System of Environmental Economic Accounting

Carbon accounting

(Levels 1 & 2)

October 2017

United Nations

Overview: carbon accounting

1. **Learning objectives**
2. **Review of level 0 (main concepts)**
   - Basic concepts
3. **Level 1 (compilers)**
   - Main concepts
   - Group exercise and discussion
4. **Level 2 (data providers)**
   - Data options, sources, examples and issues
   - Group exercise and discussion
5. **Closing discussion**

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Carbon account: learning objectives

- **Level 1:**
  - Why carbon accounts are important
  - The basics of the carbon cycle and pools, including the carbon stocks and carbon flows
  - How carbon is treated in the SEEA, including basic concepts and the structure of the accounts that include carbon
  - How to build a carbon stock account
- **Level 2:**
  - Understand the data options and sources
  - See how other countries have approached carbon accounting

Carbon accounting (level 0): review of basic concepts

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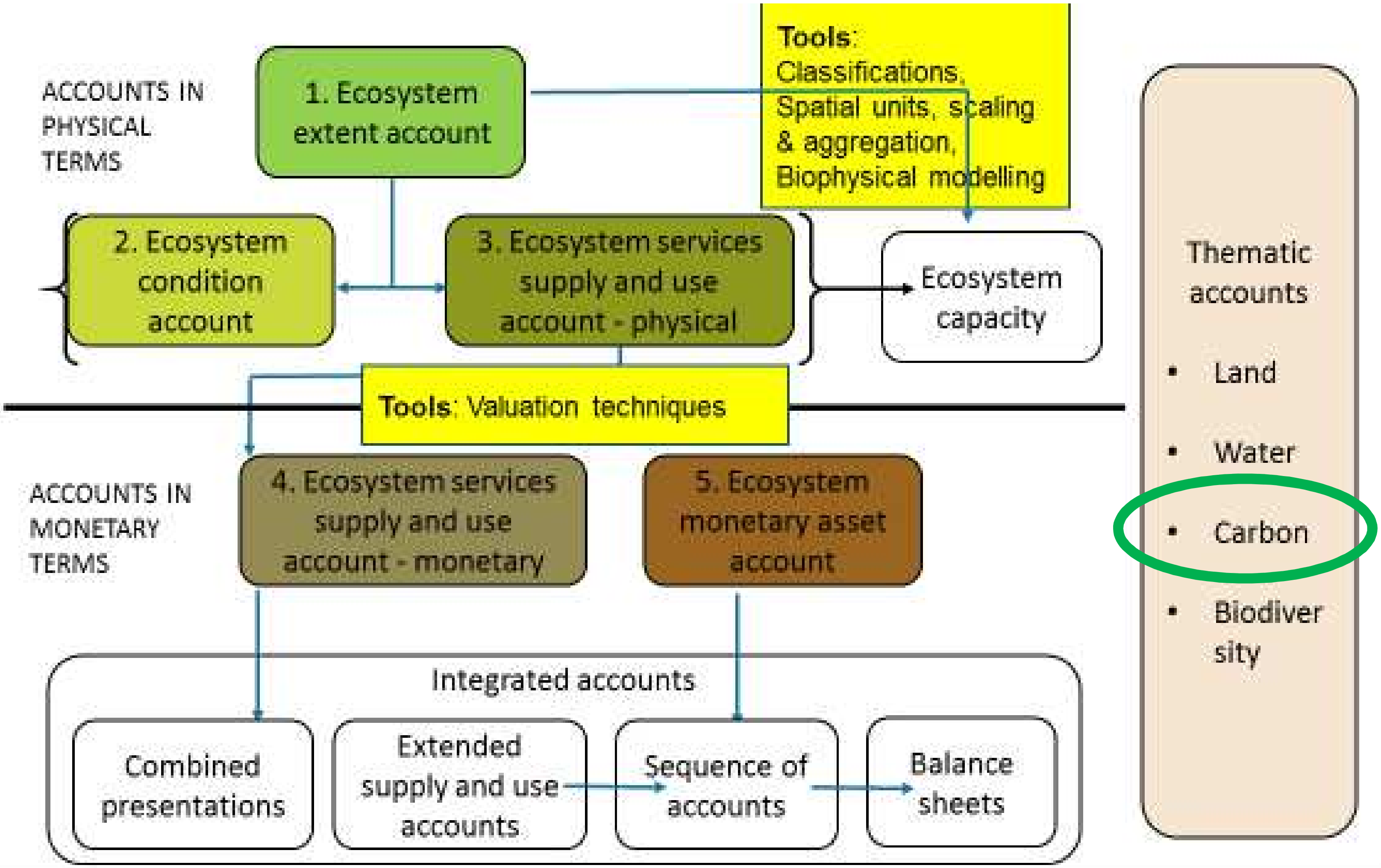
SEEA EEA accounts, tools and linkages



