ECOSYSTEM CONDITION REVIEW

Review of metrics and methods for measuring ecosystem condition and development of an implementation plan for ecosystem condition accounting

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26 th February 2026

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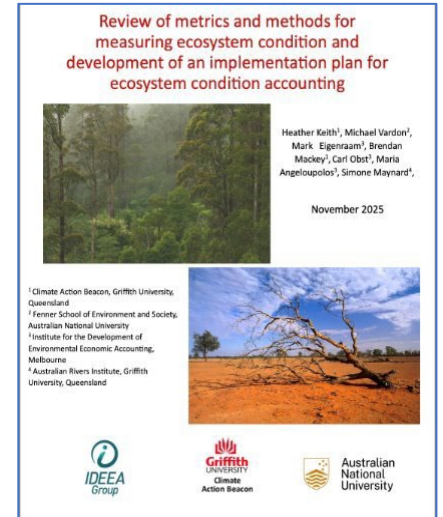
Griffith UNIVERSITY

Climate Action Beacon

IDEEA Group



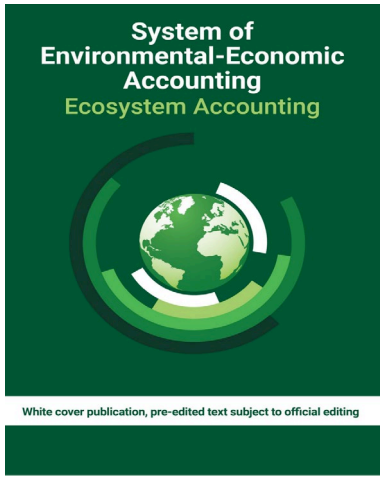
Overview of presentation

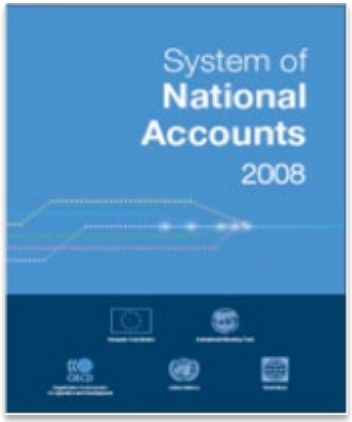
- The task for the condition review
- Introduction to the SEEA
- Conceptions of condition
- Requirements for the SEEA condition account
- Results from the review and analysis
- Recommendations

Questions addressed in the review

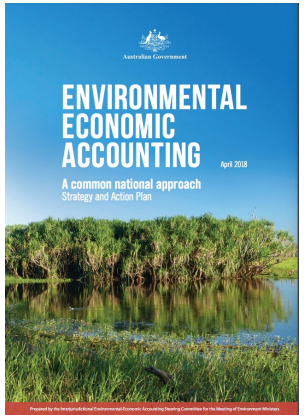
- What can be learnt from available Australian and international ecosystem condition methods to support further development of an Australian condition account? This considers the method's purpose, scope and alignment with SEEA EA.
- How can Australia implement a condition framework that is fit-for purpose?
- What ecosystem characteristics should be measured as part of future ecosystem condition accounts?
  - based on identifying metrics and methods that have been, or could be, used to describe condition
  - assessed against selection criteria
- How can the account be comprehensive of the range of characteristics described in the ecosystem condition typology?

The System of Environmental-Economic Accounting (SEEA)

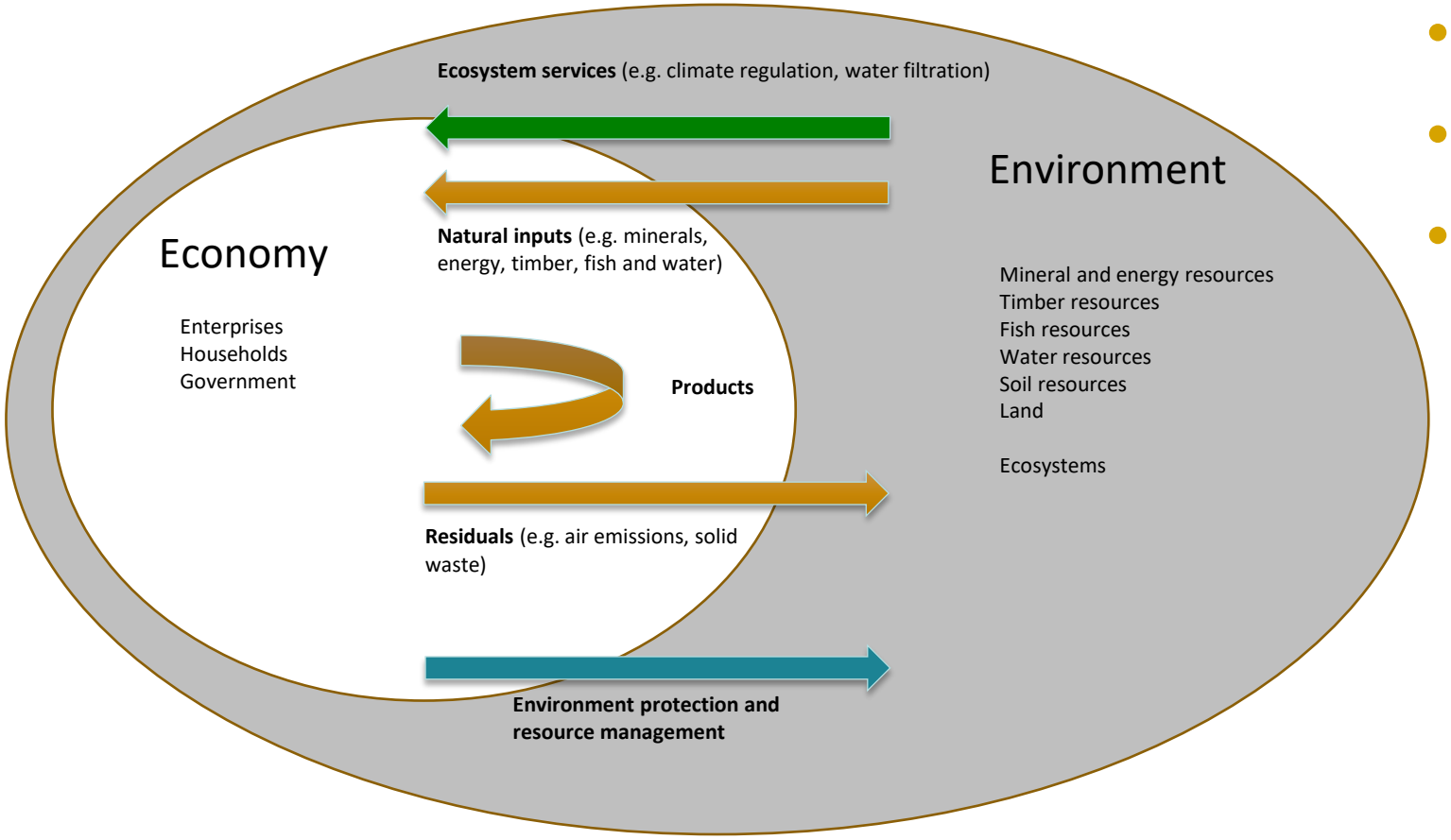




- An international standard for natural capital and ecosystem services accounting
- Organises environmental and economic information showing the interconnections
- Harmonises data from different sources
- A multidisciplinary consensus that was achieved over 30+ years
- Used in more than 90 countries
- TNFD refers to SEEA for guidance on reporting
- Australia has a strategy and action plan



Key concepts of SEEA



- Stocks and flows
- Physical and monetary metrics
- Benefits and beneficiaries

Two world views

Economic units - businesses and households - produce and use goods and services

The also use natural resources and ecosystem services

Cadastre (vector)
spatial economic ownership and management unit

The cadastre is an (imperfect) spatial link between environmental and economic units

Raster (pixels)

