	250	25,264	146	14,759	243	24,599
	Commercial	611	540	883,317	542	886,953	823	1,347,576
	Industrial	261	104	396,744	105	403,117	163	624,566
	Agricultural	78,480	453	5,768	433	5,517	651	8,292
	Mountain							
	Dense Urban Residential	81	244	3,005,093	158	1,944,110	210	2,585,526
	Urban Residential	1,383	1,424	1,030,013	782	565,687	1,462	1,057,383
	Suburban Residential	1,263	762	602,917	279	221,222	611	483,320
	Rural Residential	7,587	194	25,555	79	10,469	127	16,682
	Commercial	521	462	886,337	390	749,613	510	980,089
	Industrial	212	25	115,644	21	100,762	36	167,526
	Agricultural	218,751	2,324	10,622	2,232	10,204	2,382	10,890
Northeast Region	**West North Central**							
	Dense Urban Residential	49	104	2,115,213	74	1,511,599	108	2,191,092
	Commercial	311	145	467,459	139	447,803	189	606,056
	Industrial	151	27	180,631	27	177,656	42	279,811
	Agricultural	21,632	90	4,141	81	3,721	105	4,840
	New England							
	Dense Urban Residential	61	233	3,797,030	172	2,796,648	302	4,916,635
	Urban Residential	669	738	1,102,908	493	737,141	888	1,327,517
	Suburban Residential	1,176	399	339,247	242	205,434	601	510,792
	Rural Residential	10,836	223	20,599	166	15,338	303	28,006
	Commercial	196	68	345,794	63	319,192	92	470,474
	Industrial	90	34	374,333	20	225,877	40	441,306
	Agricultural	15,761	405	25,670	283	17,967	116	7,345
	U.S. National Totals	***1,264,975***	***$33,681***	***$26,626***	***$24,173***	***$19,109***	***$33,888***	***$26,789***

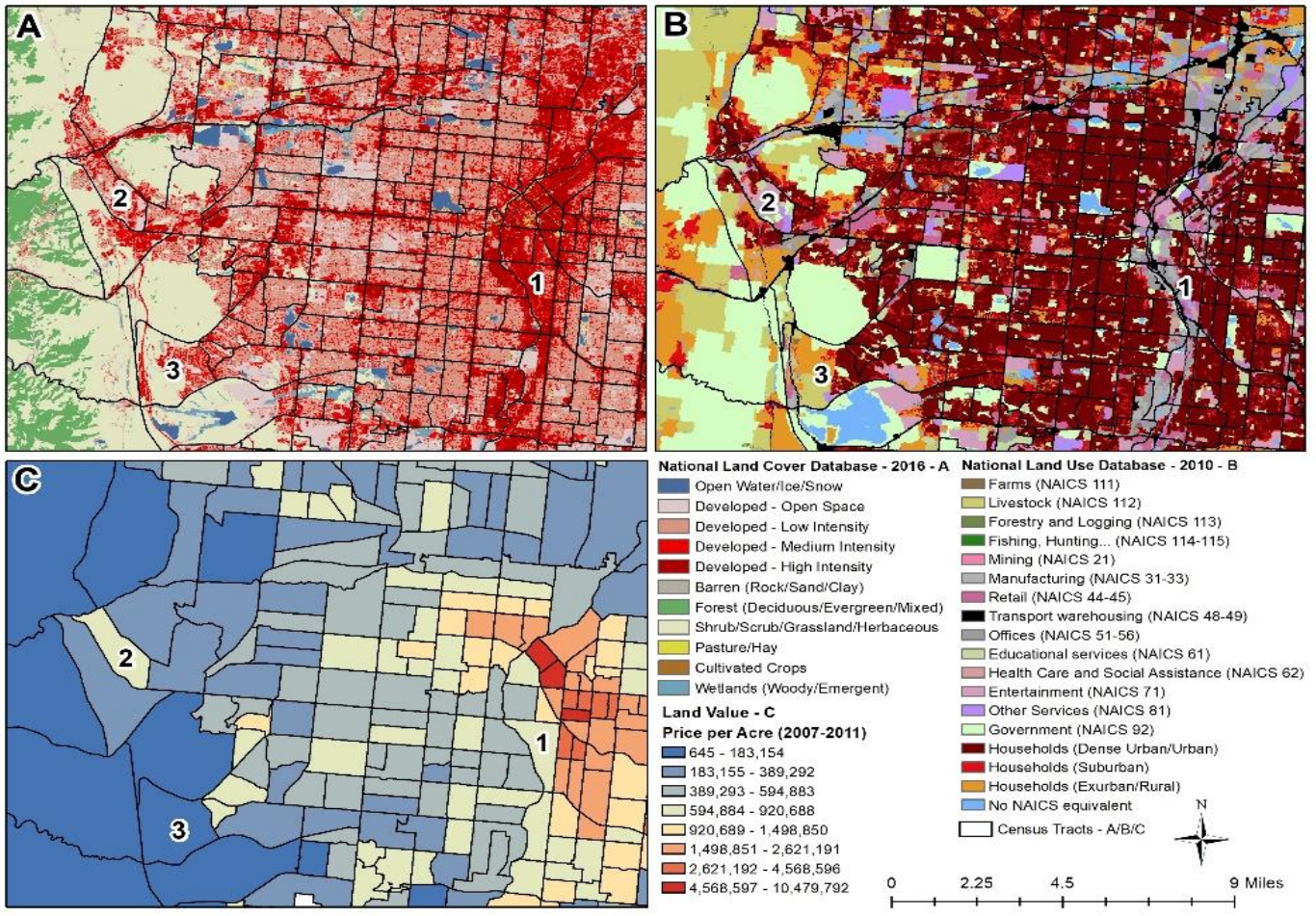
$$Residential\ Property\ Sale\ Price_{ijt} = \alpha + \sum \beta\, X_i + \gamma LOCATION_j + \sum \delta\, sq.ft._i * LOCATION_j + \sum \varphi\, acreage_i * LOCATION_j + \rho TIME_t + \varepsilon$$

