System of
Environmental
Economic
Accounting

Introduction to Land and Ecosystem Extent Accounts

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Contents

- Why account for land and ecosystem extent accounts?

- Land accounts

- Ecosystem extent accounts

- Ecosystem extent account examples

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Why account for land and ecosystem extent?

- Answers wide range of policy questions→ from urban planning, to conservation and beyond

- Land and ecosystem accounts can inform multiple (inter)national initiatives

- Post-2020 Global Biodiversity Framework
  > E.g. Goal A: Integrity of all ecosystems is enhanced, increase in area of natural ecosystems

- Sustainable Development Goals
  > E.g. 15.3.1: Proportion of land that is degraded over total land area

Land accounts

Land cover

- *The observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces*

- Current land cover is a function of natural changes in the environment and of previous and current land use

- Interim land cover classification based on FAO Land Cover Classification System

- Often misinterpreted or combined with land use

	Category
1	Artificial surfaces (including urban and associated areas)
2	Herbaceous crops
3	Woody crops
4	Multiple or layered crops
5	Grassland
6	Tree covered areas
7	Mangroves
8	Shrub covered areas
9	Shrubs and/or herbaceous vegetation, aquatic or regularly flooded
10	Sparsely natural vegetated areas
11	Terrestrial barren land
12	Permanent snow and glaciers
13	Inland water bodies
14	Coastal water bodies and inter-tidal areas

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Land use

- Land use
  - > *reflects both (i) the activities undertaken and (ii) the institutional arrangements put in place; for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions*

- Accounts include land in use (human intervention) and land not in use

- Categories not defined on economic activity, but rather general purpose and role of the user of the area
  - > Often aligns with scope of economic activity, but not always
  - > If multiple uses, go with primary/dominant use

1	**Land**
1.1	Agriculture
1.2	Forestry
1.3	Land used for aquaculture
1.4	Use of built up and related areas
1.5	Land used for maintenance and restoration of environmental functions
1.6	Other uses of land n.e.c.
1.7	Land not in use
2	**Inland waters**
2.1	Inland waters used for aquaculture or holding facilities
2.2	Inland waters used for maintenance and restoration of environmental
2.3	Other uses of inland waters n.e.c.
2.4	Inland waters not in use

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Land account: basic form

	Artificial surfaces	Crops	Grassland	Tree-covered area	Mangroves	Shrub-covered area	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow, glaciers and inland water bodies	Coastal water and inter-tidal areas
Opening stock of resources	12 292.5	445 431.0	106 180.5	338 514.0	214.5	66 475.5	73.5	1 966.5		12 949.5	19 351.5
Additions to stock											
Managed expansion	183.0	9 357.0									
Natural expansion			64.5								1.5
Upward reappraisals			4.5								
Total additions to stock	183.0	9 357.0	69.0								1.5
Reductions in stock											
Managed regression		147.0	4 704.0	3 118.5	9.0	1 560.0	1.5				
Natural regression					1.5	64.5					
Downward reappraisals						4.5					
Total reductions in stock		147.0	4 704.0	3 118.5	10.5	1 629.0	1.5				
Closing stock	12 475.5	454 641.0	101 545.5	335 395.5	204.0	64 846.5	72.0	1 966.5		12 949.5	19 353.0

- Land cover
  - Managed→ due to human activity
  - Natural→ resulting from natural processes
  - Reappraisals→ reflect changes due to use of updated information (e.g. new satellite imagery)

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Example South Africa

- Most countries only distinguish additions and reductions

Broad land cover classes (tier 1)	Natural or semi-natural	Cultivated	Built-up	Waterbodies*	TOTAL
Opening stock 1990	**100 710 016**	**16 156 026**	**3 003 883**	**2 096 528**	**121 966 453**
Additions to stock	3 366 559	1 991 959	597 238	288 754	6 244 510
Reductions in stock	2 540 175	2 339 226	400 503	964 606	6 244 510
Net change in stock	826 384	(347 267)	196 735	(675 852)	
Net change as % of opening	**0.8%**	**-2.1%**	**6.5%**	**-32.2%**	
Unchanged (opening - reductions)	98 169 841	13 816 800	2 603 380	1 131 922	
Unchanged as % of opening	97.5%	85.5%	86.7%	54.0%	
Turnover (additions + reductions)	5 906 734	4 331 185	997 741	1 253 360	
Turnover as % of opening	5.9%	26.8%	33.2%	59.8%	
Closing stock 2014	**101 536 400**	**15 808 759**	**3 200 618**	**1 420 676**	**121 966 453**

Source: Statistics South Africa 2020

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Land account: change matrix

Land cover change matrix (hectares)

Opening land cover	Closing land cover					Opening stock
	Artificial surfaces (urban)	Herbaceous crops	Grassland	Inland water bodies	Shrubs..regularly flooded (w	
Artificial surfaces (urban)	20	0	0	0	0	20
Herbaceous crops	3	142	8	0	0	153
Tree-covered areas	0	2	88	0	0	90
Inland water bodies	0	0	0	19	0	19
Shrubs..regularly flooded (wetland	0	1	0	0	5	6
Closing stock	**23**	**145**	**96**	**19**	**5**	**288**

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Land account change matrix: example India

- Important to remember: these are NET changes/conversions!