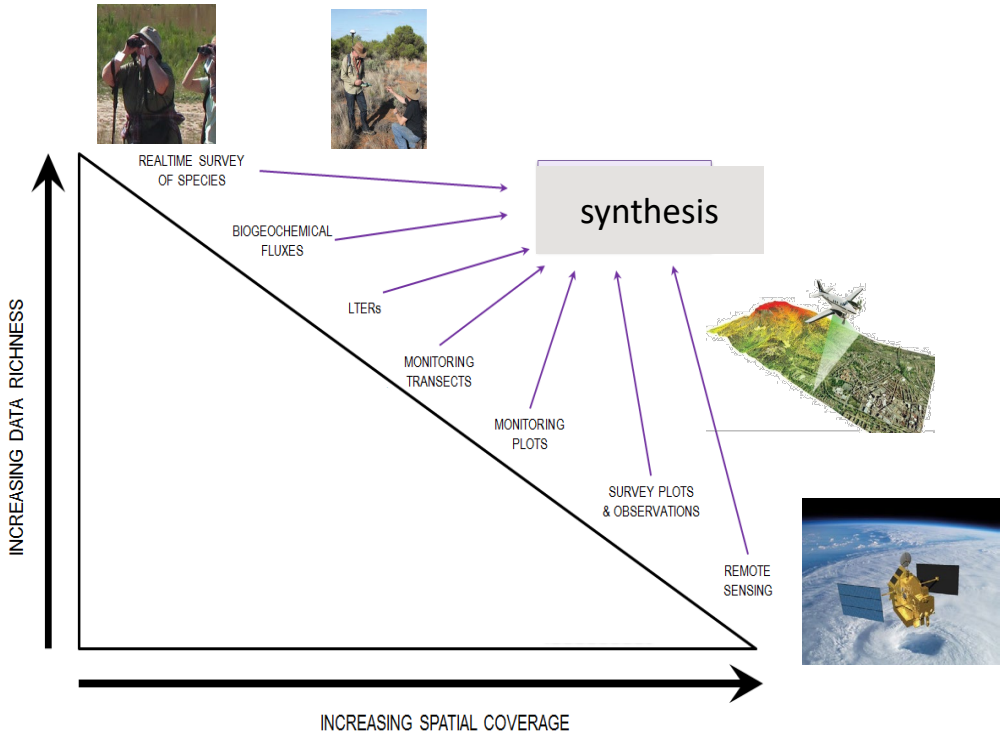
spatial environmental unit (also point data)

Environment units

- Produce natural resources and ecosystem services
- Classified to ecosystems or land covers (aggregation of like units)

Environmental and socioeconomic data sources

Physical data sources



Socio-economic data sources

Tax office

Surveys

Permits and licenses

Determinations

Annual reports

Budgets

Research

Benefits of SEEA for data

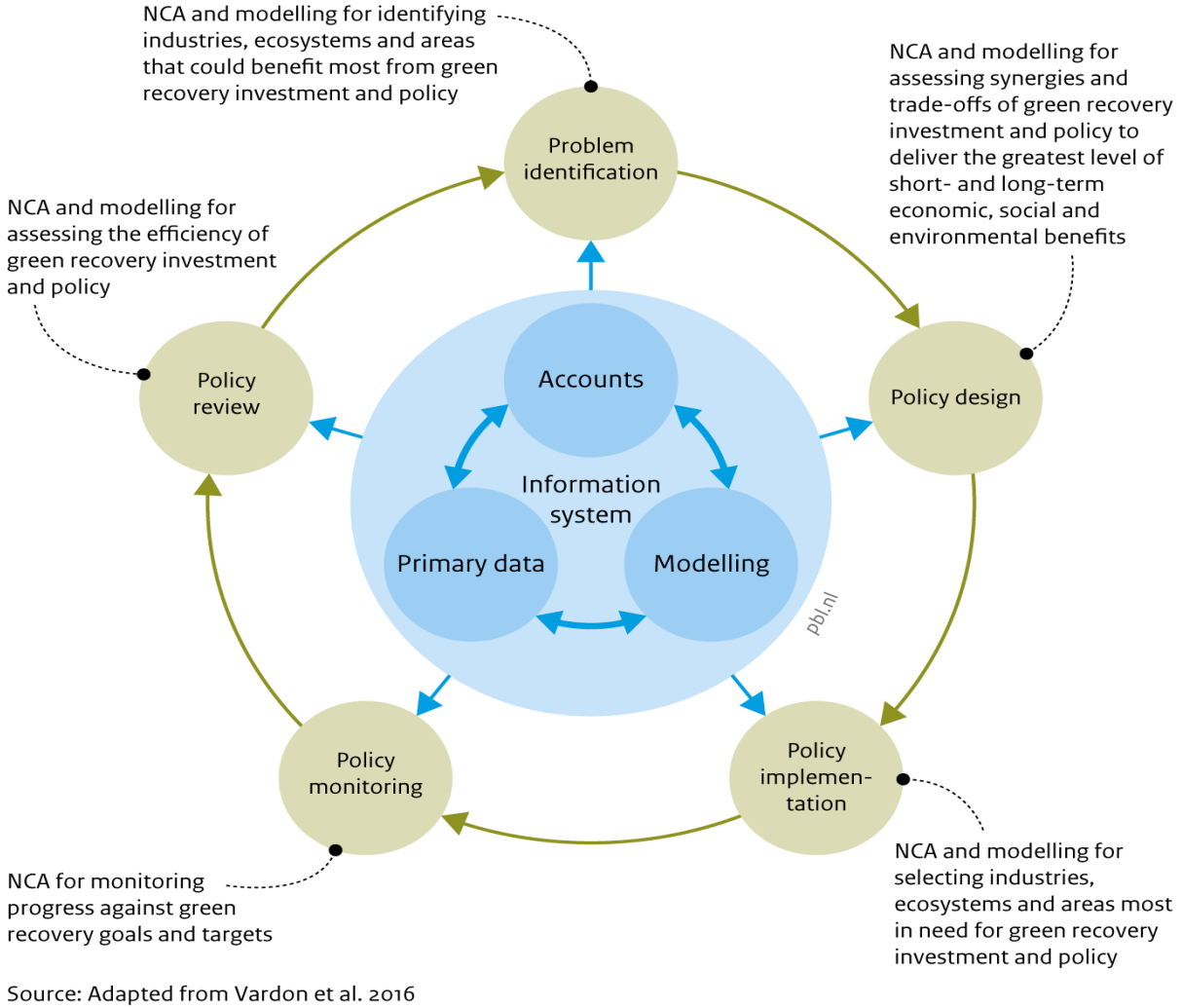
- Harmonises and links data
- Base information readily available (reduces need for ad hoc and reactive data collection)
- Allows identification of data gaps and deficiencies
- Consistent information is available over time
- Regular productions lead to more efficient production and improved data quality
- Contextualises other data sources
- Accounts can be scaled and nested
  - Local
  - Regional
  - State
  - National

Benefits of SEEA for policy

Accounts:

- Assist at all stages of the policy cycle
- Address specific policies or management regimes (e.g. circular economy, biodiversity conservation, climate change)
- Feed into models and analysis
- Co-design increases the usefulness of accounts to decision-makers