US NCA EA Results

Wentland et al., in revision

Table 4: Acreage, Total Value, and Average (Nominal) Price Per Acre by Census Division

		NLUD 2010 Total Acreage (000s)	2002 - 2006 Total Value ($Billions)	2002 - 2006 Average Price Per Acre ($)	2007 - 2011 Total Value ($Billions)	2007 - 2011 Average Price Per Acre ($)	2012 – 2016 Total Value ($Billions)	2012 – 2016 Average Price Per Acre ($)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
West Region	**Pacific**							
	Dense Urban Residential	237						
	Urban Residential	2,415						
	Suburban Residential	1,629						
	Rural Residential	9,893						
	Commercial	611						
	Industrial	261						
	Agricultural	78,480						
	Mountain							
	Dense Urban Residential	81						
	Urban Residential	1,383						
	Suburban Residential	1,263						
	Rural Residential	7,587						
	Commercial	521						
	Industrial	212						
	Agricultural	218,751						
	West North Central							
	Dense Urban Residential	49						



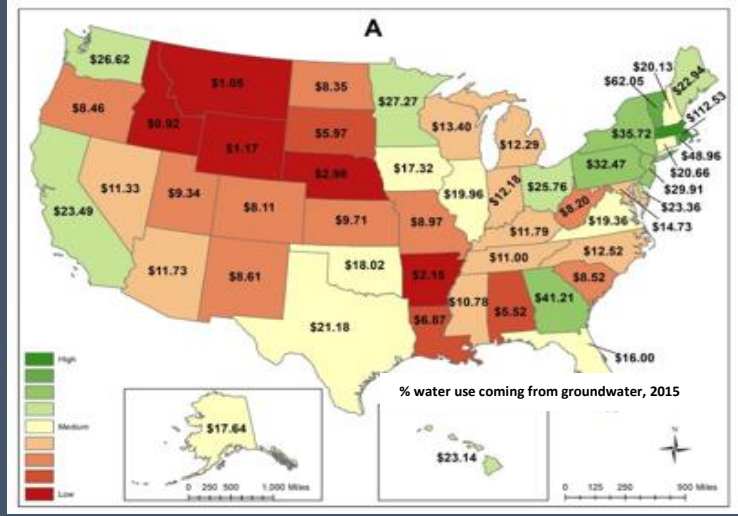
Water accounts
(Bagstad et al. in review)