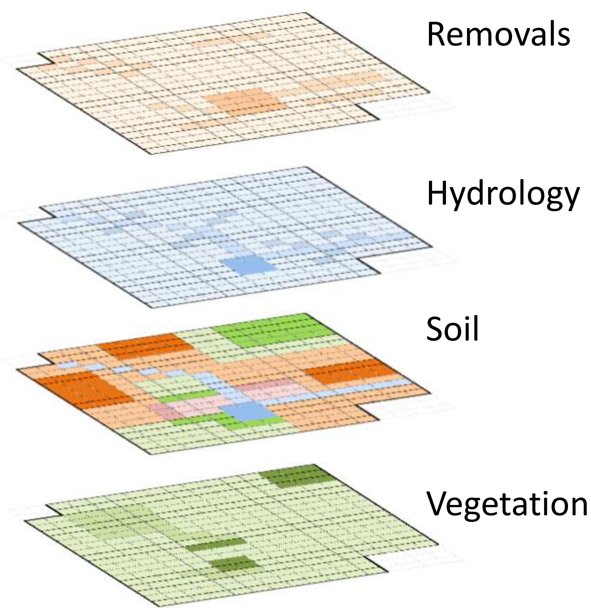
Carbon account: What and Why?

- **What?**
  - Measurement of carbon stocks and flows for all parts of the carbon cycle and all carbon pools
    - Focus of carbon accounting at this stage is on biocarbon and geocarbon
  - Carbon-related services (sequestration and storage)
  - Carbon as a characteristic of ecosystem condition (productivity)
- **Why?**
  - Policies on climate change, low-carbon economy
  - Assess changes in land cover and land use on carbon stocks and sequestration
  - Links to other SEEA accounts (**Condition**, **Services Supply**)
  - Links to SEEA CF (timber, soil, materials)
  - Links to international guidelines (IPCC and REDD+)
  - Indicators:
    - Natural and human additions to carbon stock → where
    - Natural and human removals from carbon stock → where

What does a carbon stock account look like?

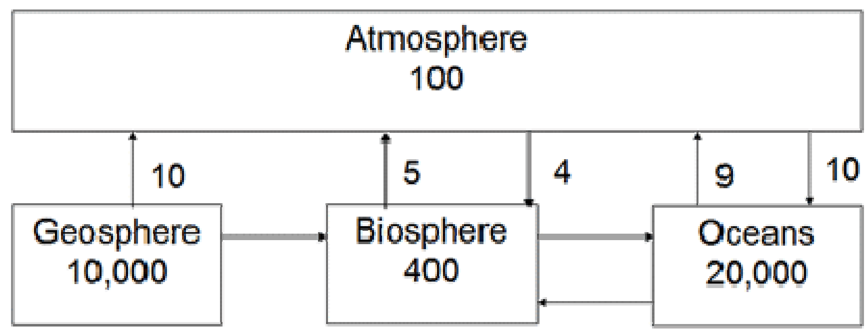
Tables

Maps



	Geocarbon	Biocarbon	Oceans	Atmosphere
	billion tonnes C			
Opening stock	10,000	400	20,000	100
Additions	-	4	10	24
Reductions	10	5	9	14
Closing stock	9,990	399	20,001	110

Scaling
Biophysical modelling



What does a carbon stock account look like?