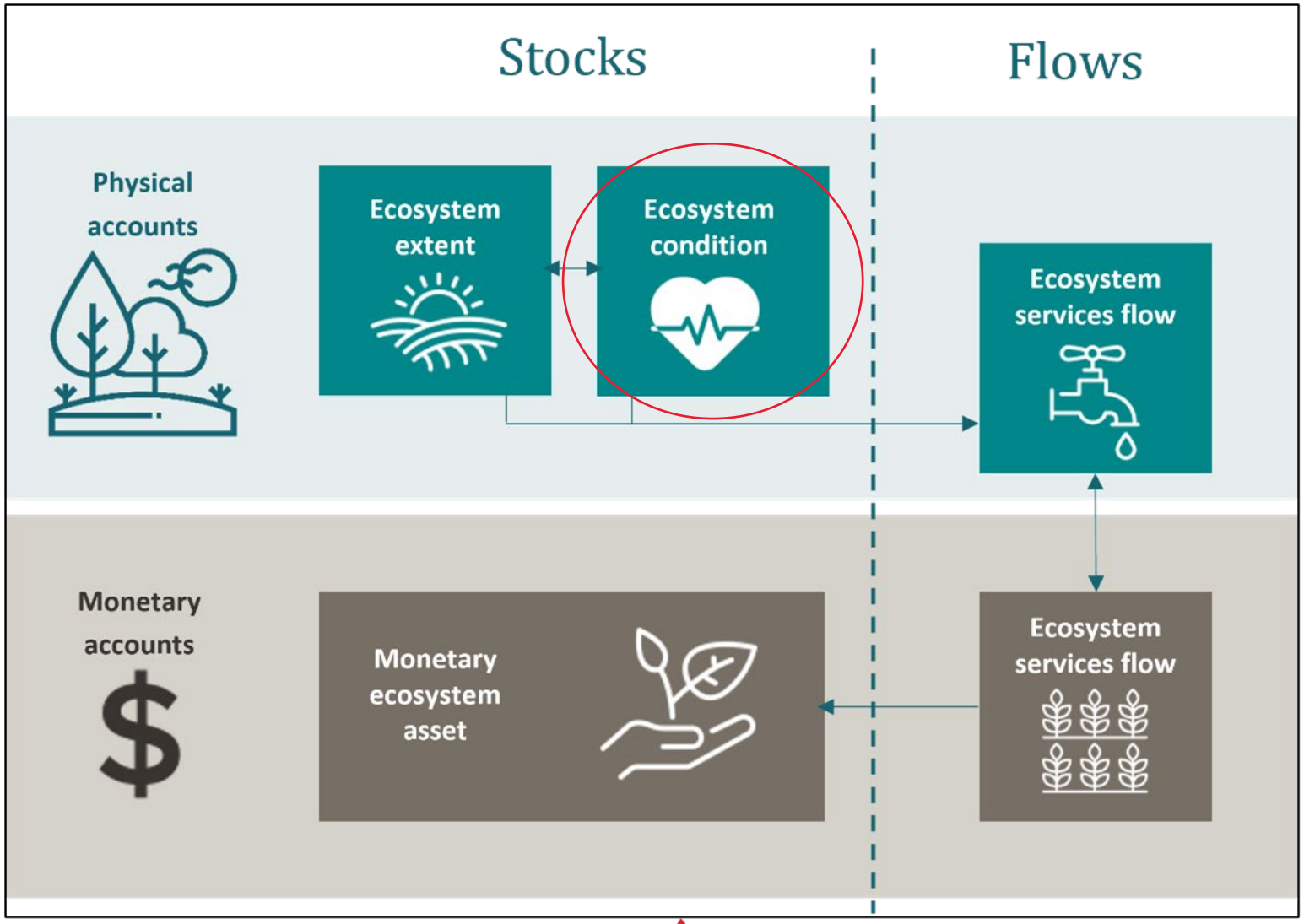
Use of natural capital accounting for green recovery across the policy cycle



Source: Adapted from Vardon et al. 2016

https://www.pbl.nl/en/publications/greening-the-recovery-to-make-it-last

Condition in the SEEA-EA

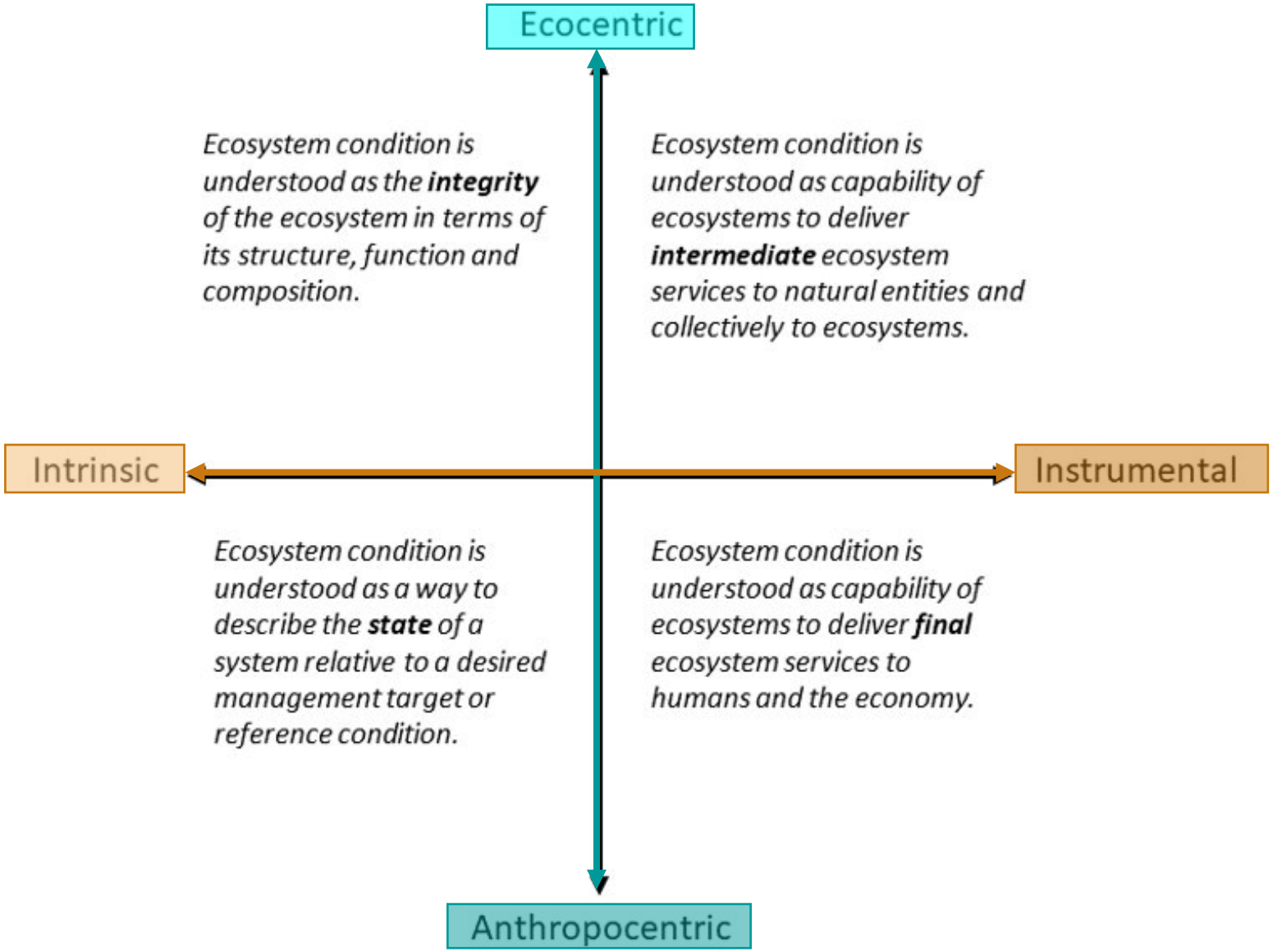


Condition definition

Ecosystem condition is the quality of an ecosystem, which may reflect multiple values, measured in terms of its abiotic and biotic characteristics, across a range of temporal and spatial scales.

- The basis for assessing condition is the capacity to maintain ecosystem integrity.
- Ecosystem integrity is the ecosystem's capacity to maintain its characteristic composition, structure, functioning and self-organisation over time within a natural range of variability.
- Characteristics of condition support the ecosystem's capacity to supply ecosystem services.