Table 1: Extent account for India's land use and land cover between 2011-12 and 2015-16
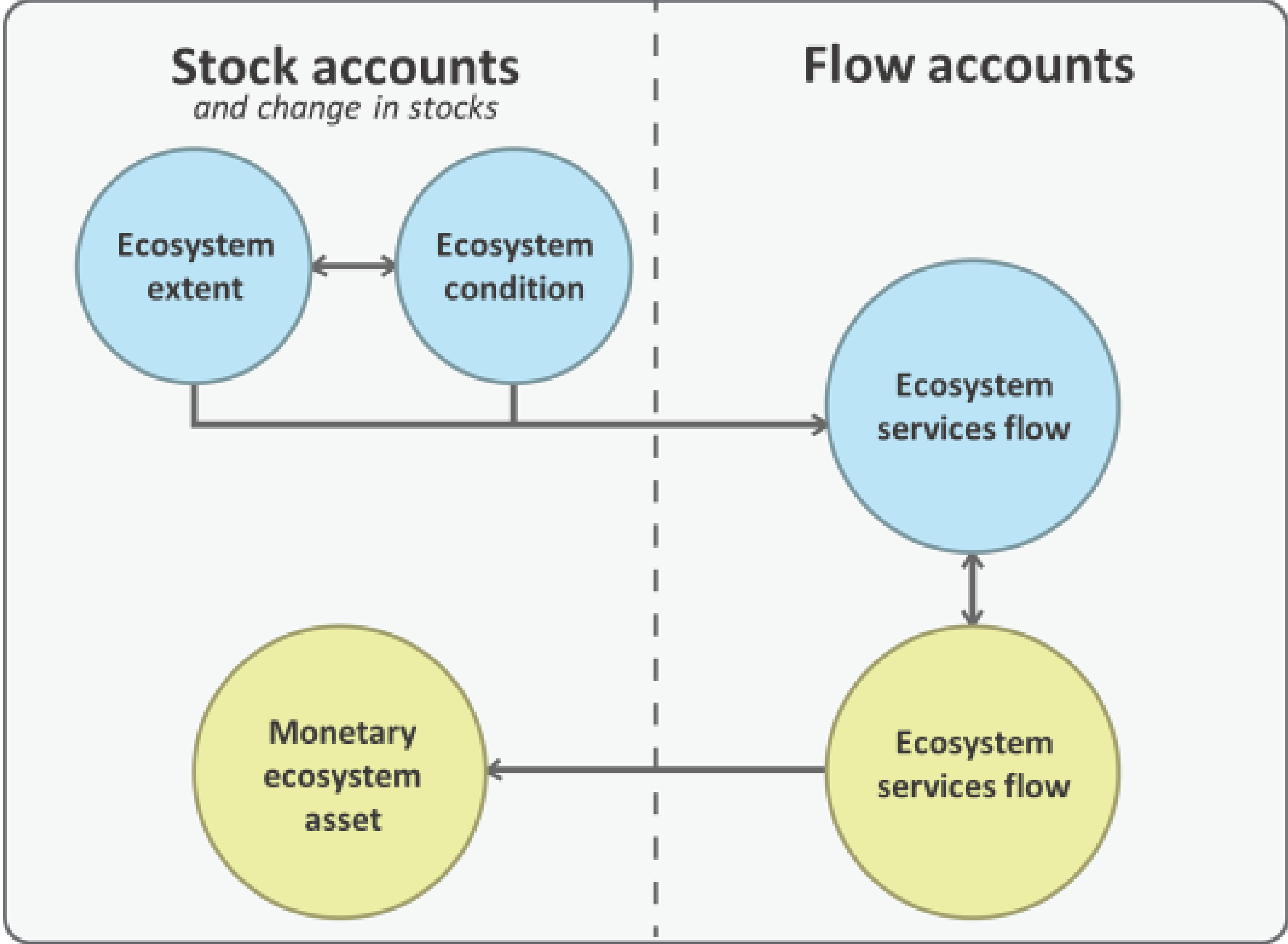
Land use / land cover classes		2015-16							Grand total (2011-12)	
		Agriculture	Barren / un-culturable	Built-up	Forest	Grass / grazing	Snow and glacier	Wetlands / water bodies	Area	% of geo-graphic area
2011-12	Agriculture	1,809,033	5,103	2,648	2,299	94	8	2,547	**1,821,732**	**55.41**
	Barren / unculturable	4,237	348,460	589	2,285	61	68,471	614	**424,717**	**12.92**
	Built-up	238	442	118,239	48	2	0	29	**118,998**	**3.62**
	Forest	5,085	6,838	205	712,342	207	637	230	**725,543**	**22.07**
	Grass / grazing	147	408	118	368	22,502	1,333	521	**25,397**	**0.77**
	Snow and glacier	0	1,643	0	131	7	30,799	1	**32,581**	**0.99**
	Wetlands / water bodies	2,536	966	49	155	679	77	133,833	**138,294**	**4.21**
Grand total (2015-16)	Area	**1,821,276**	**363,860**	**121,848**	**717,629**	**23,551**	**101,325**	**137,774**	**3,287,263**	**99.99**
	% of geo-graphic area	**55.40**	**11.07**	**3.71**	**21.83**	**0.72**	**3.08**	**4.19**		**99.99**

Ecosystem accounts

Conceptual Framework
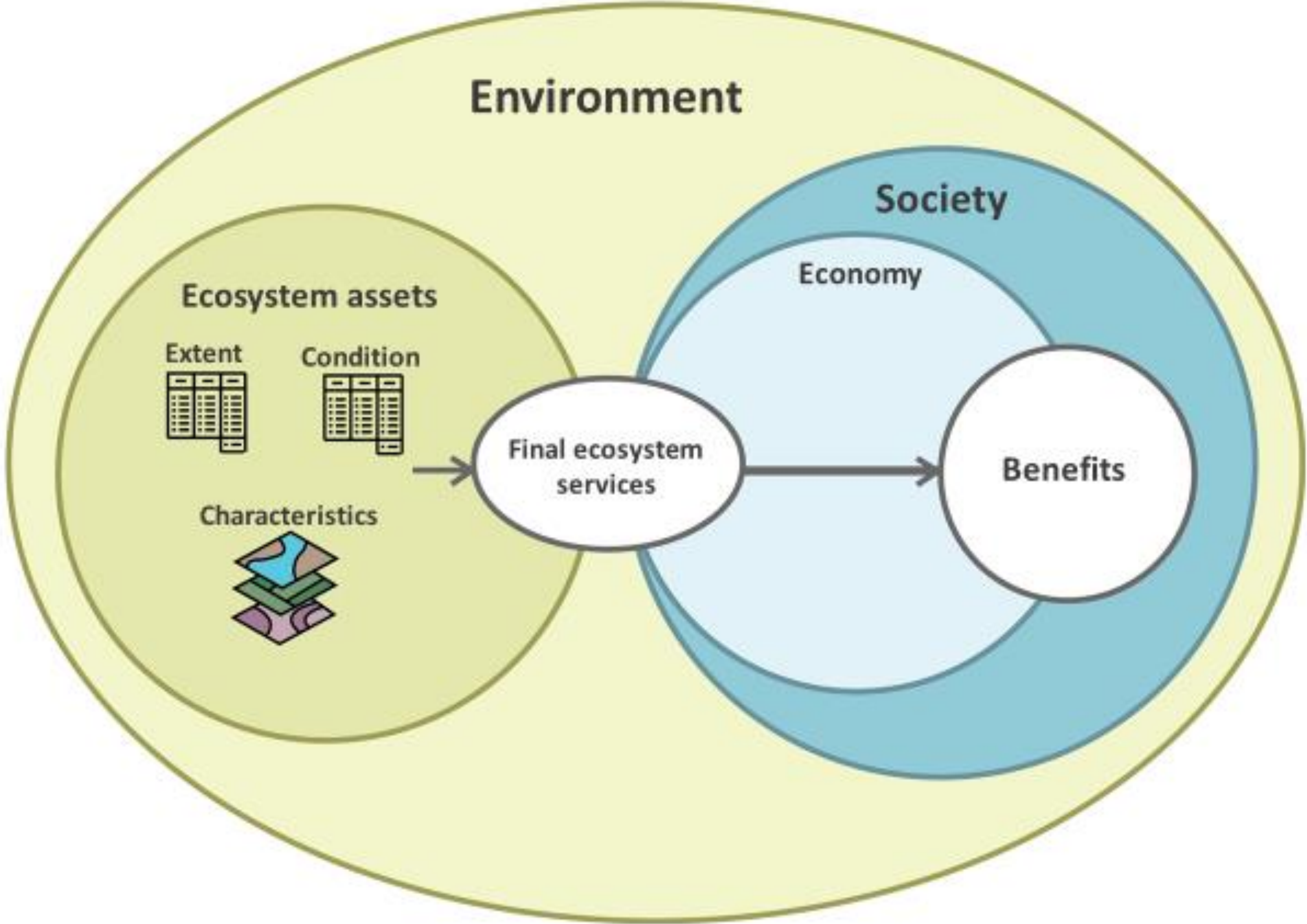
Ecosystem accounts

Ecosystem accounting area (EAA)

