System of Environmental Economic Accounting

Ecosystem Condition Accounts

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- Compiling ecosystem condition accounts
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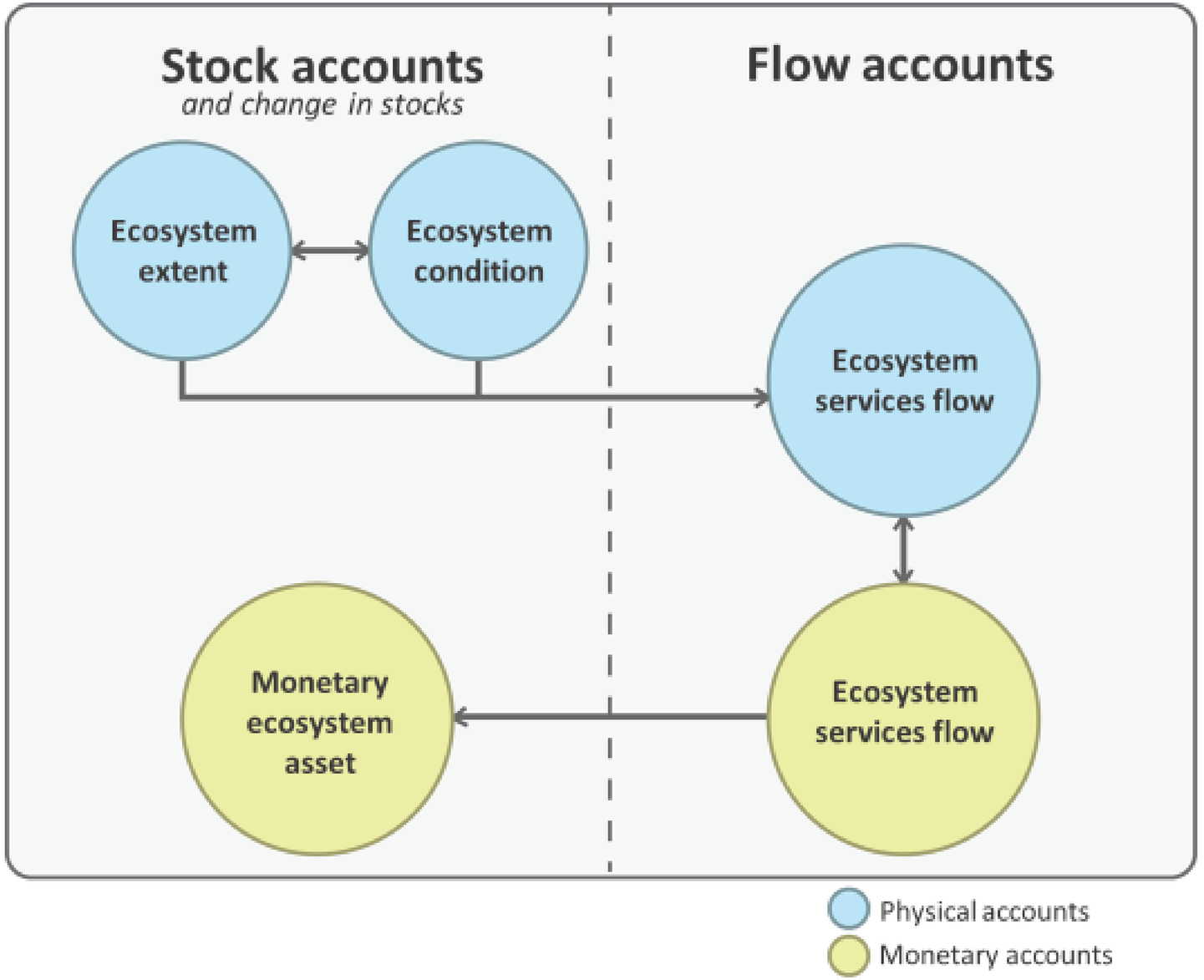
Introduction

Ecosystem condition accounts

- Why?
  - > Mainstream ecological concepts and data into economic and development planning
  - > Condition underpins the integrity of an ecosystem -- i.e. ecosystem's capacity to maintain its characteristic composition, structure, functioning and self-organization over time within a natural range of variability
    - Higher integrity usually means greater resilience
- Complement environmental monitoring systems
  - > Important information in terms of protecting, maintaining and restoring condition – time series!
  - > Accounts provide a structured approach to recording and aggregating data; build upon environmental monitoring systems

Ecosystem condition accounts

- Relationship between condition and services is complex
  - > Depends on the service
- Measures of ecosystem condition will/should tell us more than just the capacity to supply ecosystem services to humans