- Spatially detailed in terms of:
  - Carbon stocks
  - Additions and reductions
- Natural & human additions and removals

Gigagrams Carbon (GgC)	Geocarbon					Biocarbon			Atmosphere	Water in oceans	Accumulation in economy				Total
	Limestone	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories[a]	Fixed assets	Consumer durables	Waste	
Opening stock of carbon															
Additions to stock															
Natural expansion															
Managed expansion															
Discoveries															
Upward reappraisals															
Reclassifications															
Total additions to stock															
Reductions in stock															
Natural contraction															
Managed contraction															
Downward reappraisals															
Reclassifications															
Total reductions in stock															
Imports and exports															
Imports															
Exports															
Closing stock of carbon															

a Excluding inventories included in biocarbon (e.g., plantation forests, orchards, livestock, etc.).

Note: Dark grey cells are null by definition.

What do you need to compile a carbon account?

- **Ecosystem extent account**
- Common spatial infrastructure (**spatial units**)
- Lookup tables (sequestration and storage by land cover type)
- **Data:**
  - Biocarbon (above-ground biomass) from satellite data
  - Carbon sequestration and storage from vegetation cover
  - Soil carbon from soil inventories
  - Removals from agriculture, forestry data, fires
- **Expertise:**
  - Ecologists (biophysical modelling)
  - Agriculture, forestry experts
  - Geographers (GIS, remote sensing)

Carbon accounting (level 1): compilers

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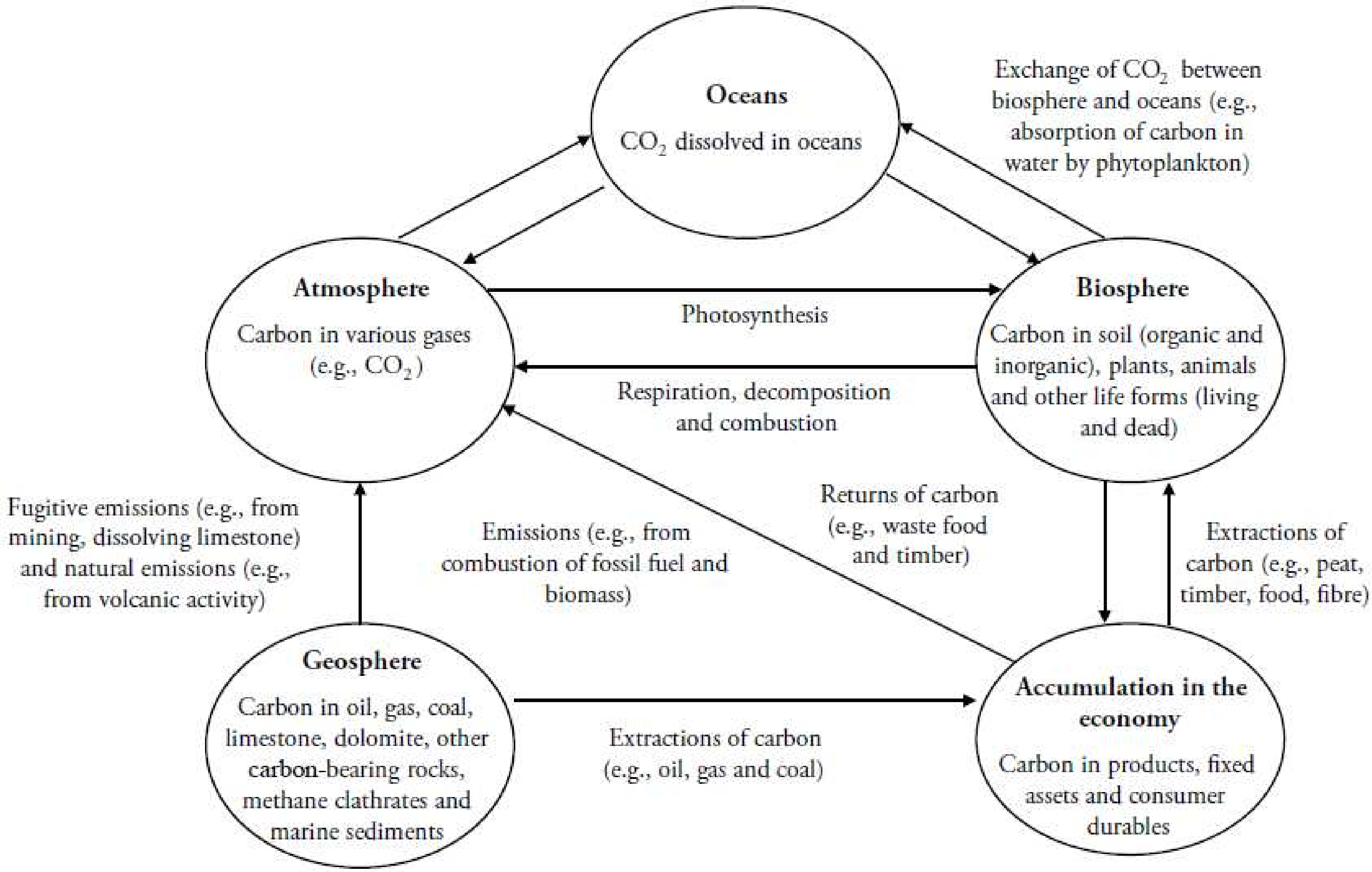
Why carbon accounts?