EA2 (ET2)
e.g., urban area

EA3 (ET3)
e.g., cropland

EA1 (ET1)
e.g., forest

EA4 (ET4)
e.g., lake

EA5 (ET2)
e.g., urban area

EA6 (ET3)
e.g., cropland
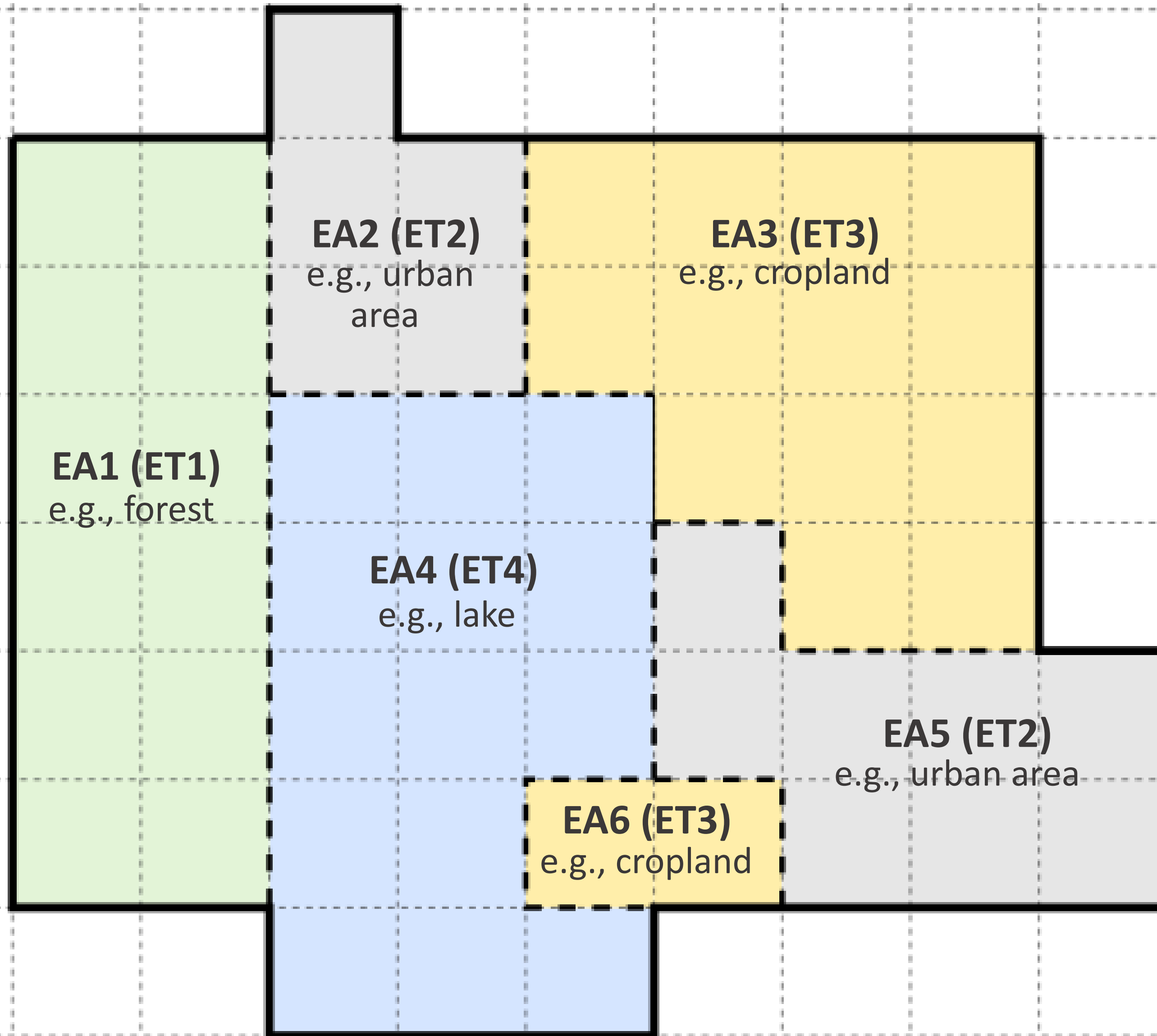
Basic spatial unit (BSU)

Ecosystem extent accounts

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Linking land cover and ecosystem accounting

- Both are spatially explicit

- Land accounts, particularly land cover, are a basis for ecosystem accounting

- For terrestrial and freshwater areas, should be a reasonable concordance between land cover and ecosystem extent

- But key differences between land cover and ecosystems
  - > Definition of ecosystems in SEEA EA: *a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit*
  - > vs. definition of land cover: *the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces*

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Land accounts vs ecosystem extent accounts

- Land cover is a fundamental layer, but extent requires more.
  - Identification of ecosystem types through delineation of various ecosystem characteristics (temperature, aridity, topography/elevation maps)
  - Example: land cover = trees; temperature > 18 C = tropical forest
- IUCN GET (Global Ecosystem Typology) as reference classification of SEEA EA
  - Hierarchical
  - Ecosystems represented by ecosystem functional groups
  - Ecosystem functional groups: *group of related ecosystems within a biome that share common ecological drivers, which in turn promote similar biotic traits that characterise the group. Derived from the top-down by subdivision of biomes.*

IUCN Global Ecosystem Typology 2.0
Descriptive profiles for biomes and ecosystem functional groups
David A. Keith, Jose R. Ferrer-Paris, Emily Nicholson and Richard T. Kingsford (editors)

Ecosystem types

- 6 levels – accounts are compiled at 3rd level of Ecosystem Functional Groups (EFGs)

- Realms (terrestrial) -> biomes (tropical forest) -> Ecosystem Functional Groups (EFGs) -> montane tropical forest

IUCN Global Ecosystem Typology 2.0
Descriptive profiles for biomes and ecosystem functional groups
David A. Keith, Jose R. Ferrer-Paris, Emily Nicholson and Richard T. Kingsford (editors)
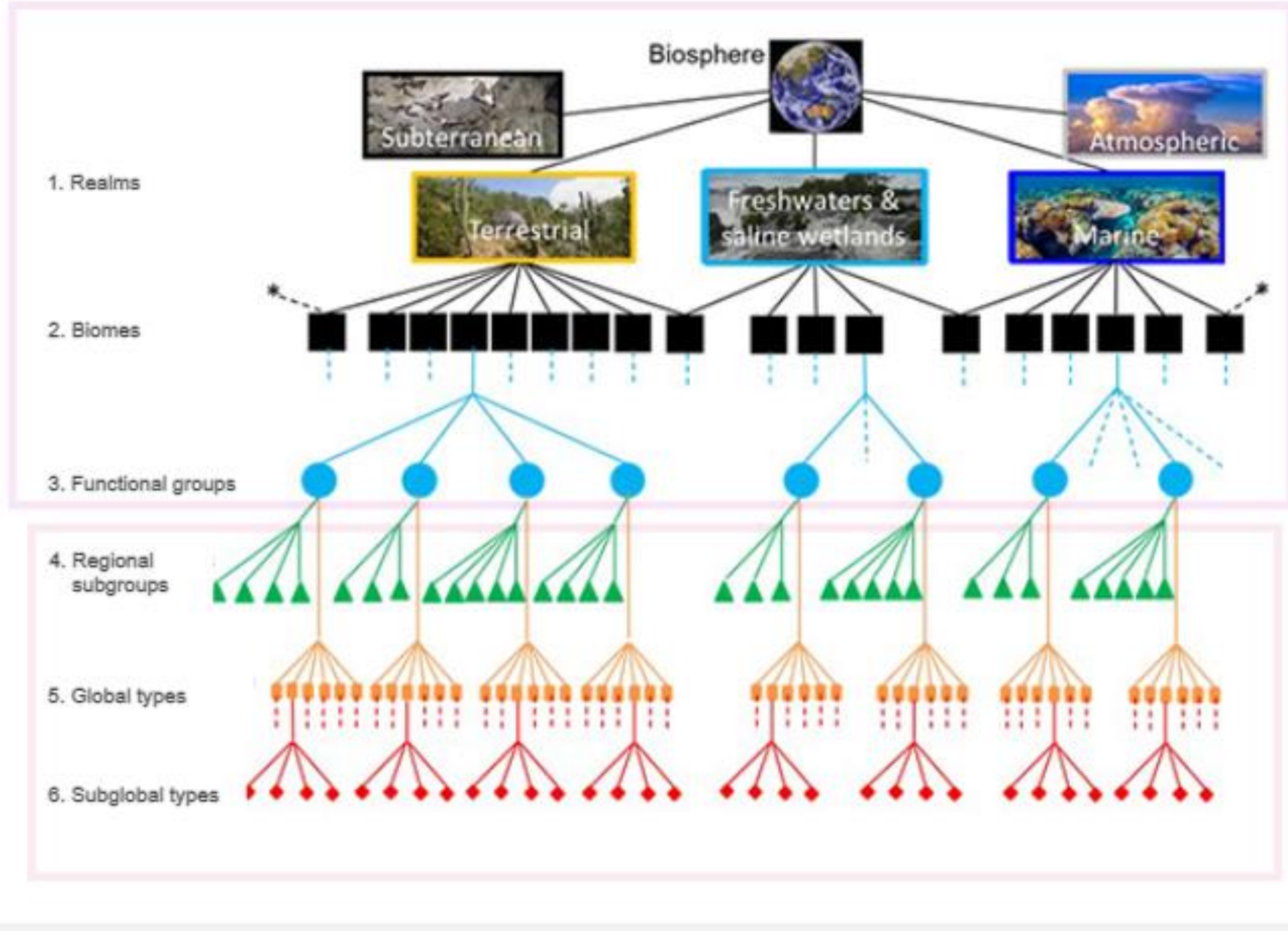
- 110 EFGs
  - 34 terrestrial
  - 22 freshwater
  - 24 marine
  - 3 subterranean
  - 27 in transitional realm