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Ecosystem condition accounts

- Ecosystem condition: **quality of an ecosystem** measured in terms of its abiotic and biotic characteristics.
  - Characteristics => properties of ecosystems and its (a)biotic components
- What are some of the characteristics that might tell us about the quality or health of an ecosystem?
  - Water quality
  - Air pollutant concentrations
  - Species diversity
  - Many many, more…

Ecosystem condition accounts

- Focus on characteristics that show change over time as a result of both natural processes and human activity, such as precipitation, temperature, water quality and species abundance
- Ecosystem condition accounts are diverse—dependent on measurement focus, ecosystem types present, and what compiler has defined and selected as ecosystem characteristics
  - > Single characteristic can have many different variables
- How can we think about ecosystem condition in a structured way?

Ecosystem condition typology

Ecosystem condition typology

- Hierarchical typology for organizing data on ecosystem condition characteristics
- Can be used as a template for variable/indicator selection and provide a structure for aggregation

ECT groups and classes
Group A: Abiotic ecosystem characteristics
Class A1. Physical state characteristics: physical descriptors of the abiotic components of the ecosystem (e.g., soil structure, water availability)
Class A2. Chemical state characteristics: chemical composition of abiotic ecosystem compartments (e.g., soil nutrient levels, water quality, air pollutant concentrations)
Group B: Biotic ecosystem characteristics
Class B1. Compositional state characteristics: composition / diversity of ecological communities at a given location and time (e.g., presence / abundance of key species, diversity of relevant species groups)
Class B2. Structural state characteristics: aggregate properties (e.g., mass, density) of the whole ecosystem or its main biotic components (e.g., total biomass, canopy coverage, annual maximum normalized difference vegetation index (NDVI))
Class B3. Functional state characteristics: summary statistics (e.g., frequency, intensity) of the biological, chemical, and physical interactions between the main ecosystem compartments (e.g., primary productivity, community age, disturbance frequency)
Group C: Landscape level characteristics
Class C1. Landscape and seascape characteristics: metrics describing mosaics of ecosystem types at coarse (landscape, seascape) spatial scales (e.g., landscape diversity, connectivity, fragmentation)

Ecosystem condition typology

Table 5.1: The SEEA Ecosystem Condition Typology (ECT)

ECT groups and classes
Group A: Abiotic ecosystem characteristics
Class A1. Physical state characteristics: physical descriptors of the abiotic components of the ecosystem (e.g., soil structure, water availability)
Class A2. Chemical state characteristics: chemical composition of abiotic ecosystem compartments (e.g., soil nutrient levels, water quality, air pollutant concentrations)
Group B: Biotic ecosystem characteristics
Class B1. Compositional state characteristics: composition / diversity of ecological communities at a given location and time (e.g., presence / abundance of key species, diversity of relevant species groups)
Class B2. Structural state characteristics: aggregate properties (e.g., mass, density) of the whole ecosystem or its main biotic components (e.g., total biomass, canopy coverage, annual maximum normalized difference vegetation index (NDVI))
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Group C: Landscape level characteristics
Class C1. Landscape and seascape characteristics: r… coarse (landscape, seascape) spatial scales (e.g., lan…

Table 5.2: Ecosystem condition variable account

SEEA Ecosystem Condition Typology Class	Variables		Ecosystem type		
	Descriptor	Measurement unit	Opening value	Closing value	Change
Physical state	Variable 1				
	Variable 2				
Chemical state	Variable 3				
Compositional state	Variable 4				
	Variable 5				
Structural state	Variable 6				
Functional state	Variable 7				
Landscape/seascape characteristics	Variable 8				

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Compiling ecosystem condition accounts

Approach to compiling ecosystem condition accounts

- Primary spatial units are ecosystem assets and these are expected to be delineated such that they are reasonably homogeneous in terms of their main characteristics
- Aggregation/dissemination by ecosystem type as each type has distinct characteristics
- SEEA EA: a three-stage approach to account for ecosystem condition.
  - > **Variables → indicators →** indices
  - > The move from one stage to the next requires a progressive building of data and the use of additional assumptions.
  - > Outputs at each stage are relevant for policy and decision making

Stage I: Variable account

- Precise structure will depend on selected characteristics, data availability, uses of the accounts and policy applications
- Shown by ecosystem type
- **Variable** = soil organic carbon stock, tC/ha (abiotic characteristic, chemical state)
  - > Opening: 100
  - > Closing: 95