Ecosystem condition reflecting multiple purposes and values



Ecosystem condition typology for classification of characteristics

Groups	Classes	Examples
A. Abiotic ecosystem characteristics	A1. Physical state characteristics Physical descriptors of the abiotic components of the ecosystem	Soil structure Water availability Impervious surfaces Bulk density
	A2. Chemical state characteristics Chemical composition of the abiotic components of the ecosystem	Soil nutrient concentration Water quality Air pollutant concentration
B. Biotic ecosystem characteristics	B1. Compositional state characteristics Composition/ diversity of ecological communities at a given location and time	Species richness Genetic diversity Threatened species
	B2. Structural state characteristics Aggregate properties (e.g. mass, density) of the biotic components on the ecosystem	Canopy cover Vegetation density Habitat structure
	B3. Functional state characteristics Summary statistics (e.g. frequency, intensity) of the biological, physical and chemical interactions between ecosystem compartments	Productivity and decomposition Reproduction, dispersal Disturbance regimes Community age
Landscape / seascape	C1. Landscape and seascape characteristics Metrics describing mosaics of ecosystem types at coarse spatial scales	Ecosystem diversity Connectivity / fragmentation Ecosystem type mosaics

[Keith et al. 2020 One Ecosystem 5:e58216; Czucz, Keith, et al. 2021 One Ecosystem 6: e58218; Czucz, Keith, Maes et al. 2021 Ecological Indicators 133: 108376]

Reference condition

- The condition against which past, present and future ecosystem condition is compared in order to measure relative change over time.
- Based on the on the principle of maintaining ecosystem integrity, stability and resilience over ecological timeframes.

Assessment framework

Ecosystem	Possible reference conditions
Natural ecosystems	Undisturbed or minimally disturbed
	Historical condition considered to represent natural state
	Least disturbed condition or current best available
	Contemporary condition allowing comparable data
Anthropogenic ecosystems	Historical condition considered to represent stable socio-ecological state
	Least disturbed or current best available
	Contemporary condition allowing comparable data
	Best attainable condition under best possible management practices and attaining a stable socio-ecological state

Methods

1. Reference sites
2. Modelled reference condition
3. Statistical approach from distributions
4. Historical observations and data
5. Contemporary data
6. Prescribed levels
7. Expert opinion

AND combinations of methods

Decreasing preference

Requirements for the national ecosystem condition account

- ‘Fit-for-purpose’ for the **National Ecosystem Accounts**
- Aligns with the SEEA EA **Ecosystem Condition Typology**
- Coverage of **terrestrial, freshwater, marine realms** across the Australian continent and exclusive economic zone.
- Metrics that support **multiple views and dimensions**, and their uses of ecosystem condition accounts
- Requires expertise from a **range of disciplines** to implement
- **Timeframe** for implementing updates to the condition accounts
  1. Short-term, data available that can be employed in the next 2-3 years
  2. Long-term, development of data that may be available for the continuous improvement program to 2031.

Identifying the purpose of the condition account

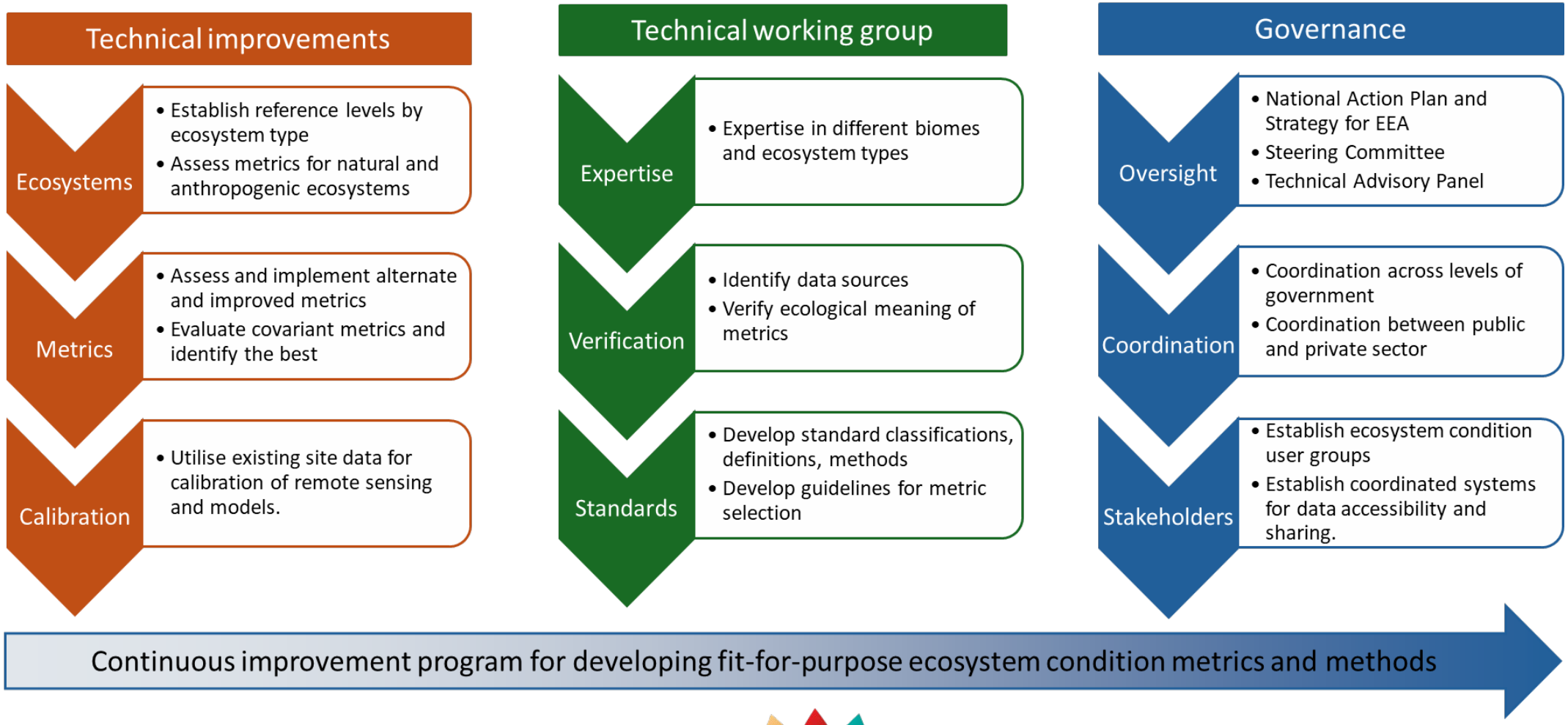
1. International reporting obligations
   - reporting on Australia's progress in meeting the targets of the Kunming-Montreal Global Biodiversity Framework (GBF)
2. National reporting obligations
   - National State of Environment report
3. Environmental assessments under the EPBC Act
   - other national scale environmental policy, management, and planning initiatives
4. Business uses at national scales
   - understanding environmental risks and opportunities
   - reporting on nature-related financial disclosures
   - undertaking environmental assessments
   - benchmarking performance