- 15 of 110 are anthropogenic

Ecosystem types   https://global-ecosystems.org/explore
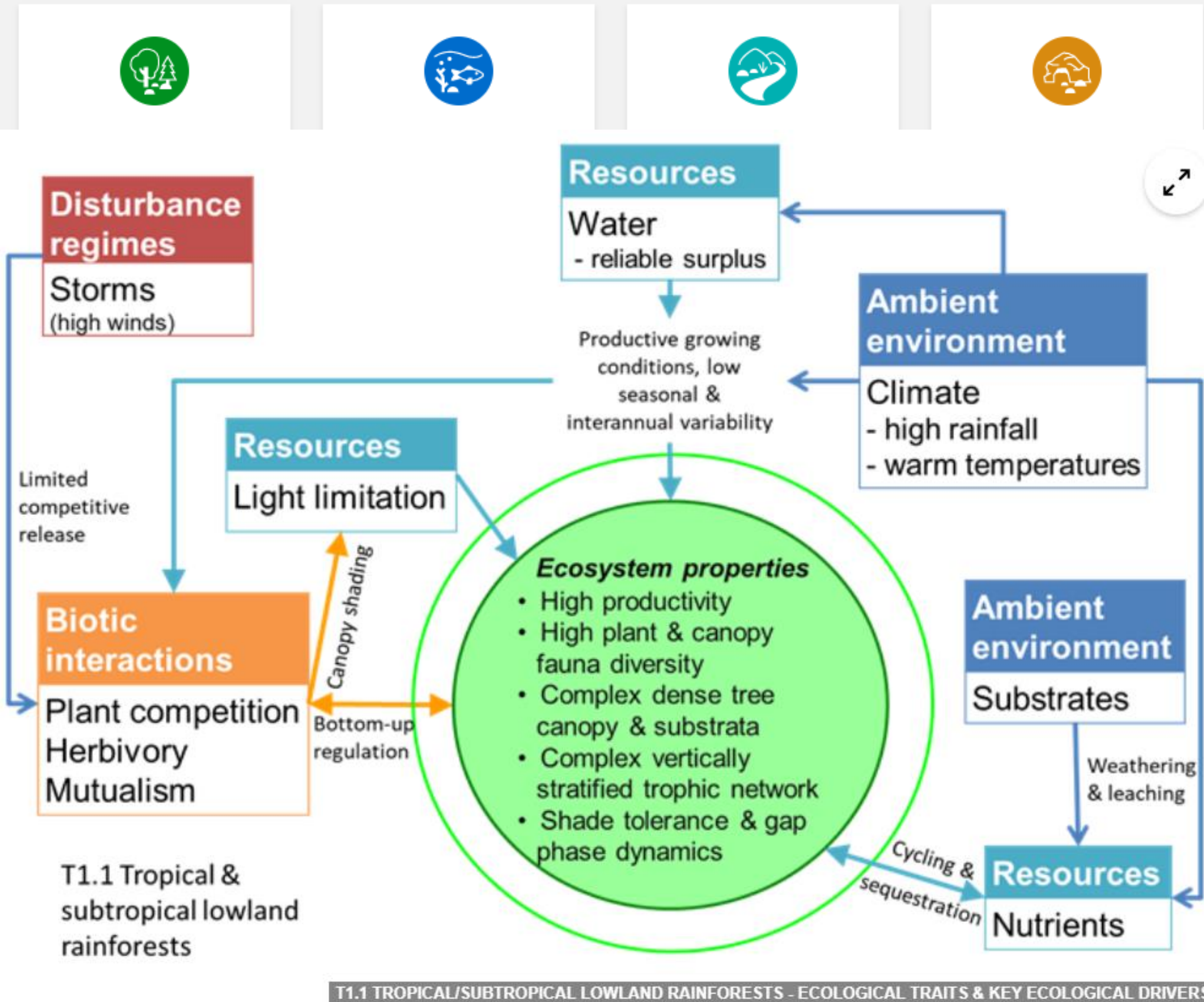
- Probabilistic maps with major and minor occurrences
- Can show if an ecosystem is **likely** found in your country
- Description of ecosystem properties, ecological drivers, global distribution

Integrating local classifications into the GET framework

Scaling up & scaling down

- Level 6 –placeholder for established national/subnational/regional classifications

- Established national-regional classifications
  - Built from local evidence base – reliable and country-owned
  - Often integrated into policy & decision-making
  - But not internationally comparable

- Each Level 6 unit can be assigned to an EFG (Level 3) by matching its functional features (e.g. key drivers and traits)