Forest

SEEA Ecosystem Condition Typology Class		Variable descriptor	unit	Variable values (observed)		
				Opening	Closing	Change
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Abiotic characteristics	Physical state	Vegetation water content - NDWI	index (-1 to 1)	0.31	0.29	-0.02
	Chemical state	Soil organic carbon stock	tC/ha	100	95	-5
		Foliar or litter nitrogen concentration	mg N / g dry weight	18	17	-1
Biotic characteristics	Compositional state	Tree species richness	number	6	5	-1
	Structural state	Tree cover	%	81	75	-6
	Functional state	Vegetation index - NDVI	index (-1 to 1)	0.65	0.63	-0.02
Landscape/seascape characteristics		Forest area density	%	74	59	-15

Stage II: Indicator account

- Why indicators?
  - > Allows easier interpretation of trends, especially across variables
    - Especially if it is dimensionless
    - Can allow for indices
- How are indicators calculated for condition accounts?
  - > Rescaled ecosystem variables to arrive at individual condition indicator
  - > Suggest to use dimensionless scale (0-1)
- How to re-scale?
  - > You need to compare past/present/future measured values of the variable to some reference

Stage II: Indicator account - reference condition

- One reference condition should reflect high ecosystem integrity
- How to choose reference condition?
- Ecosystem condition is often defined by measuring the similarity (or the distance) of a current ecosystem to a reference state, such as minimally impacted by people or a historical state
- Meant to reflect a high ecosystem integrity
- Undisturbed/natural state is preferred reference condition, but may not always be meaningful/feasible

	Possible reference conditions
	Undisturbed or minimally-disturbed condition of an intact ecosystem. The condition of an ecosystem with maximal ecosystem integrity with no or minimal disturbance.
	Historical condition: The condition of an ecosystem at some point or period in its history that is considered to represent the stable natural state (e.g., the pre-industrial period or pre-intensive agriculture).
	Least-disturbed condition: the currently best available condition of an ecosystem.
	Contemporary condition: The condition of an ecosystem at a certain point or period in its recent history for which comparable data are available.

Stage II: Indicator account - reference condition

- The simplest conversion uses two reference conditions to reflect a high or low condition.
- Once you have a reference condition, you need the **reference levels** for specific condition variables and then can determine an overall reference condition for the ecosystem
  - > The indicators are then calculated by re-scaling data for individual variables using the reference levels as high and low bounds on the variable range.

Stage II: Indicator account

- Ecosystem condition indicator
  - > I = (V – VL) / (VH – VL)

  where I is the value of the indicator, V is the value of the variable, VH is the high reference level value and VL is the low reference level value.
- Example:
  - > Pristine state→250 tC/ha
  - > Bare earth→0 tC/ha
  - > Indicator for opening stock of 100 tC/ha and closing stock of 95 tC/ha?

Forest

SEEA Ecosystem Condition Typology Class		Variable descriptor	Measurement unit	Variable values (observed)		Reference level values		Indicator values (rescaled)		
				Opening	Closing	Lower level	Upper level	Opening	Closing	Change
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Abiotic characteristics	Physical state	Vegetation water content - NDWI	index (-1 to 1)	0.31	0.29	-1	1	0.66	0.65	-0.01
	Chemical state	Soil organic carbon stock	tC/ha	100	95	0	250	0.40	0.38	-0.02
		Foliar or litter nitrogen concentration	mg N / g dry weight	18	17	4	40	0.39	0.36	-0.03
Biotic characteristics	Compositional state	Tree species richness	number	6	5	0	10	0.60	0.50	-0.10
	Structural state	Tree cover	%	81	75	0	100	0.81	0.75	-0.06
	Functional state	Vegetation index - NDVI	index (-1 to 1)	0.65	0.63	-1	1	0.83	0.82	-0.01
Landscape/seascape characteristics		Forest area density	%	74	59	0	100	0.74	0.59	-0.15