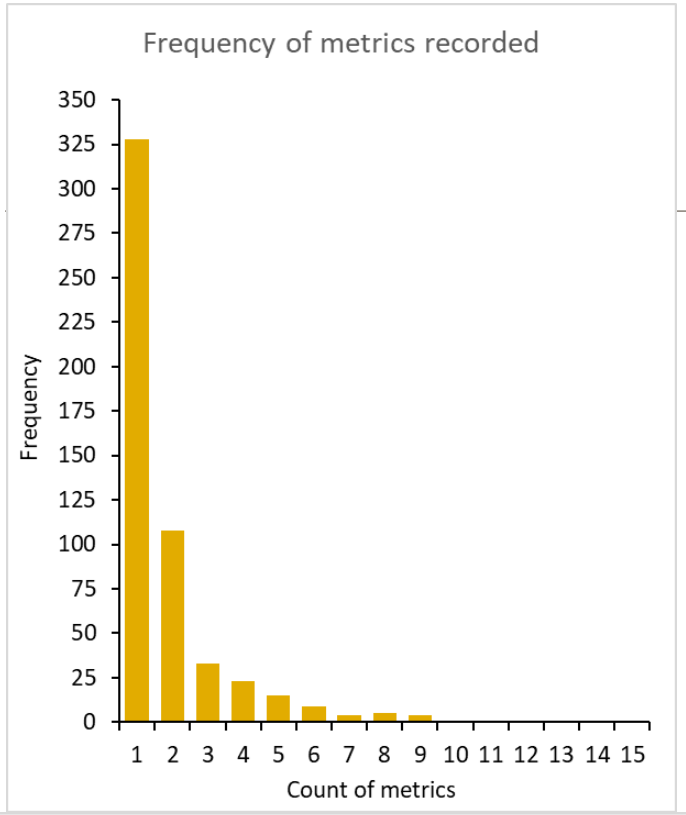
Strategy and methods for the review

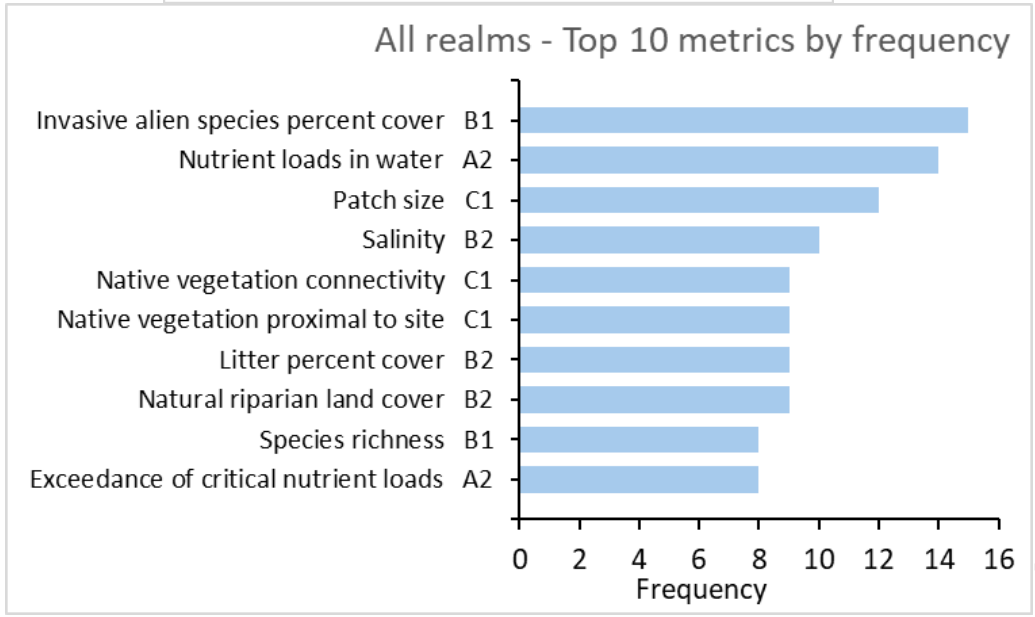
- Identified and clarified key issues for the national ecosystem condition accounts
- Comprehensive review that classified and analysed available metrics currently in use and potential metrics from research studies. Systems currently using condition variables:
  - 22 Australian national and state systems
  - 17 international system
  - total of 518 metrics
- Covered the terrestrial, freshwater, marine and transitional realms in Australia
- Reported metrics related to the classification of ecosystem types and their spatial distribution
- Constructed a database mapping metrics and their associated information using relational tables:
  - Current purpose and use
  - Compliance with selection criteria
  - Classification against ecosystem condition typology
  - Spatial and temporal scale and data availability
  - Reference citation
- Established a process and criteria for the selection of metrics
- Provided recommendations to guide an implementation plan for national ecosystem condition accounts
  1. ecosystem condition metrics
  2. institutional and governance
  3. technical and analytical

Report Summary

Process for the integration of technical improvements, expertise and governance within an implementation plan for the continuous improvement of fit-for-purpose condition accounts







Key Findings (1)

Ecosystem condition metrics

1. >500 metrics identified in Australia and internationally
2. Many systems and programs are independently developing and testing metrics
3. Metrics were highly variable across realms and biomes
4. The same ecological concepts of characteristics were measured in multiple ways, creating covariance among metrics
5. Many metrics are measures of pressure rather than condition
6. Reference levels differed in reporting, meaning and quantification
7. Remote-sensing data dominate national level metrics but require ground truthing

Same characteristic but different metrics – need for consistency

Example of metrics describing freshwater quality

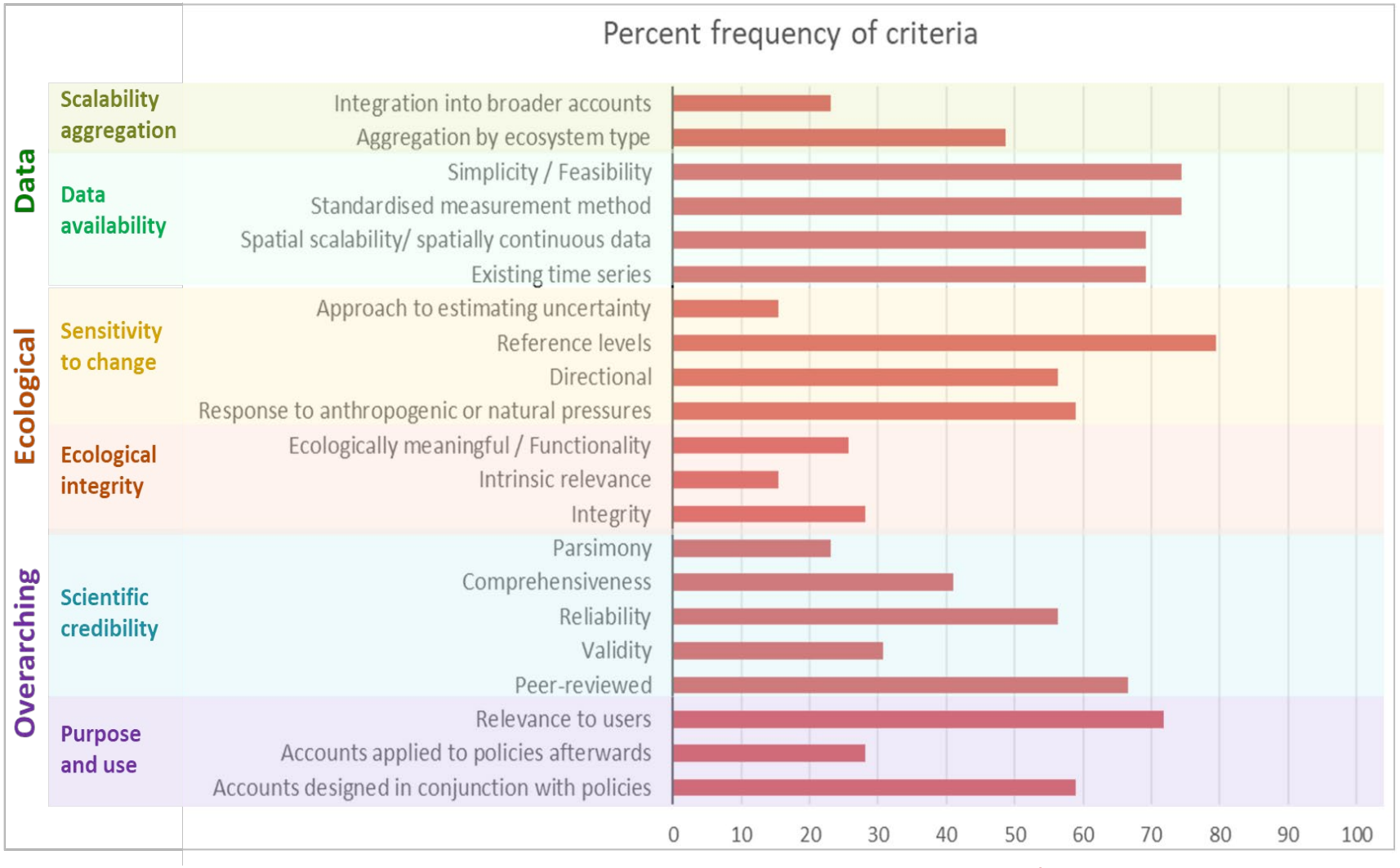
Chemical metrics:

- Carbonate concentration
- Alkalinity
- Acidity
- pH
- Oxygenation condition
- Dissolved oxygen
- Salinity
- Electrical conductivity
- Cation concentration
- Colour