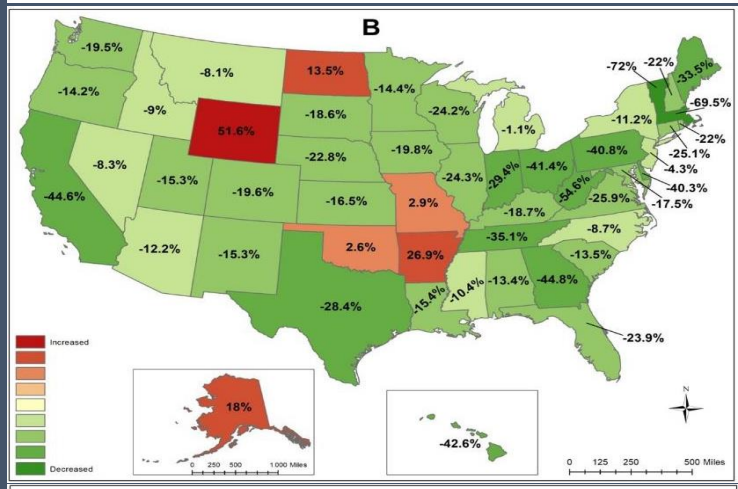
A) Water productivity (economic activity/100 gal water use);

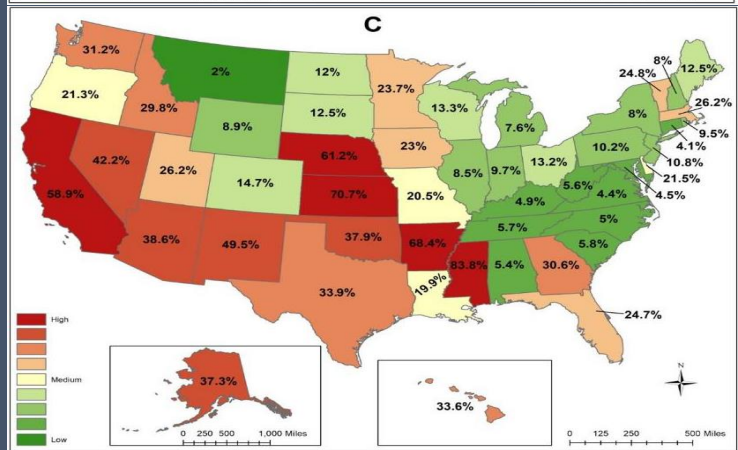
B) % change in water use, 2000-2015;

C) % of state water use from groundwater

- Data on water quality & emissions
- Identified data gaps in comprehensive water accounts for the U.S.
- *Potential uses:* In other countries supported water allocation, pricing, etc. (Colorado River account prepared by BOR)







US NCA EA Results

Water accounts tables

Year	11. Agriculture, Forestry, Fishing, and Hunting			21. Mining	2211. Electric Power Generation, Transmission and Distribution			2213. Water, Sewage & Other (Irrigation)		31-33. Manufacturing	713910. Golf Courses and Country Clubs	Households (Domestic self-supply)	Total
	111. Crop Production (Irrigation)	112. Animal Production (Livestock)	1125. Aquaculture		Thermoelectric Power (Once-through cooling)	Thermoelectric Power (Closed-loop cooling)	Hydroelectric (Evaporative Use)	221310. Water supply (Public supply)	221320. Sewage treatment facilities (Wastewater)				
2000	138,172.2	2,362.1	5,792.9	4,129.6	174,307.8	18,395.4	14,630.1	42,740.8	N/R	19,496.6	1,971.2	3,576.3	425,575.0
2													
2													
2													