Condition index

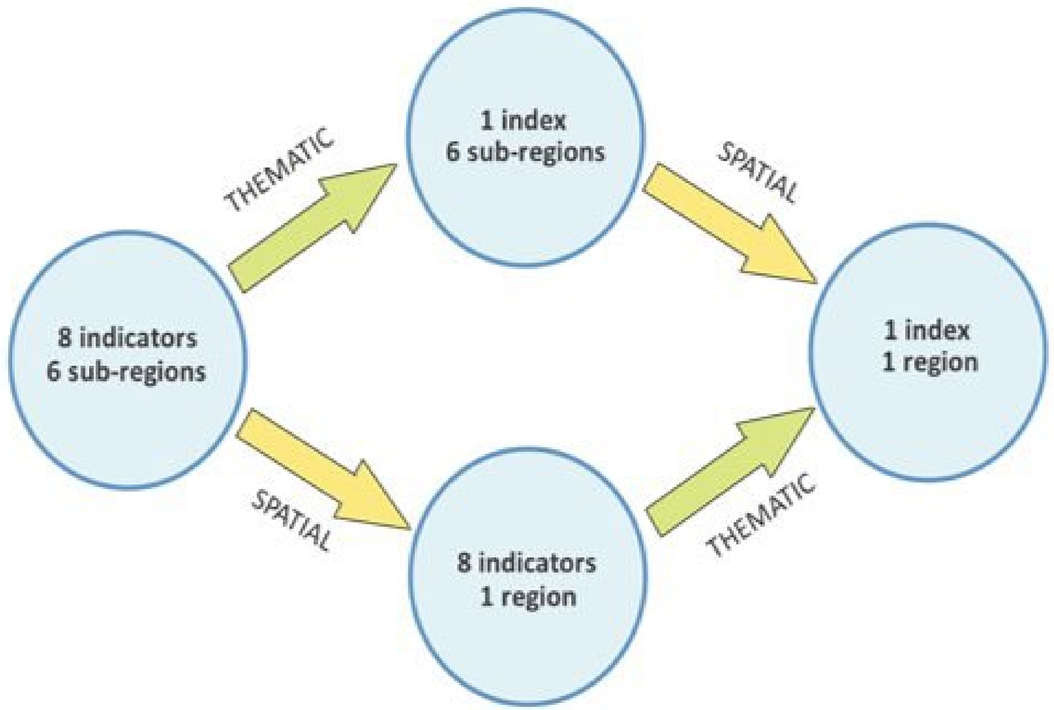
- Composed of composite indicators that are aggregated from individual ecosystem condition indicators
- Aggregation process is underpinned using comparable reference levels from a common reference condition.
  - > Component indicators are scaled according to reference levels, normalized to a common scale and direction of change, and combined to form a composite index.
- E.g.:
  - > Condition index applied to each ecosystem type
  - > Weighted by area of ecosystem type within your ecosystem accounting area
  - > Summed for all ecosystem types
- Pros and cons of indices→ index account is optional!

Condition index

- Aggregation can be done in multiple ways
- Thematic aggregation
  - > Combining indicators according to ECT classes/groups
    - Each ecosystem type may have different indicators, but typology classes/groups are same
  - > Assumes that different indicators can compensate for each other
    - Increasing value of one indicator vs. declining value of another → stable condition
- Spatial aggregation
  - > Aggregation across ecosystem types, e.g. region, province
  - > Care is needed; is aggregation meaningful? e.g. aggregation across tropical heath forests and photic coral reefs
  - > Should be considered only if ecosystem types have same reference condition

Condition index

- Several choices for aggregation functions:
  - > Arithmetic mean
  - > Geometric mean,
  - > Quantiles and median
  - > One out, all out approach… etc etc
- Aggregation commutativity
- Selection of weighting system depends on relative importance of each indicator to overall condition of the ecosystem
  - > Need to involve ecologists, ministry of environment, etc.



Condition index

Table 5.4: Ecosystem condition indices reported using rescaled indicator values ('mean values' approach) i.e. sum of the weighted values for abiotic/biotic/landscape characteristics

SEEA Ecosystem Condition Typology Class	Indicators	Ecosystem type				
		Indicator value			Index value	
	Descriptor	Opening value	Closing value	Indicator weight	Opening value	Closing value
Physical state	Indicator 1	0.5	0.25	0.05	0.025	0.013
	Indicator 2	0.9	0.7	0.05	0.045	0.035
	Sub-index				*0.07*	*0.048*
Chemical state	Indicator 3	0.625	0.5	0.1	0.063	0.05
Total Abiotic characteristics					0.133	0.098
Compositional state	Indicator 4	0.94	0.89	0.067	0.063	0.062
	Indicator 5	0.75	0.50	0.033	0.025	0.017
	Sub-index				*0.088*	*0.079*
Structural state	Indicator 6	0.5	0.25	0.12	0.06	0.03
Functional state	Indicator 7	1	0.66	0.08	0.08	0.053
Total Biotic characteristics					0.228	0.162
Landscape and seascape characteristics	Indicator 8	0.5	0.2	0.5	0.25	0.1
Ecosystem condition index	**Index**			**1.0**	**0.611**	**0.360**

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Multiple ecosystem types

Table 5.6: Ecosystem condition account (condition indices) for multiple ecosystem types

Accounting entries	Stylized ecosystem types					
	Forests	Lakes	Cropland	Urban areas	Wetlands	Seagrass
Opening condition value						
Change in abiotic ecosystem characteristics (physical and chemical state)						
Change in biotic ecosystem characteristics (composition, structure and function)						
Change in landscape/seascape characteristics						
Net change in condition						
Closing condition value						