- All metrics are valid
- Which metric is best?
- Reduce duplication of characteristics measured
- Depends on the purpose
- Depends on ecosystem type
- Require input from discipline experts and consensus
- Aim for an efficient and enduring system of ongoing monitoring

Key Findings (2)

Criteria for selection of metrics
- frequency they were described in the systems reviewed



Ecosystem condition metrics

8. Criteria for selection or evaluation are inconsistently applied and poorly documented.
9. Integration across systems and levels of governance remains weak
10. Covariance among metrics needs to be tested and reduces their information value
11. Biotic functional characteristics are under-represented
12. Spatial and temporal coverage are uneven across datasets

Recommendations – Technical and Analytical (1)

Suggested specific additions or alternatives for condition metrics used in the national ecosystem accounts

1. Establish **reference levels** for each metric for each ecosystem type.

2. Use satellite-based **active sensors** (LiDAR, radar) for metrics of woody vegetation structure.

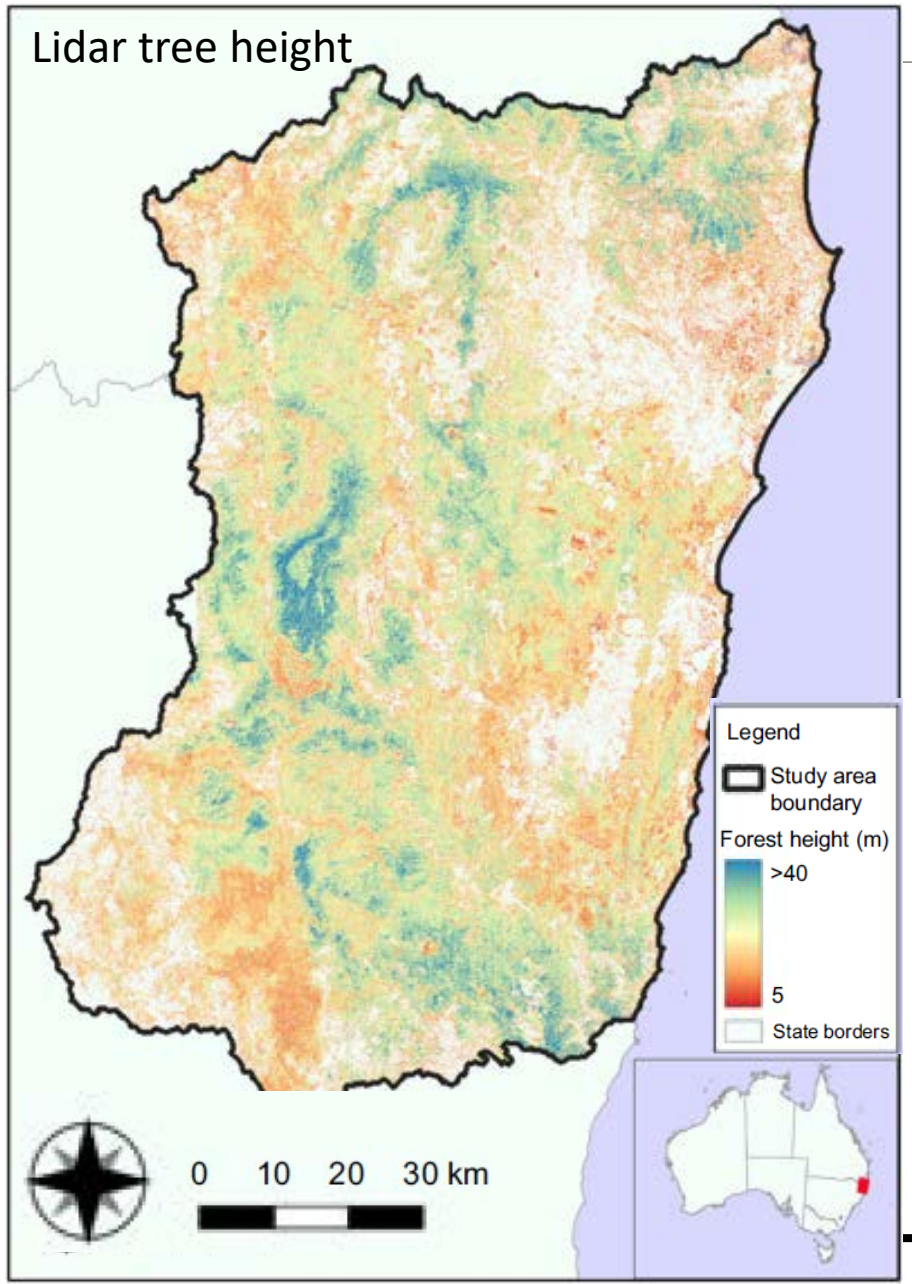
3. Measures of **photosynthetically active cover** should separately model woody (perennial) fPAR from herbaceous (ephemeral) fPAR.

4. Use data on **woody vegetation structure** from FullCAM model.

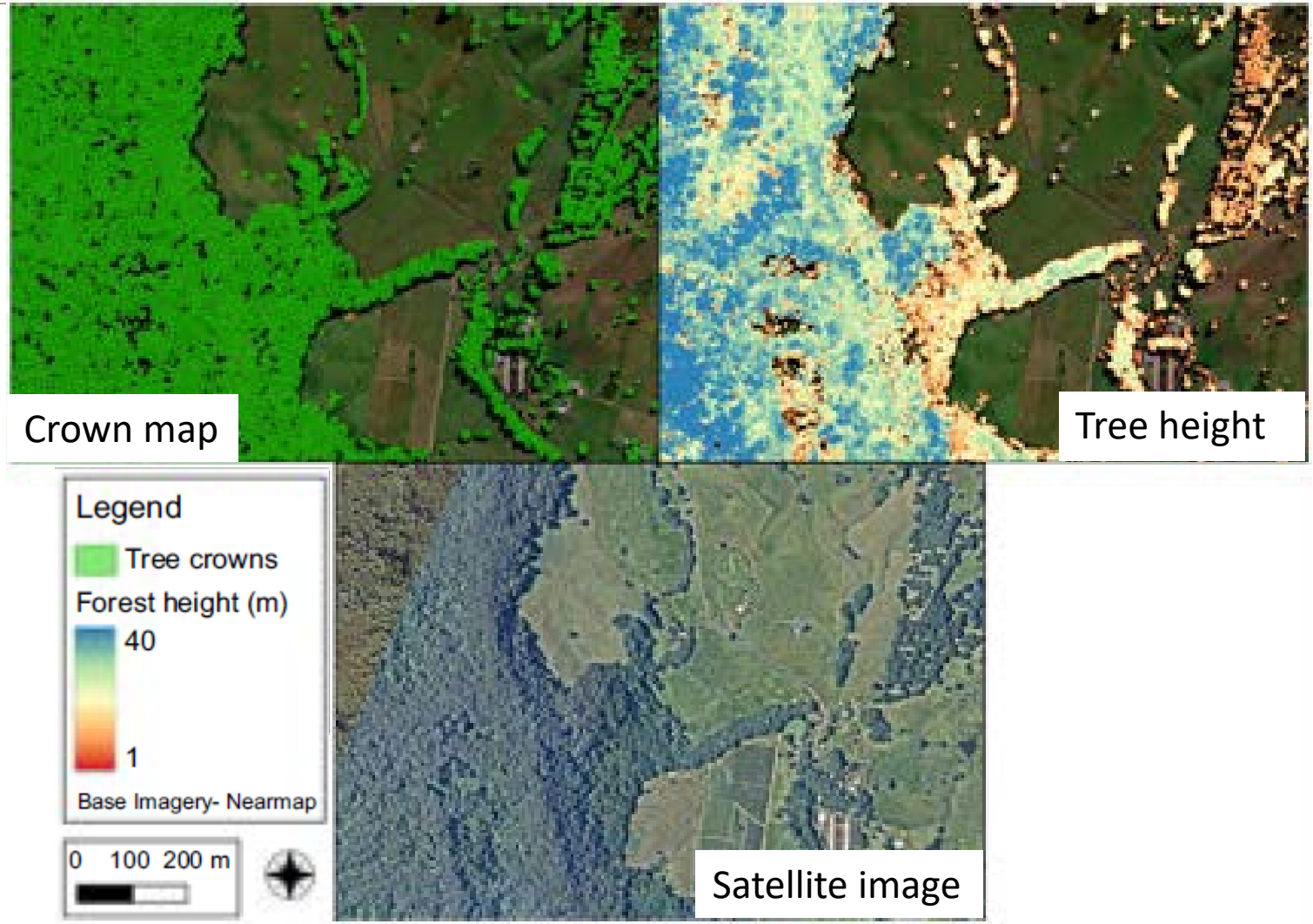
5. Apply biodiversity-specific **connectivity metrics** to account for the mobility and habitat resource needs of species or guilds.