- Increasing atmospheric carbon is causing climate change:
  → Increasing temperatures, changes in rainfall, sea level rise

- Information on carbon stocks and flows supports:
  - > Assessing the impact of changes in land cover and land use on carbon stocks and carbon sequestration
  - > Assessing the impact of different policy options on industries and sectors. For example, a mandated reduction in the level of emissions from fossil fuels on the mining, manufacturing and agricultural industries
  - > Information compilers to improve coherence between data sources and systematically address gaps and deficiencies in primary information sources

The carbon cycle (main elements)



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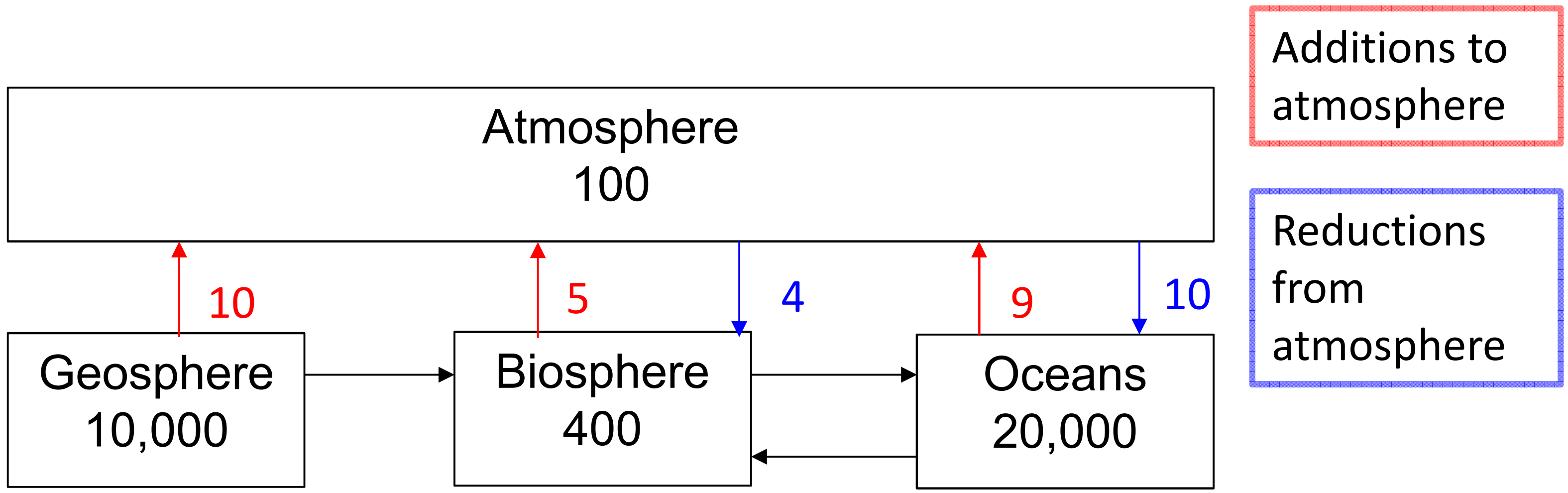
Source: SEEA EEA, p. 88