	11. Agriculture, Forestry, Fishing, and Hunting			21. Mining[b]	2211. Electric Power Generation, Transmission and Distribution			2213. Water, Sewage & Other (Irrigation)		31-33. Manufacturing[b]	713910. Golf Courses and Country Clubs	Households (Domestic)	Total
	111. Crop Production (Irrigation)	112. Animal Production (Livestock)	1125. Aquaculture[b]		Thermoelectric Power (Once-through cooling)	Thermoelectric Power (Closed-loop cooling)	Hydroelectric (Evaporative Use)[a]	221310 Water supply (Public supply)[b]	221320 Sewage treatment facilities (Wastewater)[b]				
A. Water Use													
1. Total abstraction	117,018.2	2,093.8	7,450.0	3,996.4	126,110.2	5,027.0	14,113.8	38,419.3	N/R	14,784.0	1,445.1	3,255.8	333,713.3
1.i.1. Surface Water, of which is	60,338.5	868.6	5,839.4	1,132.2	125,986.1	4,555.4	14,113.8	23,268.4	N/R	12,076.9	754.4	46.6	248,980.2
Fresh	60,338.5	868.6	5,833.1	876.5	90,621.6	4,085.0	14,113.8	23,264.6	N/R	11,334.0	754.4	46.6	212,136.5
Saline	0.0	0.0	6.3	255.7	35,364.5	470.5	0.0	3.9	N/R	742.9	0.0	0.0	36,843.7
1.i.2. Ground Water, of which is	56,679.7	1,225.2	1,610.7	2,864.2	124.1	471.5	0.0	15,150.8	N/R	2,707.1	690.7	3,209.2	84,733.1
Fresh	56,679.7	1,225.2	1,610.7	1,004.1	80.8	342.5	0.0	14,887.7	N/R	2,664.2	690.7	3,209.2	82,394.6
Saline	0.0	0.0	0.0	1,860.1	43.4	129.0	0.0	263.1	N/R	42.9	0.0	0.0	2,338.5
2. Use of water from other economic units	0.0	0.0	0.0	0.0	51.8	112.3	0.0	0.0	N/R	376.2	0.0	22,952.4	23,492.7
Reclaimed wastewater	654.7	0.0	0.0	0.0	8.2	141.2	0.0	331.0	N/R	92.9	266.6	0.0	1,494.7
3. Total use of water	117,672.8	2,093.8	7,450.0	3,996.4	126,170.3	5,280.5	14,113.8	38,750.3	N/R	15,253.1	1,711.7	26,208.1	358,700.7
B. Water supply													

	Industries (by NAICS 2017 category)															Other industries*	Total	% as other industries
	211. Oil & Gas Extraction	212. Mining (Except Oil & Gas)	2211. Electric Power Generation	221310. Water supply & irrigation systems	221320. Sewage Treatment Facilities	311. Food Manufacturing	312. Beverage & Tobacco Product Manufacturing	321. Wood Product Manufacturing	322. Paper Manufacturing	325. Chemical Manufacturing	326. Plastics & Rubber Products Manufacturing	488. Support Activities for Transportation	493. Warehousing & Storage	562. Waste Management & Remediation Services	721. Accommodation			
Nitrogen	1,959	176	30,800	4,625	1,707,044	9,076	224	2,305	4,477	11,390	690	2,745	276	41,457	1,713	61,160	1,880,116	3.3%
Phosphorus	1,813	1,080	3,518	278	229,370	46,984	483	67	3,062	4,483	22,353	57	1	53	7,846	2,468	323,917	0.8%
Organic enrichment	17,864	1,528	7,921	1,878	794,385	126,283	58,362	63,112	221,832	31,190	32,722	32,693	102,963	89,413	7,771	213,202	1,803,117	11.8%
Solids	31,839	47,734	815,669	1,413,230	2,402,702	256,620	4,365	189,360	319,346	291,293	937,321	268,139	5,059	305,549	15,089	3,023,845**	10,327,160	29.3%
Metals	84,022	94,431	53,179	15,175,582	486,175	9,731	82	361	1,338	4,025	8	97,101	73	60,816	21	184,521	16,251,467	1.1%

Early Movers:

1. Millennium Ecosystem Assessment (2005); ES only, no accounts
   "4 Types": Supporting | Provisioning, Regulating, Cultural
   - vocabulary dominant – by first mover consensus, *not* by function for task
   - few aware why their measures will not fit ES supply-and-use tables …
   - building institutional momentum before addressing technical issues