Recommendation example 1: tree height

Case study region of NSW Northern rivers



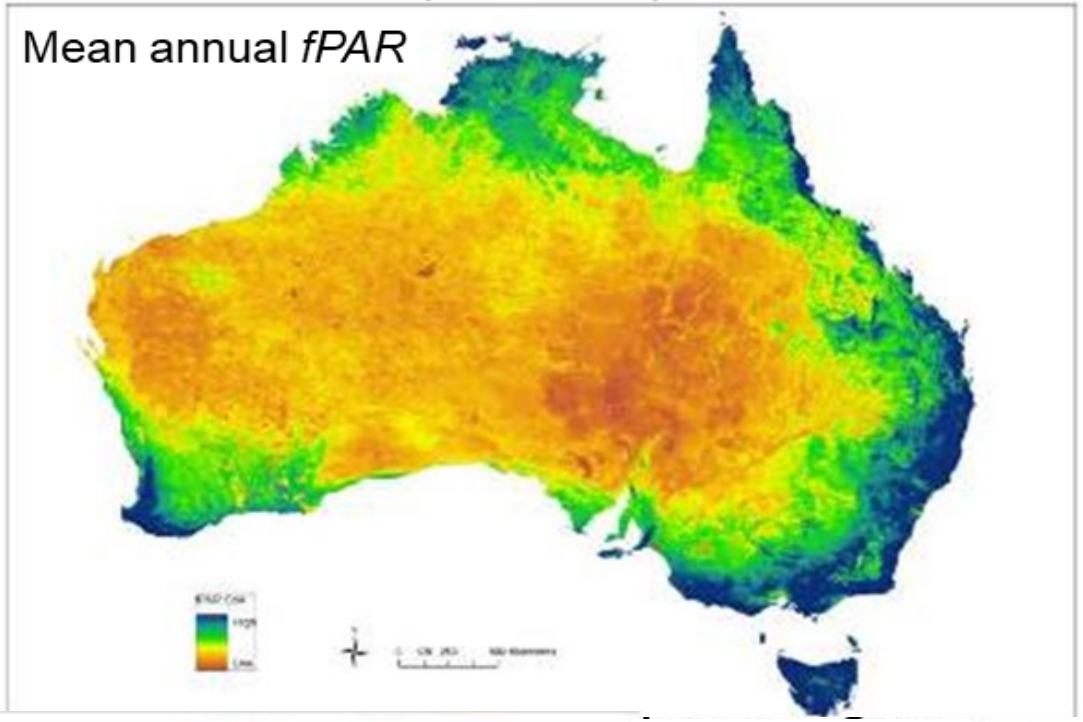
Zoom in example comparing spatial layers

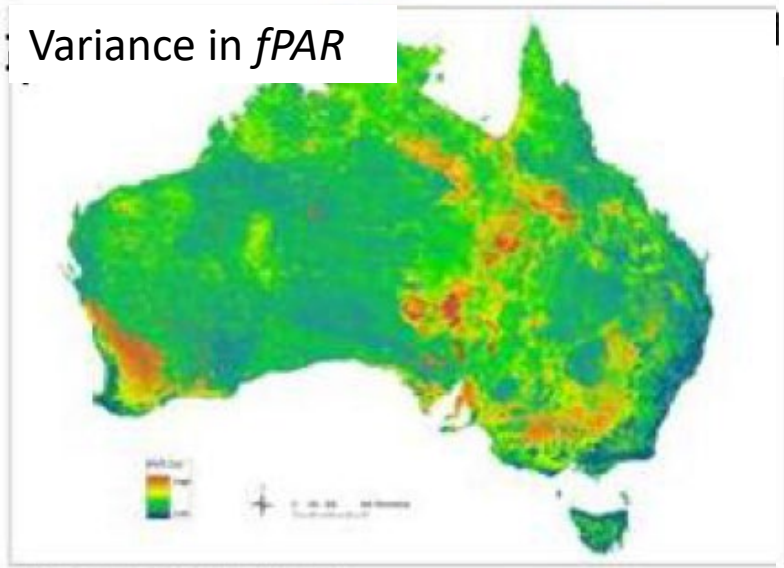


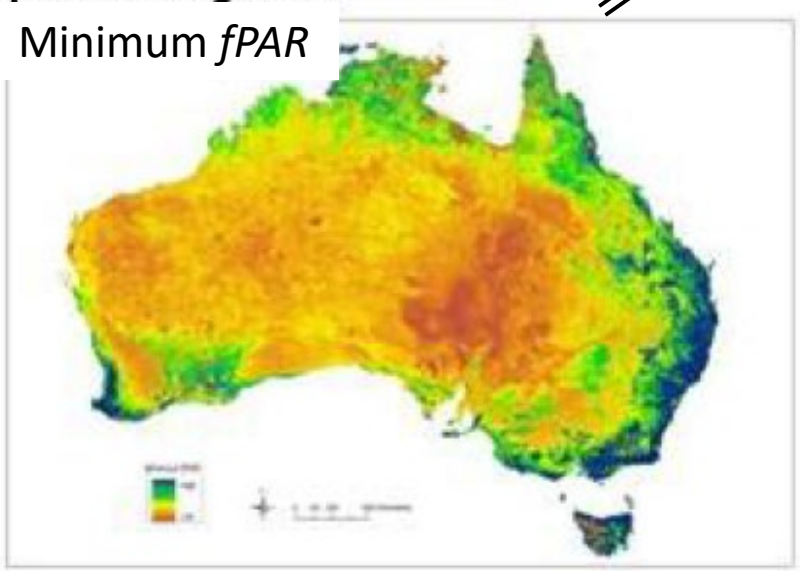
Norman et al. 2025 Aust. J. Bot. doi:10.1071/BT25031