Carbon account

The SEEA EEA describes:

1. Carbon as an asset
   > Fossil fuels, soil carbon
2. Carbon-related ecosystem services
   > ***Storage*** = stored in soil, water and biomass
   > ***Sequestration*** = removal from the atmosphere
3. Carbon as a characteristic of ecosystem asset condition (condition account)
   > Biomass accumulation is an indicator of productive ecosystems

Simplified carbon stock account



	Geocarbon	Biocarbon	Oceans	Atmosphere
Opening stock	10,000	400	20,000	100
Additions	-	4	10	24
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Closing stock	9,990	399	20,001	110

Compilation group exercise (30 min)

- Situation:
  - Have land cover account (from **ecosystem extent account**)
  - Need to calculate: carbon stock and carbon sequestration
- Objective (in groups of 3-5):
  1. Calculate a simplified carbon stock account
  2. Calculate account for ecosystem services from carbon sequestration
  3. Report and discuss results

Group exercise: step 1

Step 1 – Calculate carbon stock account

Land cover account

Carbon stock account

Table 1: Physical Account for Land Cover

	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	**Total**
Opening Stock	16	7	14	23	7	19	7	6	1	0	100
Additions to Stock	3	11	0	0	0	0	0	1	0	0	15
Reductions in Stock	0	0	1	8	1	2	0	3	0	0	15
Closing Stock	19	18	13	15	6	17	7	4	1	0	100

Table 4: Simplified Carbon Stock Account

	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	Total
Carbon Stored (tonnes/ha)	5	40	10	200	800	80	300	8	0	0	
Carbon Stock											
Opening											
Increases											
Decreases											
Net change											
Closing											

Note: Opening is Opening Land area * Carbon Stored

Net change is Increases - Decreases

Multiply land cover area by carbon stored (lookup table)
e.g. opening 16ha artificial surface * 5 tonnes/ha = 80 tonnes
Net change = increases - decreases

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Group exercise: step 2

Step 2 – Calculate carbon sequestration

Land cover account

Table 1: Physical Account for Land Cover

	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	**Total**
Opening Stock	16	7	14	23	7	19	7	6	1	0	100
Additions to Stock	3	11	0	0	0	0	0	1	0	0	15
Reductions in Stock	0	0	1	8	1	2	0	3	0	0	15
Closing Stock	19	18	13	15	6	17	7	4	1	0	100

Carbon sequestration service

Table 5: Account of Ecosystem Services from Carbon Sequestration (tonnes/ha/year)

	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	Total
Carbon Sequestration (tonnes/ha/year)	0	20	2	30	100	5	40	1	0	0	
Carbon Sequestration (tonnes/year)											
Opening: Carbon Sequestration											
Closing: Carbon Sequestration											
Net change											

Note: Opening is Opening land area * Carbon Sequestration

Multiply land cover area by carbon sequestration (lookup table)
e.g. opening 7ha crops * 20 tonnes/ha/year = 140 tonnes/year
Net change = closing - opening

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Group exercise: questions

- Is everyone clear on the objectives?
- 30 minutes group work
- Please ask questions!
- Questions:
  > Each group report:
    - Net change in storage
    - Net change in sequestration
    - What was the main source of change?

  > Bonus question:
  Why does deforestation and degradation of forests often result in higher releases to the atmosphere?