National Vegetation Map
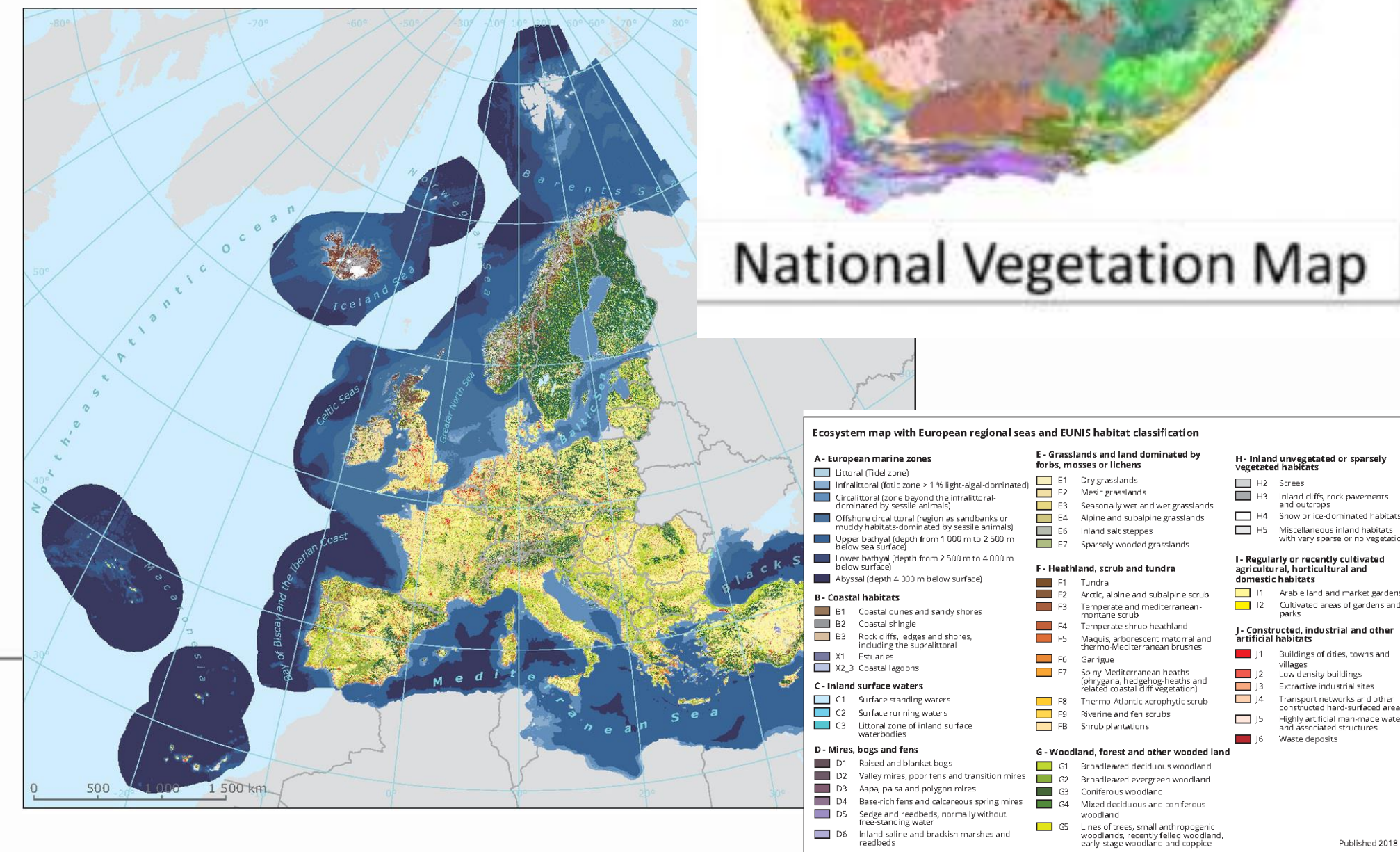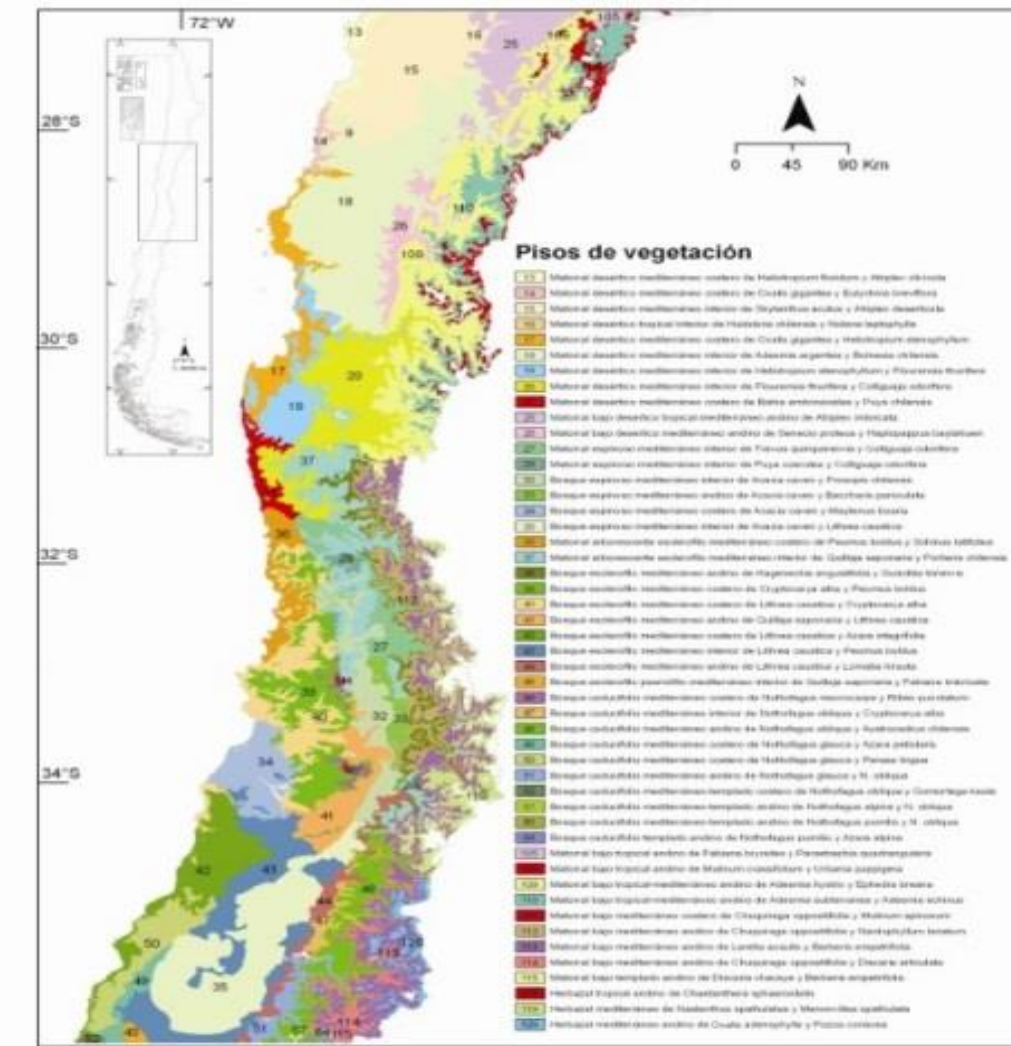
Source: Nicholson, E, et. Al. (2022), Presentation on Forests in the IUCN Global Ecosystem Typology at the SEEA EA Forest Working Group meeting
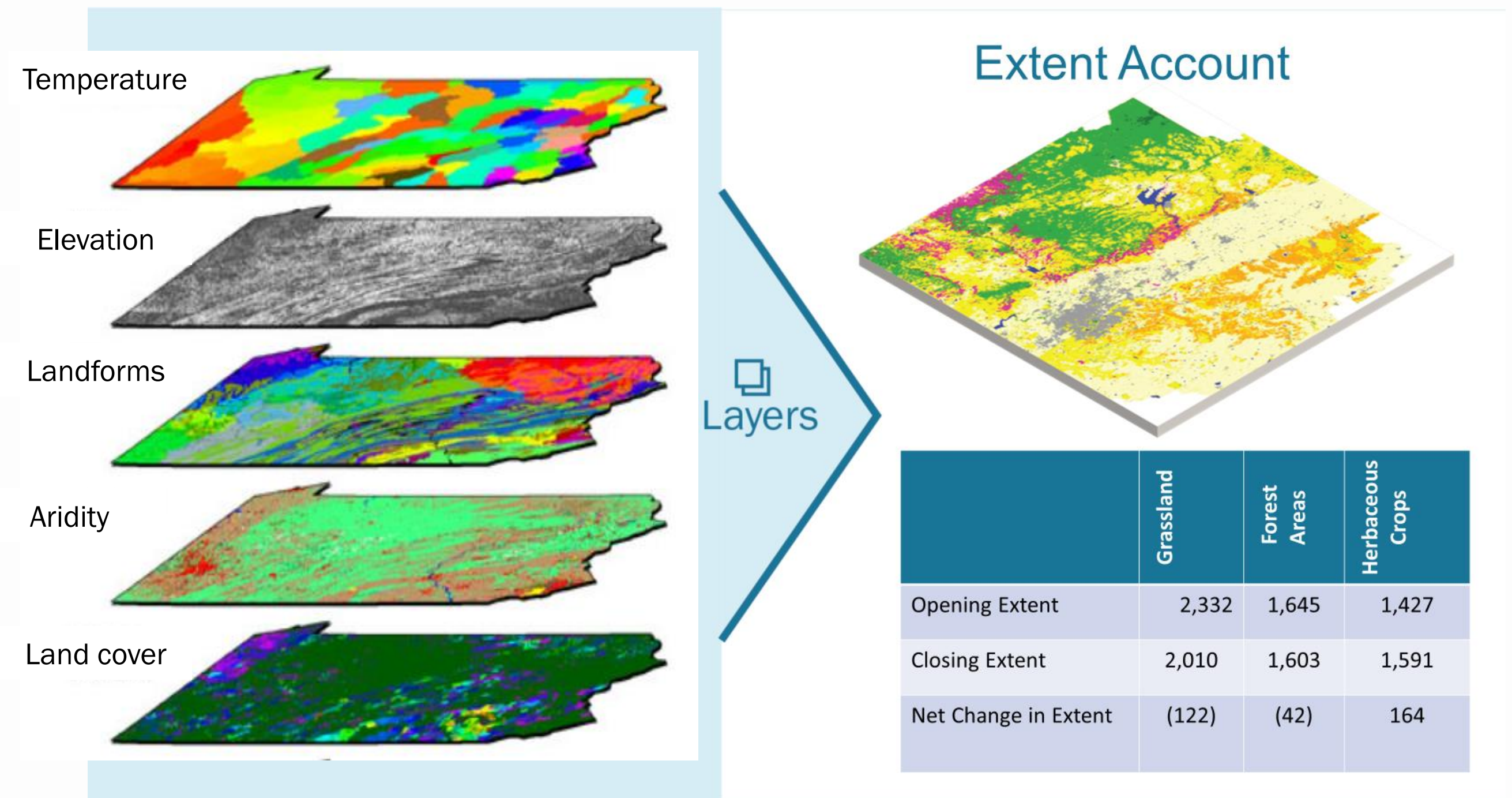
Ecosystem extent account

		Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																TOTAL
Realm		Terrestrial											Freshwater			Marine		
Biome		T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...			T7	F1	...	FM1	M1	...	MFT1	
Selected Ecosystem Functional Group (EFG)		Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Deriived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	
		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	
Opening extent																				
Additions to extent																				
Managed expansion																				
Unmanaged expansion																				
Reductions in extent																				
Managed reductions																				
Unmanaged reductions																				
Net change in extent																				
Closing extent																				

Source: SEEA EA

Ecosystem extent account – change matrix

Compiling extent accounts

- Maps based on ecological ground-truthing would be ideal, but probably not practical/feasible

- Model extent on the basis of a multi-dimensional look-up table

  > Inputs: land cover map, digital elevation model, temperature and landforms, etc.
    - Time series of land cover maps
    - Comparable maps (i.e. same classification; preferably also same techniques)

  > Model derives which ecosystem type is to be found, where.

Temperature
Elevation
Landforms
Aridity
Land cover

Layers

Extent Account

	Grassland	Forest Areas	Herbaceous Crops
Opening Extent	2,332	1,645	1,427
Closing Extent	2,010	1,603	1,591
Net Change in Extent	(122)	(42)	164

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Compiling extent accounts

- Combining maps--simple example for illustration purposes only!
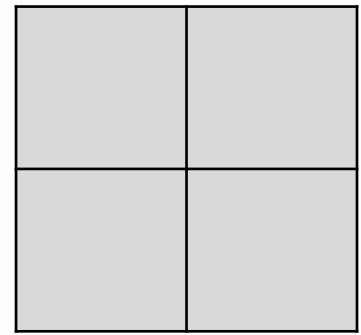
- Land cover
  - > Grey = tree-covered area
  - > Green = non tree-covered area
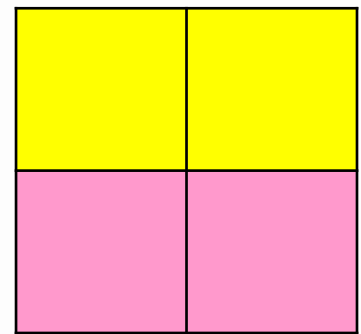
- Temperature
  - > Yellow = annual mean temperature > 18 C
  - > Pink = annual mean temperature <= 18 C
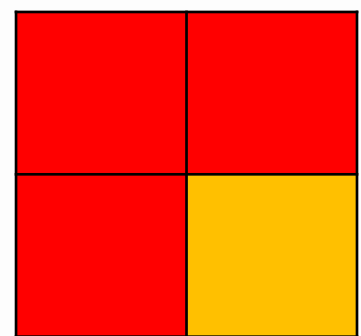
- Aridity
  - > Red = aridity index >.65 (moist)
  - > Orange = aridity index <= .65 (dry)
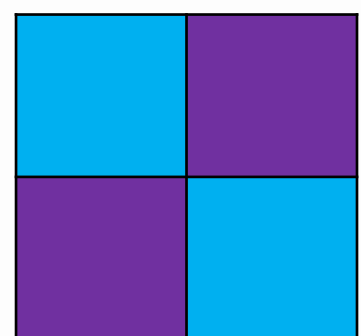
- Elevation
  - > Purple = elevation < 300m
  - > Blue = elevation >= 300m
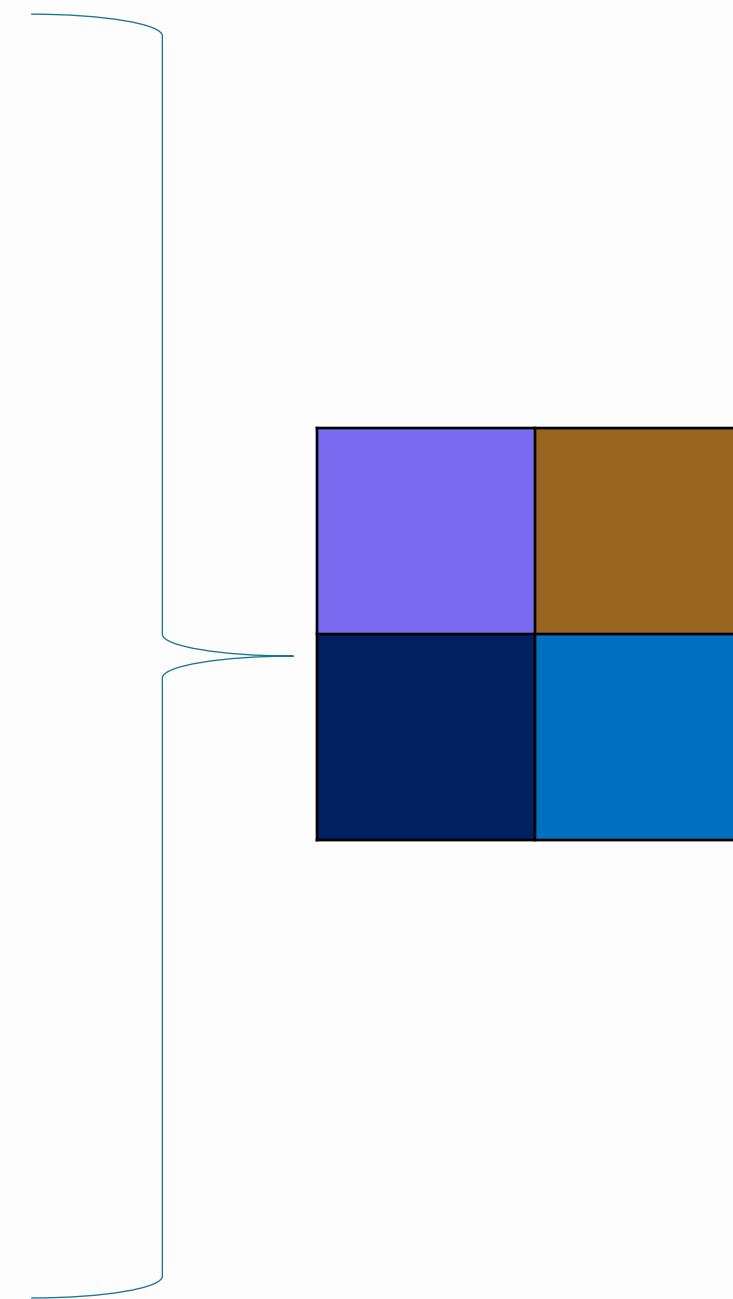
- Hot, humid, elevated forest
  - > **T1.3** Tropical/subtropical montane rainforests

- Hot, humid, low-lying forest
  - > **T1.1** Tropical/subtropical lowland rainforests

- Temperate, humid, low-lying forest
  - > **T2.5** Temperate pyric humid forests

- Temperate, dry, elevated forest
  - > **T2.6** Temperate pyric sclerophyll forests and woodlands

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ARIES for SEEA extent model

Methods
Maps **29 ecosystem functional groups** (EFGs, primarily terrestrial & wetland) based on IUCN GET 2.0 methods.[1] Consulted virtually with D. Keith & colleagues.