Table 5.7: Examples of ecosystem condition variables for selected ecosystem types[52]

		A1 Physical state	A2 Chemical state	B1 Compositional state	B2 Structural state	B3 Functional state	C1 Landscape / seascape
T1	**Tropical-subtropical forests**	Soil water availability in the driest quarter; Wetness	Soil organic carbon content; Leaf and litter nitrogen concentration	Tree species richness; Bird species richness	Tree cover density; Dominant tree height; Number of canopy layers; Deadwood volume; Forest age class distribution; Density of epiphytes	Dry matter productivity; Presence of seed dispersing species (capacity for regeneration); Water stress index	Forest area density; Landscape diversity; Forest connectivity; Ratio of edge distance to interior area of forest patches
T2	**Temperate-boreal forests & woodlands biome**	Vegetation water content (NDWI)	Soil organic carbon content; Air pollutant concentration; Foliar and litter nitrogen concentration	Tree species richness; Lichen species richness; Bird species richness	Forest floor depth (soil layer thickness); Tree cover density; Deadwood volume; Forest age class distribution	Dry matter productivity; Density of trees with hollows for nesting; Presence of top predator species (food web functionality); Vegetation index (NDVI); Water stress index	Forest area density; Landscape diversity; Forest connectivity;
T3	**Shrublands & shrubby woodlands**	% Burnt area; Soil layer thickness	Soil organic carbon content; Soil phosphorus concentration	Bird species richness	Tree cover density	Dry matter productivity; Proportion of re-sprouting species after fire (capacity for regeneration)	Landscape diversity; Shrubland/forest connectivity
T4	**Savannas and grasslands**	% Bare ground	Soil organic carbon content; Soil pH	Bird species richness; Butterfly species richness; Proportion of non-native species	The presence/density of trees/shrubs	Dry matter productivity Abundance of termite mounds (organic matter turnover)	Connectivity of trees; Grassland connectivity
T5	**Deserts and semi- deserts**	Water availability; Degree of surface crusting	Soil pH	Reptile species diversity or abundance	Vegetation cover	Density of viable seeds in soil (capacity for regeneration)	Spatial distribution of waterholes
T6	**Polar-alpine (cryogenic)**	% Bare ground; Snow depth; Extent of sea ice	Pollutant concentrations	Lichen species richness	Vegetation cover; Lichen cover or abundance on rocks		Diversity of habitat types; Connectivity of routes for migratory species
T7.1	**Annual croplands**	Water holding capacity; Soil bulk density; Vegetation water content (NDWI)	Soil organic carbon content; Soil nutrient availability	Bird species richness	Share of organic farming; Crop diversity; Share of time or area as fallow land	Soil respiration rate (decomposition); Gross primary production	The presence/ share of semi-natural vegetation fragments (small woody features); Landscape diversity (mosaic)
T7.4	**Urban and**	Imperviousness	NO_2 concentration	Bird species richness	Share of urban green		Average distance of residents to

Examples ecosystem condition

EU: Forest condition variable account

Table 2: Forest condition variable account for EU28 (spatially averaged values)

Condition group	Condition class	Descriptor	Units	Opening stock (2010)	Closing stock (2020 - projected)	Change (% per decade)	Confidence
Abiotic characteristics	**Physical state**	Soil moisture content	%	13.50	13.45	-0.4	medium
	Chemical state	Effective rainfall	mm/year	-32	-44	-38	high
		Exceedances of critical loads for eutrophication	equivalent/ha/ year	251.8	173.7	-31	medium
		Tropospheric ozone concentration	ppb hours	19 265	13 293	-31	high
Biotic characteristics	**Composition**	Common forest birds index (1)	Index (1990 = 100)	93.23	104.86	17.8	medium
	Structure	Biomass volume	m³/ha	200	220	10	medium
		Dead wood	tonne/ha	4.1	4.5	10.3	medium
		Defoliation	%	20	22	10	high
	Function	Evapotranspiration	mm/year	482.0	490.2	1.7	high
		Dry matter productivity	tonne/ha/year	11.8	13.1	11.1	high
Landscape characteristics		Forest area density	%	72.0	72.1	0.1	high

Source: sdg_15_60, EU Ecosystem Assessment

(1) Closing stock for the common forest bird index uses year 2017

- Some findings:
  - > Forest pollution levels are declining across the EU28 but absolute levels of still very high
  - > Forest productivity increased.
  - > Pressures from climate change are increasing (evapotranspiration up; effective rainfall down)
  - > Concerning trend is defoliation
  - > Fragmentation remained virtually constant since 2010.