Table 4: Simplified Carbon Stock Account

	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	Total
Carbon Stored (tonnes/ha)	5	40	10	200	800	80	300	8	0	0	
Carbon Stock											
Opening											
Increases											
Decreases											
Net change											
Closing											

Note: Opening is Opening Land area * Carbon Stored
Net change is Increases - Decreases

Table 5: Account of Ecosystem Services from Carbon Sequestration (tonnes/ha/year)

	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	Total
Carbon Sequestration (tonnes/ha/year)	0	20	2	30	100	5	40	1	0	0	
Carbon Sequestration (tonnes/year)											
Opening: Carbon Sequestration											
Closing: Carbon Sequestration											
Net change											

Note: Opening is Opening land area * Carbon Sequestration

Group exercise: results

Simplified carbon stock account

- Net change in storage = -2,131

Main source of change = loss of tree covered areas

Table 2: Simplified Carbon Stock Account

	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	**Total**
Carbon Stored (tonnes/ha)	5	40	10	200	800	80	300	8	0	0	
Carbon Stock (tonnes)											
Opening	**80**	**280**	**140**	**4,600**	**5,600**	**1,520**	**2,100**	**48**	**0**	**0**	**14,368**
Increases	15	440	0	0	0	0	0	8	0	0	463
Decreases	0	0	10	1,600	800	160	0	24	0	0	2,594
Net change	*15*	*440*	*-10*	*-1,600*	*-800*	*-160*	*0*	*-16*	*0*	*0*	*-2,131*
Closing	**95**	**720**	**130**	**3,000**	**4,800**	**1,360**	**2,100**	**32**	**0**	**0**	**12,237**

Carbon sequestration

- Net change in sequestration = -131

Table 3: Account of Ecosystem Services from Carbon Sequestration (tonnes/year)

	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	**Total**
Carbon Sequestration (tonnes/ha/year)	1	20	2	30	100	5	40	1	0	0	
Carbon Sequestration (tonnes/year)											
Opening: Carbon Sequestration	16	140	28	690	700	95	280	6	0	0	1,955
Closing: Carbon Sequestration	19	360	26	450	600	85	280	4	0	0	1,824
Net change	*3*	*220*	*-2*	*-240*	*-100*	*-10*	*0*	*-2*	*0*	*0*	*-131*

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Carbon accounting (level 2): data providers

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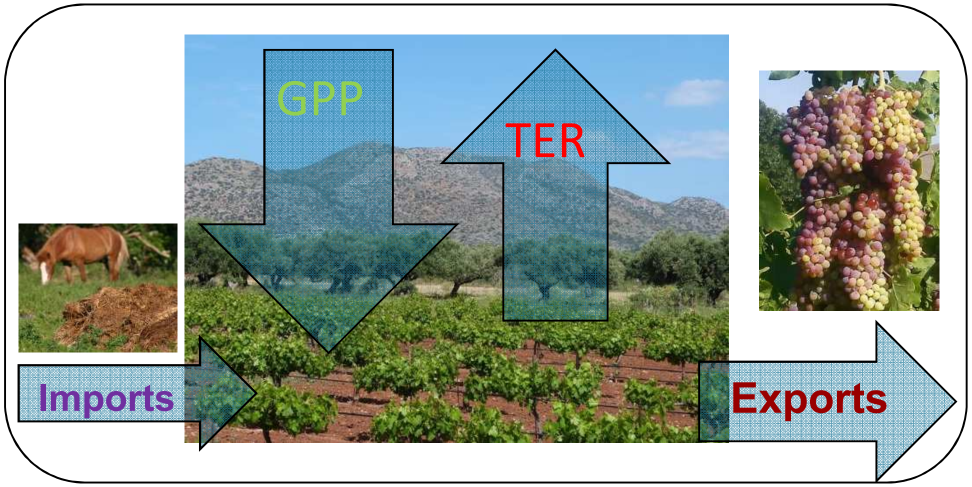
Carbon stocks, flows and balance

- Carbon stored in main pools SOIL and BIOMASS and transfers between them and within them