Recommendation example 2: separating perennial and ephemeral leaf cover

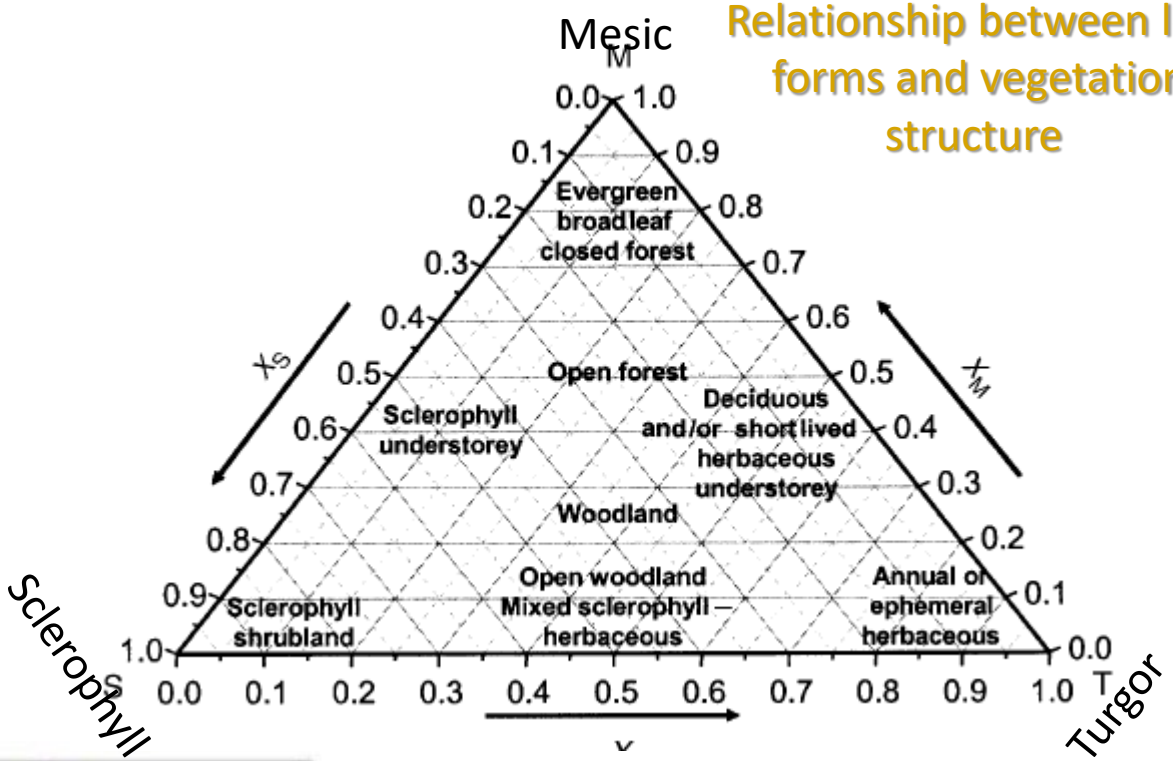
Fraction of Photosynthetically Active Radiation







Relationship between leaf forms and vegetation structure



Berry and Roderick 2002, 2004
Mackey et al. 2008

Recommendations – Technical and Analytical (2)

Suggested specific additions or alternatives for condition metrics used in the national ecosystem accounts

6. Add ecosystem **fragmentation metrics**

7. Calibrate the **burn area ratio metric** for each ecosystem type and combined with regrowth

8. Produce **land use data annually** to identify changes in ecosystem extent

9. Ecosystem condition assessments based on an appropriate level of **ecosystem type classification** to differentiate characteristics

10. **Human dominated ecosystems** often require different or modified metrics and reference levels, but should also be assessed against the natural ecosystem reference.

Recommendation example 3: include fragmentation metrics

Examples of fragmentation metrics derived from the extent data:

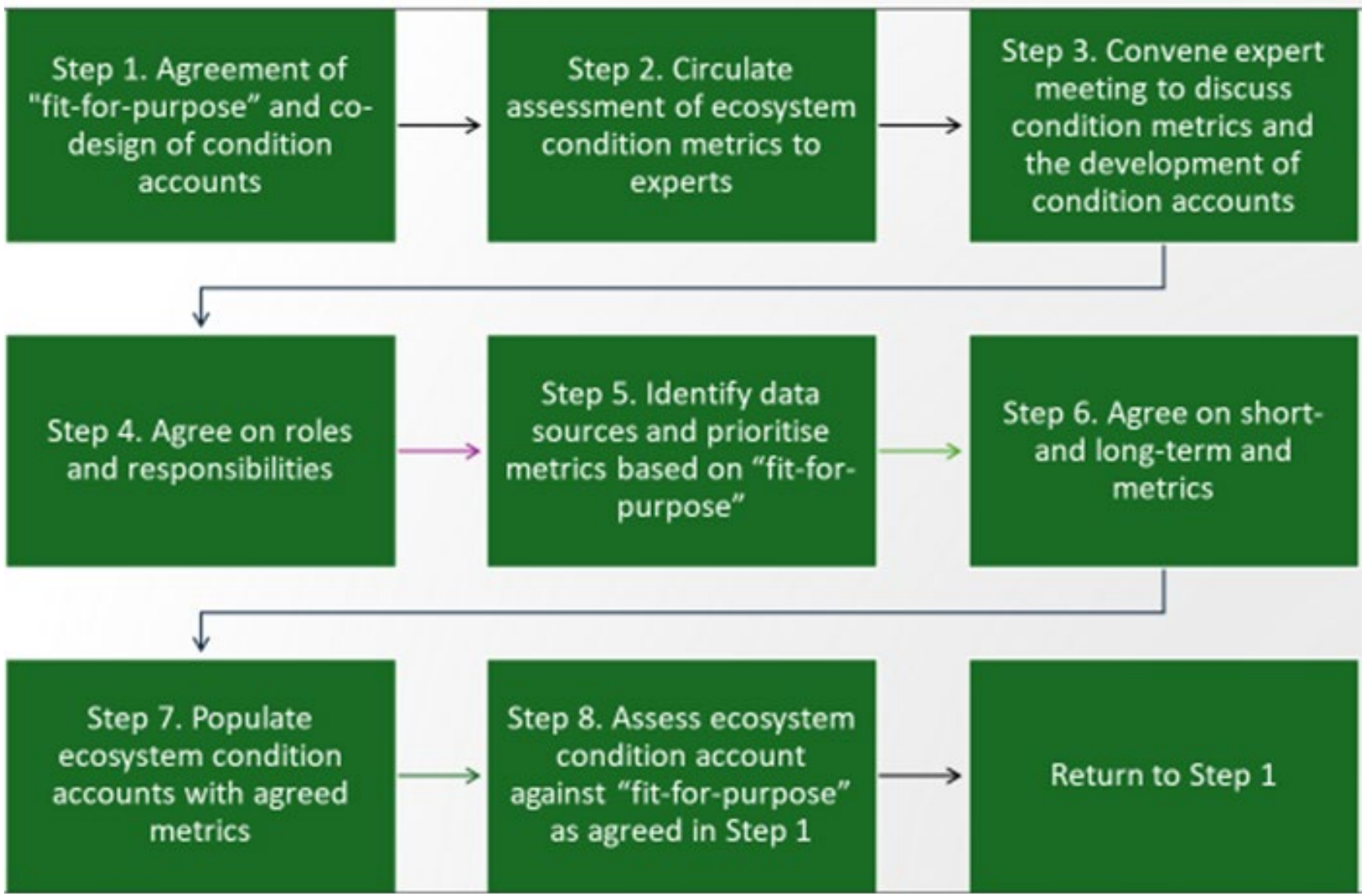
- Patch area
- Mean patch size
- Linkage between patches
- Terrestrial connectivity
- Hydrological connectivity
- Proportion of habitat
- Patch connectivity

- Current examples of regional studies using fragmentation metrics that could be scaled up.
- Analytical methods are available
- Ecologically meaningful and applied to biodiversity conservation
- Metrics can be tailored to mobile and migratory species.

Recommendations - Institutional and Governance

1. Build on mechanisms formed under the **National Action Plan and Strategy** for Environmental-Economic Accounting
2. **Coordinate** with other Commonwealth and State agencies and the private sector
3. Establish a **Technical Working Group** on Ecosystem Condition Accounting
4. Establish ecosystem accounting **user groups**
5. Ensure **State of the Environment** (SoE) reporting uses ecosystem condition metrics that are consistent with the National Ecosystem Accounts as they develop
6. Improve **data accessibility** and management through shared repositories and interoperable systems
7. Develop **guidelines for metric selection** to ensure ecological relevance, policy alignment, and methodological rigour
8. Address **data scaling** challenges

Example process for development of ecosystem condition metrics and methods appropriate for accounts



Defining fit-for-purpose

- Balance of scientific integrity, policy needs and practical feasibility
- Defining the purpose and matching the scale and metrics
- Providing information about ecosystems that is systematic, comparable over time and space, and can be integrated with economic data.

Key messages

- 500+ condition metrics are being used, with few common metrics, and multiple metrics describing similar characteristics
- Which metrics are best is dependent on the purpose
- 10 short-term improvements are identified for the national ecosystem condition account
- Processes are needed for long-term development, acceptance and use of condition metrics

Thank you and acknowledgements

This work benefited greatly from the inputs of DCCEEW and ABS staff at meetings to scope and develop the report as well as follow-up interaction.

The report also benefited from feedback on a draft report.

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