Data
Lookup table to model **IUCN EFGs,** based on: **temperature, landform, elevation, aridity, land cover**

Outputs
Net change, additions & reductions, change matrix for ecosystems & land cover types

Current work
Expanding to 39 terrestrial/wetland EFGs, including all forest EFGs, collaborating with IUCN GET team, expand to further freshwater/marine EFGs in future

1: **Keith, D. et al. 2020**. IUCN Global Ecosystem Typology 2.0. IUCN: Gland, Switzerland. - **2**: Using thresholds from **Sayre, R., et al. 2020**. An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. Global Ecology and Conservation 21:e00860.

Multi-dimensional look-up table

IUCN Global Ecosystem Typology v. 2.0 (SEEA)			ARIES Ecosystem Types Parameters					
Level 1 (realms)	Level 2 (biomes)	Level 3 (functional group)	ARIES ecosystem types	Landcover	Aridity index	Annual mean temp. (C)	Landform	Elevation (m)
		T1.1 Tropical-subtropical lowland rainforest	Tropical-subtropical lowland rainforest	Forest	> 0.65	> 18	all but mountain	all
		T1.2 Tropical-subtropical dry forests & thicket	Tropical-subtropical dry forest and thicket	Forest	0.05-0.65	> 18	all	all
		T1.3 Tropical-subtropical montane rainforests	Tropical-subtropical montane rainforest	Forest	> 0.65	> 18	mountain	all

Steps in compiling ecosystem extent accounts

- Design of classification process –what are defining characteristics?

- Selecting input data

- Pre-processing

- Classification

- Post-processing, quality assurance

- Crosswalk map/table to the IUCN Global Ecosystem Typology

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Compiling extent accounts

- Combining different maps and using a multi-dimensional lookup table has advantages and challenges
  - > Advantages:
    - Many countries do not have ecosystem maps and this allows you to model ecosystem types in a simple way
    - Input maps are often readily available (e.g. temperature, elevation, etc)
    - Can use global tools such as ARIES as a starting point
  - > Challenges
    - Global tools such as ARIES use models which may not be accurate in every situation; current model does not include all possible EFGs yet
    - Will need to specify national thresholds/parameters
    - Can be computationally demanding at high resolution

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Compiling extent accounts

- Alternative method: derive extent based on existing ecosystem type map

- Historic biomes

  > Overlay static ecosystem type map with dynamic land cover data

  > See where natural ecosystems → anthropogenic systems /// see additions in extent due to restoration

- Need authoritative ecosystem map (can be vegetation map) / preferably cross-walked to IUCN GET

- Synergies with Red List of Ecosystem Assessments (current distribution of ecosystems compared to historic distribution)

- May be easier approach if you have an authoritative ecosystem map

Example South Africa

Table 14.   Extent account for terrestrial ecosystem types summarised by biome, 1990 and 2014, in hectares*

	Albany Thicket	Desert	Forest	Fynbos	Grassland	IOCB	Nama-Karoo	Savanna	Succulent Karoo	Azonal vegetation	Culti-vated*	Built-up*	Water-bodies**	Total
Historical extent	3 531 231	626 207	462 518	8 165 366	33 090 325	1 171 284	24 936 548	39 418 522	7 821 579	2 742 873				121 966 453
Additions to extent	0	0	0	0	0	0	0	0	0	0	16 156 026	3 003 883	2 096 528	21 256 437
Reductions in extent	230 091	8 237	70 673	2 253 375	11 330 606	619 656	420 995	5 396 119	251 373	675 312				21 256 437
Net change in extent	-230 091	-8 237	-70 673	-2 253 375	-11 330 606	-619 656	-420 995	-5 396 119	-251 373	-675 312				
Net change as % of historical	-6,5%	-1,3%	-15,3%	-27,6%	-34,2%	-52,9%	-1,7%	-13,7%	-3,2%	-24,6%				
Closing extent 1990	3 301 140	617 970	391 845	5 911 991	21 759 719	551 628	24 515 553	34 022 403	7 570 206	2 067 561	16 156 026	3 003 883	2 096 528	121 966 453
Opening extent 1990	3 301 140	617 970	391 845	5 911 991	21 759 719	551 628	24 515 553	34 022 403	7 570 206	2 067 561	16 156 026	3 003 883	2 096 528	121 966 453
Additions to extent	44 432	1 142	24 900	241 184	1 444 446	75 114	146 910	1 160 055	38 422	189 954	1 991 959	597 238	288 754	6 244 510
Reductions in extent	36 008	1 260	7 689	196 035	1 180 183	63 783	78 038	885 303	33 631	58 021	2 339 226	400 503	964 606	6 244 286
Net change in extent	8 424	-118	17 211	45 149	264 263	11 331	68 872	274 752	4 791	131 933	-347 267	196 735	-675 852	
Net change as % of opening	0,3%	0,0%	4,4%	0,8%	1,2%	2,1%	0,3%	0,8%	0,1%	6,4%	-2,1%	6,5%	-32,2%	
Net change in relation to historical extent	-221 667	-8 355	-53 462	-2 208 226	-11 066 343	-608 325	-352 123	-5 121 367	-246 582	-543 379				
Net change as % of historical	-6,3%	-1,3%	-11,6%	-27,0%	-33,4%	-51,9%	-1,4%	-13,0%	-3,2%	-19,8%				
Closing extent 2014	3 309 564	617 852	409 056	5 957 140	22 023 982	562 959	24 584 425	34 297 155	7 574 997	2 199 270	15 808 759	3 200 618	1 420 676	121 966 453

* Cultivated areas, built-up areas and waterbodies are treated as biomes for the purpose of the ecosystem extent account table. There is no reliable spatial information on the historical extent of waterbodies, subsistence cultivation or habitation.

** Changes in the extent of waterbodies between 1990 and 2014 reflect primarily that 1990 was a much wetter year than 2014. Waterbodies include both natural and artificial water bodies (such as dams).

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Additional examples - ecosystem extent

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Example Brazil – SEEA and Goal A monitoring

Ecosystem extent accounts in Brazil (2000-2018)

- The ecosystem extent accounts (2000-2018), by biomes, show that Brazilian terrestrial biomes lost about 500 thousand km² of their natural areas, due to conversion into modified areas such as land used for crops and grazing.