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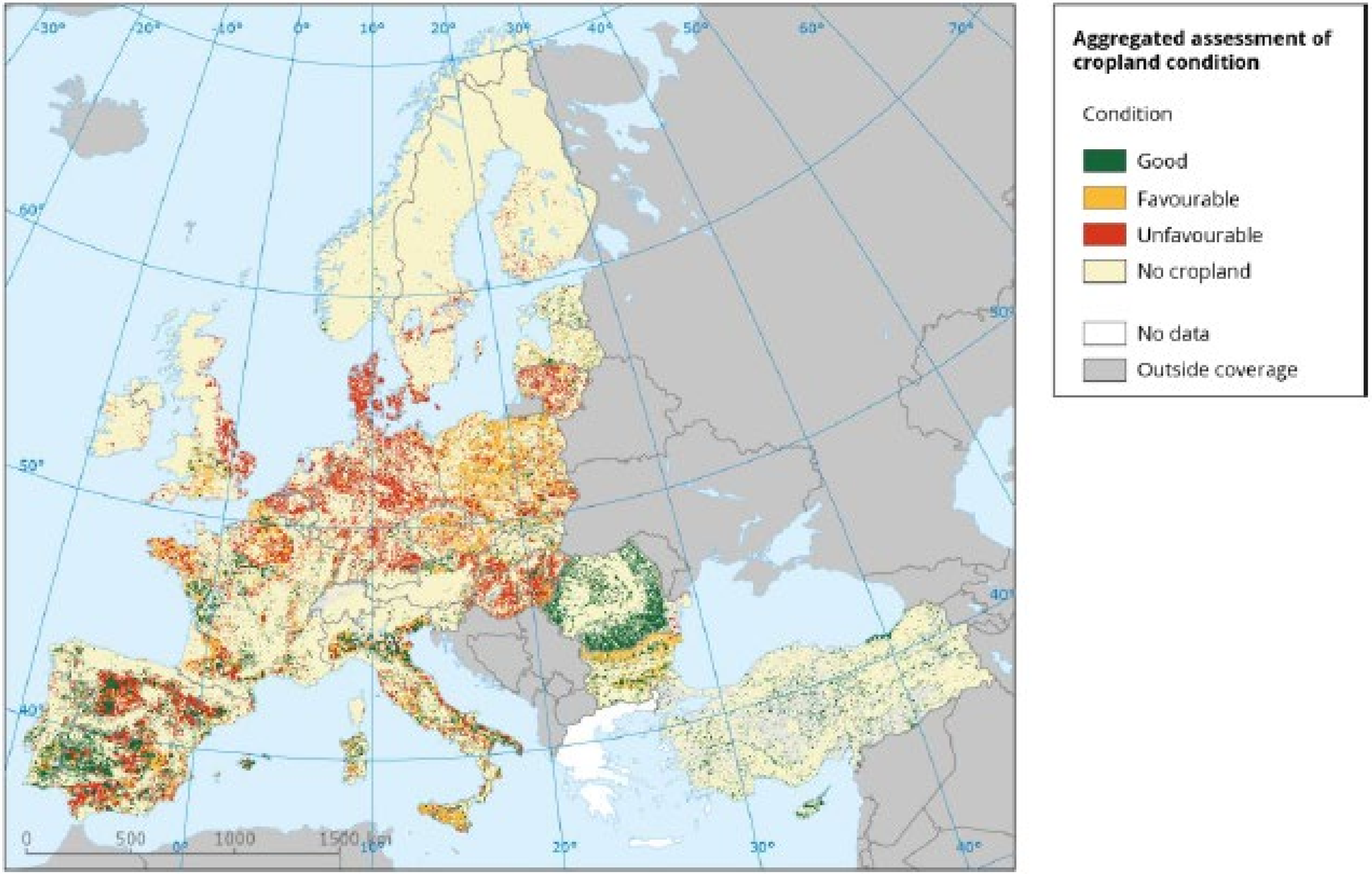
Source: Accounting for ecosystems and their services in the European Union INCA Final Report; Vysna et al 2021

EU: Cropland index account



Experimental System of Ecosystem Accounts in Spain

MAIA
Mapping and Assessment for Integrated ecosystem Accounting

2. CONDITIONS ACCOUNTS: The SEEA-EA condition is a metric that captures, through a set of key indicators, the state and functioning of the ecosystem in relation to both its ecological condition and its capacity to provide ecosystem services.