2. World Bank – Wealth Accounting and Valuation of Ecosystem Services
   - major report: Changing Wealth of Nations 2018
   - further WAVES activities to build accounts awaits funding

Right Now:

3. Netherlands, United Kingdom, Germany, EU Joint Research Council and KIP INCA, Norway, et alia
   - continue to lead and innovate, with national and EU funding
   - China is gaining ground quickly, with academics and officials

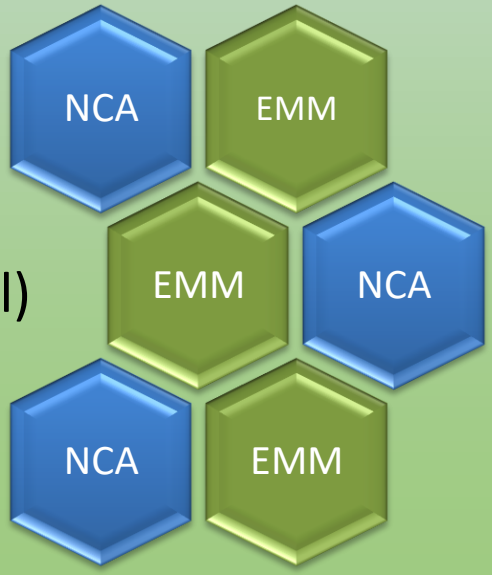
Right Now (cont'd):

4. World Business Council for Sustainable Development / Natural Capital Protocol
   - private-sector interest is growing rapidly, and in large accounting firms
   - compatibility issues with government standard-setting practices?

5. German Federal Agency for Nature Conservation (Bundesamt für Naturschutz)
   "Expert Meeting on Ecosystem Valuation in the Context of Natural Capital Accounting"
   - Economists and accountants are close partner fields, so ecosystem accounting can easily use 30 years of environmental economists' value estimates?
   - No! – Germans, as a world leader, host "Expert Meeting" to discuss (Bonn, 2018)
   - Bottom line: the values can be applied, but not directly, and only when crunched back through core economic theory

The Future is Here, for Those Who Build It:

6. Proactive modeling and data providers
   - *NASA, European Space Agency, ARIES* (USGS and global)
   - Working with potential modeling and data clients to develop own work and to increase demand for own modeling and data products



Take-Away Lessons

Leveraging "what to model/measure?" into a proven powerful framework

Lesson 1: Influence for decision makers, adaptive management, makes NCA framing attractive

Lesson 2: Frameworks require rigorous rules & feedback, including classifications & definitions – faithfulness to organizing frameworks is important

Lesson 3: Pause and discuss when deciding "what to measure?" when passing the baton to specific users

Lesson 4: What you actually measure vs. what you want to can change where your results fit in NCA framework

Lesson 5: If you think it is important to measure, it will be useful somewhere, even if not where you thought

Lesson 6: You can keep your complex models, but NCA wants stock and flow numbers in its tables, est.'d averages over ecosystem and economic units over a year

US NCA *BioScience* paper:
https://www.researchgate.net/publication/329554563_The_Natural_Capital_Accounting_Opportunity_Let's_Really_Do_the_Numbers;

UN Statistics Division SEEA EEA Technical Recommendations:
https://seea.un.org/sites/seea.un.org/files/Presentations/Training_China_2017/seea_eea_tech_rec_final_v3.2_16oct2017.pdf;

La Notte and Rhodes 2020 - Theoretical frameworks behind integrated environmental, ecosystem, and economic accounting systems and their classifications

German Federal Agency for Nature Conservation (Bundesamt für Naturschutz), conference website in English:
https://seea.un.org/events/expert-meeting-ecosystem-valuation-context-natural-capital-accounting

World Bank Forum on Natural Capital Accounting for Policy Decisions:
http://documents.worldbank.org/curated/en/904211580129561872/pdf/Forum-on-Natural-Capital-Accounting-for-Better-Policy-Decisions-Taking-Stock-and-Moving-Forward.pdf