Source: (IBGE 2020), Ecosystem Accounts: Land Use in Brazilian Biomes 2000-2018

Example Brazil – SEEA and Goal A monitoring

Variáveis	Total		Bioma			
			Amazônia		Cerrado	
	Áreas naturais	Áreas antro-pizadas	Áreas naturais	Áreas antro-pizadas	Áreas naturais	Áreas antro-pizadas
2000						
Extensão de abertura	5 877 298	2 510 306	3 684 512	450 865	1 185 192	790 693
Adições	2 955	460 530	1 282	248 427	509	135 983
Reduções	326 066	137 419	193 539	56 170	96 274	40 218
2010						
Extensão	5 554 187	2 833 417	3 492 255	643 122	1 089 427	886 458
Adições	1 509	107 787	385	39 064	284	37 357
Reduções	69 316	39 980	27 376	12 073	23 068	14 573
2012						
Extensão	5 486 380	2 901 224	3 465 264	670 113	1 066 643	909 242
Adições	3 592	93 615	2 043	39 654	320	35 913
Reduções	49 030	48 177	21 123	20 574	18 392	17 841
2014						
Extensão	5 440 942	2 946 662	3 446 184	689 193	1 048 571	927 314
Adições	2 118	60 715	644	36 413	314	16 599
Reduções	36 435	26 398	23 541	13 516	8 417	8 496
2016						
Extensão	5 406 625	2 980 979	3 423 287	712 090	1 040 468	935 417
Adições	12 894	74 296	8 185	38 566	2 706	25 583
Reduções	32 098	55 245	16 761	30 057	10 688	17 671
2018						
Extensão final	5 387 421	3 000 030	3 414 711	720 599	1 032 486	943 329
Saldo das mudanças						
Absoluto (km²)	(-) 489 877	489 724	(-) 269 801	269 734	(-) 152 706	152 636
Percentual (%)	(-) 8,34	19,51	(-) 7,32	59,83	(-) 12,88	19,30
Movimentação						
Absoluto (km²)	536 013	1104 162	294 879	534 514	160 972	350 234
Percentual (%)	9,12	43,99	8,00	118,55	13,58	44,29

> The higher absolute totals of natural area reduction were concentrated on the Amazônia and Cerrado biomes (86,2%)

Source: (IBGE 2020), Ecosystem Accounts: Land Use in Brazilian Biomes 2000-2018

Example: ecosystem extent accounts in EU (1/3)

- In 2015, the EU launched a pilot project for an integrated system of ecosystem accounting, INCA
  - > Resulted in the compilation of extent, condition and ecosystem services accounts (Vysna et al., 2021)

- 2011 EU Directive on Environmental-economic accounts covers 6 modules
  - > Being expanded to include also ecosystems accounts; forest accounts and accounts for environmental subsidies + similar transfers

Accounting for ecosystems and their services in the European Union
(INCA) | 2021 edition

Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU

Ecosystem extent account (2/3)

Inland vegetation and habitats
- Tundra
- Arctic, alpine and subalpine scrub and grassland
- Mediterranean-mountain scrub and brushes
- Heathland scrub
- Grasslands and land dominated by forbs
- Regularly or recently cultivated agricultural, horticultural and domestic habitats
- Sparsely wooded grasslands
- Broad leaved deciduous and evergreen woodland
- Mixed deciduous and coniferous woodland
- Coniferous and broad leaved evergreen woodland
- Mires, bogs and fens

Inland unvegetated or sparsely vegetated habitats
- Screes, inland cliffs
- Snow or ice-dominated habitats
- Miscellaneous inland habitats with very sparse or no vegetation

Human made constructions and habitats
- Constructed, industrial and other artificial habitats

Non classified areas
- Unclassified areas
- Outside area of interest

Ecosystem map (aggregated)

Marine waters
- European regional seas
- Open waters

Marine seabed and coastal habitats
- Sublittoral sediment
- Infralittoral and circalittoral rock and other hard substrata
- Marine habitats
- Coastal habitats

Inland surface waters
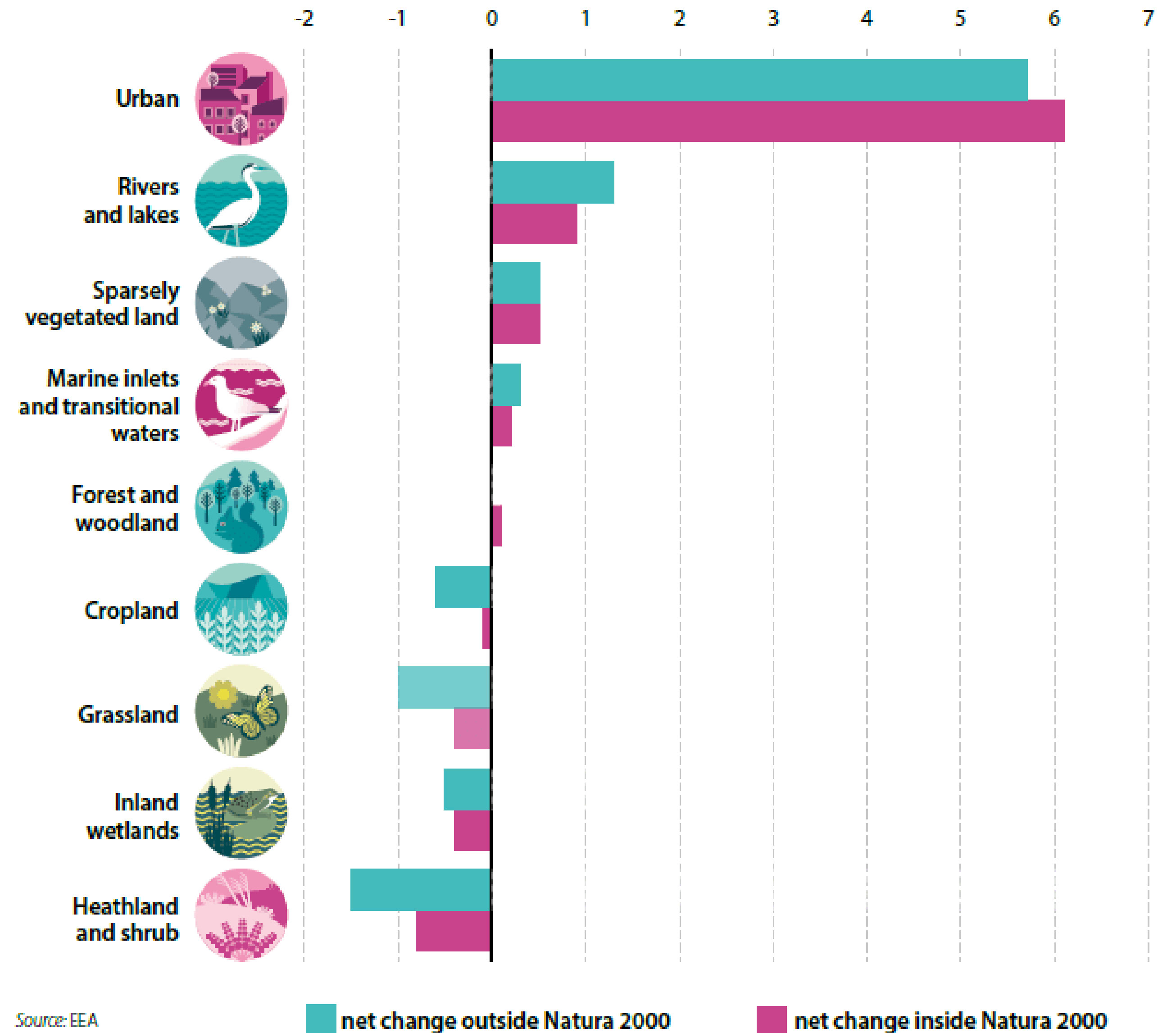- Inland waters and shores

- Built on Corine LC data, aggregated into 9 broad ETs

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Extent example, cont. (3/3)

- Some of the findings are:
  - > Urban ecosystems increased in extent by 5.8% (2000 – 2018) at the expense of farmland and semi-natural ecosystem.
  - > Changes in the extent of semi-natural ecosystem types are mostly smaller within the Natura 2000 protected areas than outside.

Figure 3: Changes in ecosystem extent inside and outside Natura 2000 areas, 2000-2018, EU28 (%)

Source: EEA

net change outside Natura 2000   net change inside Natura 2000