Indicators used in the forest condition in Spain

Group	Class	Weigth	Indicator	Source	Resolution (m)
Abiotic characteristics	Physical state	0,07	NDWI	Landsat	30
		0,07	Soil organic carbon	Lucas	1000
	Chemical state	0,07	Ozone (AOT40f)	EEA	2000
		0,07	Nitrogen Deposition (Critical Loads)	EEA	5000
Biotic characteristics	Composition state	0,1	Forest bird richness	MITERD	1000
		0,1	Richness of forest flora	MITERD	1000
	Structural state	0,12	Tree cover	Modis	250
	Functional state	0,1	NDVI	Landsat	30
		0,08	Gross primary production	Modis	500
Landscape characteristics	Landscape characteristics	0,12	Forest area density	Guidos	50
		0,1	Naturalness index	Guidos	50

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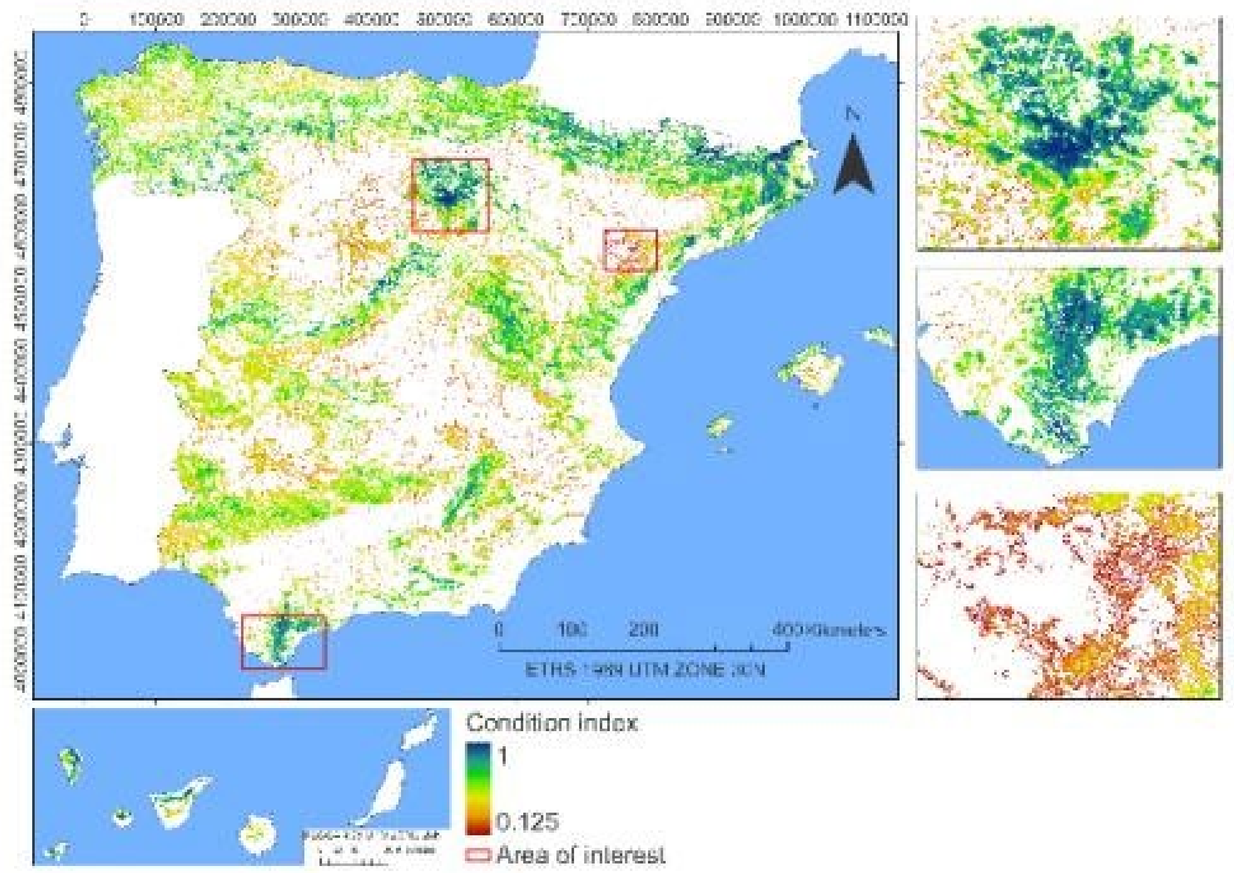
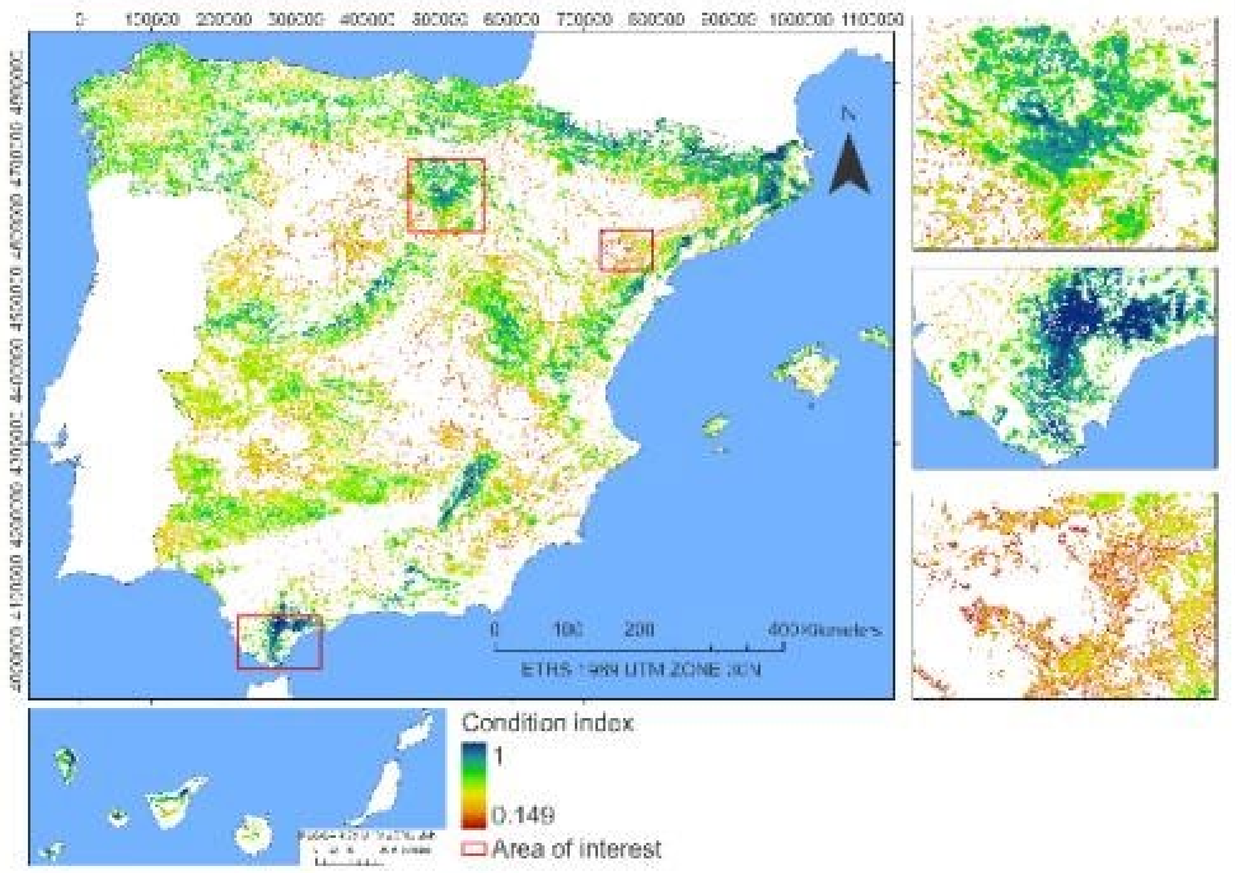
MAIA
Mapping and Assessment for Integrated ecosystem Accounting

2. CONDITIONS ACCOUNTS: results are presented in maps for forest ecosystems for different time periods between 2000-2015.

2000



2015



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Condition index by forest type

Forest Type	2000	2015	Change	Forest Type	2000	2015	Change
Broad. Sclerophyllous Med.	0.536	0.561	0.025	Con. Atlantic	0.601	0.630	0.029
Broad. Continental Med.	0.556	0.565	0.009	Con. Alpine	0.735	0.730	-0.005
Broad. Mountain Med.	0.607	0.598	-0.009	Con. Insular	0.585	0.660	0.075
Broad. Atlantic	0.568	0.602	0.033	Mixed Sclerophyllous Med.	0.571	0.601	0.030
Broad. Alpine	0.661	0.693	0.032	Mixed Continental Med.	0.602	0.606	0.005
Broad. Insular	0.661	0.712	0.050	Mixed Mountain Med.	0.591	0.601	0.009
Con. Sclerophyllous Med.	0.546	0.573	0.027	Mixed Atlantic	0.580	0.616	0.036
Con. Continental Med.	0.593	0.596	0.003	Mixed Alpine	0.758	0.775	0.017
Con. Mountain Med.	0.609	0.606	-0.003	Mixed Insular	0.654	0.716	0.063