- Biomass, forest assets, regulatory and provisioning services

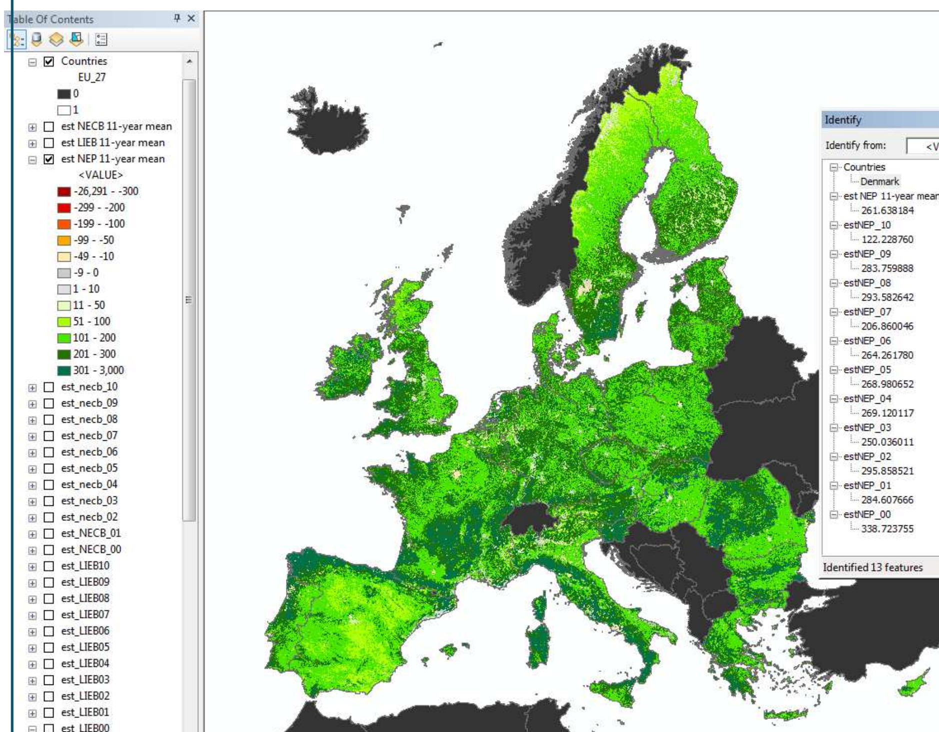
Data sources by account item

Carbon	Accounting items	Data sources
Opening Stocks	1. Soil Organic Carbon (SOC)	Joint Research Centre (JRC) map of SOC (Hiederer and Köchy, 2012), the top soil (1-30cm) and subsoil layer (30-100cm); and EEA estimate of SOC, 30cm.
	2. Biomass (TCB)	Downscaled forest biomass by EEA Upscaled biomass for non-forest biomass by EEA
Fluxes and transfers	3. Gross Primary Production (GPP)	Downscaled NASA-CASA NPP (from 8km to 1km), converted to GPP by adding autotrophic respiration from MODIS (Running et al., 2004)
	4. Terrestrial Ecosystem Respiration (TER) (carbon release / respiration)	Downscaled NASA-CASA Soil respiration (from 8km to 1km), converted to TER by adding autotrophic respiration from MODIS (Running et al., 2004)
	5. Human use of primary production (TPPU)	Downscaled regional statistics on crops (EUROSTAT), timber (EFISCEN, National FI and EFIMED) and grazing livestock, using land-cover and vegetation indices
	6. Carbon imports (TCR)	Downscaled deposition of dry sludge and manure (from livestock distribution)
Balances	7. Net Ecosystem Production (NEP), Net Ecosystem Carbon Balance (NECB)	NEP estimated from GPP and TER, NECB estimated by aggregating all flows