World Bank: Changing Wealth of Nations 2018

UN Environment Program, World Conservation Monitoring Centre, Natural Capital Report:
https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/377/original/Natural_Capital_Report_WEB.pdf?1460119504

US EPA National Ecosystem Services Classification System (*NESCS*; currently being upgraded to an online tool as *NESCS Plus*):
https://www.epa.gov/sites/production/files/2015-12/documents/110915_nescs_final_report_-_compliant_1.pdf

USGS et al., *ARIES* modeling platform: Artificial Intelligence for Ecosystem Services (ARIES) modeling framework

NASA's Biodiversity and Ecological Forecasting program

Reserve Slides Below

Return to Intro

Without measures of economic aggregates like GDP, policymakers would be adrift in a sea of unorganized data. The GDP and related data are like beacons that help policymakers steer the economy toward the key economic objectives.

Paul Samuelson,* 1995

[The Human Development Index] is people-centered … GDP is commodity-centered.

Amartya Sen,* 2010

GDP tells you nothing about sustainability.

Joseph Stiglitz,* 2008

(GDP) measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country. It measures everything in short, except that which makes life worthwhile.

Robert F. Kennedy, 1968

*Nobel Prize recipient

Cite: https://ec.europa.eu/environment/beyond_gdp/key_quotes_en.html

Ecosystem Services: Groupings and Classifications

Millennium Ecosystem Assessment (MA) – Four Groups

The Economics of Ecosystems and Biodiversity (TEEB) – ES are not Benefits

Common International Classification of Ecosystem Services (CICES, v 5.1) – Hierarchy

Final Ecosystem Services Classification System (FEGS-CS) *and* National Ecosystem Services Classification System (NESCS) – conscious break from MA-based approach

- **Ecological conditions and functions** (e.g. habitat)
- **Ecological end-products** (e.g., biophysical elements)
- **Economic activity/Use of ES** (e.g., hunting)
- **Benefits** (e.g., lower insurance premiums)

UK National Capital Accounting (NCA) – final ES elements

China National Capital Accounting (NCA) – final ES elements

Nature's Contribution to People (NCP)

Why a National Ecosystem Services Classification (NESCS)?

Boyd and Banzhaf (2007): ***Final Ecosystem Services***

"… are components of nature, directly enjoyed, consumed, or used to yield human well-being."

- separate *ecosystem* services from *economic* services
- count only those ES that directly enter the human economy, at the point they do

From an "FES perspective," consider:

- at the point that they enter human systems "ecological endpoints" *have no price* – no human pays nature for birdsong, seashells, or soil productivity
- *crops* are *not* final ecosystem services
  - cultivars are joint products of ecosystem and economic inputs
  - crop value *can* be used as a crude measurement proxy for a suite of ecosystem services…until better measures developed

Core Features for a Desirable Final Ecosystem Services Classification System

Exhaustive and Mutually Exclusive

uniquely identifies all **structures, processes, functions, and products of natural systems (separate from human-driven systems) that humans use or appreciate**

Non-Duplicative

focuses attention and measurement **on those ecosystem services that humans use or appreciate directly (*final* versus intermediate *ecosystem services*), *to avoid double-counting***

Practical for Users

groups or separates candidate elements in a way easy to conceive and use, with clear definitions, and rules for classifying that appeal across disciplines and users –
avoiding overwhelming complexity, confusion, fuzzy classification boundaries, and thus avoiding divergent choices for similar cases by similar users

Helpful for Selecting Appropriate Metrics

uniquely identifying **the environment, the precise flows of ecosystem services, the users, and how they use the ES, all**
help to determine what ecologists and economists should measure

Wish List:

Modular

a "bonus" for practical use, if system interfaces with other standard classification systems or ecosystem service tools without extensive exceptions and patching

Appropriate to be a Standard

a "bonus" for practical use, if system is stable, its rules for use are well-explained, and it is practical enough to serve as the standard for many types of applications

Proposed 4-Group NESCS Structure – "Wiring Diagram" with Proposed Metrics By Group

Example: (a) lake, river, or stream water for drinking – m^3 fresh water (m3frshw)

(b) same water in composite viewing environment – degree natural/unbuilt