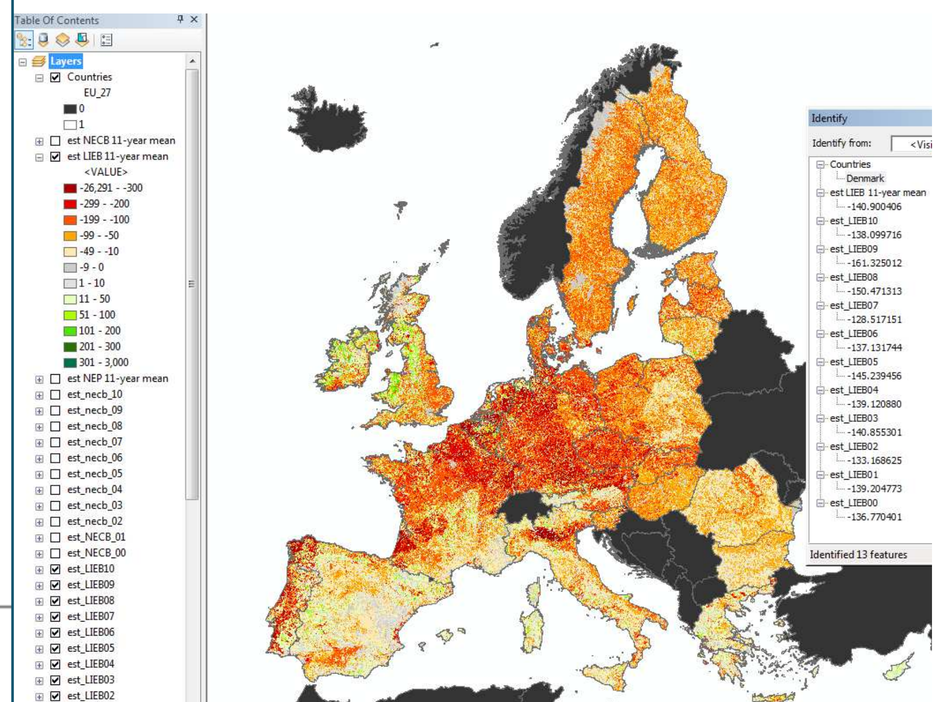
Balancing estimates

The two basic balancing items are designed to summarize ‘vertical’ and ‘horizontal’ carbon transfers

Net ecosystem production (NEP) = Gross Primary Production (GPP) – Terrestrial Ecosystem Respiration (TER)



Balance of lateral imports and exports = Carbon returns – carbon ‘uses’



Full Carbon Account

- Linking carbon stocks and flows to ecological and economic information

By type of resource (e.g. coal, oil, gas)

Ecosystem /land cover classification

Sector and industry classification

Carbon stock account (billion tonnes C)

	Geocarbon	Biocarbon	Accumulation in economy
Opening stock			
Additions to stock			
Reductions in stock			
Imports & exports			
Closing stock			

Linkage to carbon flows (i.e. national GHG inventory reports under IPCC guidelines)

Concordance tables for products

Linkage to economic information through SNA

Linked through SEEA: consistency in concepts, standards and classifications

Linkage to biodiversity & other ecosystem information through SEEA EEA (research in progress)

Explanation: additions

- **Additions to stocks:**
  - Natural expansion (e.g. natural growth of unmanaged ecosystems)
  - Managed expansion (e.g. human managed growth of plantations)
  - Discoveries (geocarbon)
  - Upwards reappraisals (new information resulting in increased estimates of stock)
  - Reclassifications (e.g. between semi-natural and natural ecosystems)
  - Imports (show separately from exports)

Explanation: reductions

- **Reductions in stocks:**
  - Natural contraction (natural losses from unmanaged ecosystems, e.g. due to fire or floods)
  - Managed contraction (e.g. human removal of timber from plantations)
  - Downwards reappraisals (new information resulting in decreased estimates of stock)
  - Reclassifications (e.g. between semi-natural and natural ecosystems)
  - Exports (show separately from imports)
  - Catastrophic losses (allocated between natural contraction and managed contraction)

Data sources for biocarbon

- **Building carbon accounts – data sources and methods**
  - Biocarbon is the focus:
    - Land cover or vegetation maps are the starting point for estimates of stocks and flows
    - Global land cover or vegetation maps are available
    - Standard "look-up" tables convert land cover information into stocks of carbon

International data sources – carbon stocks

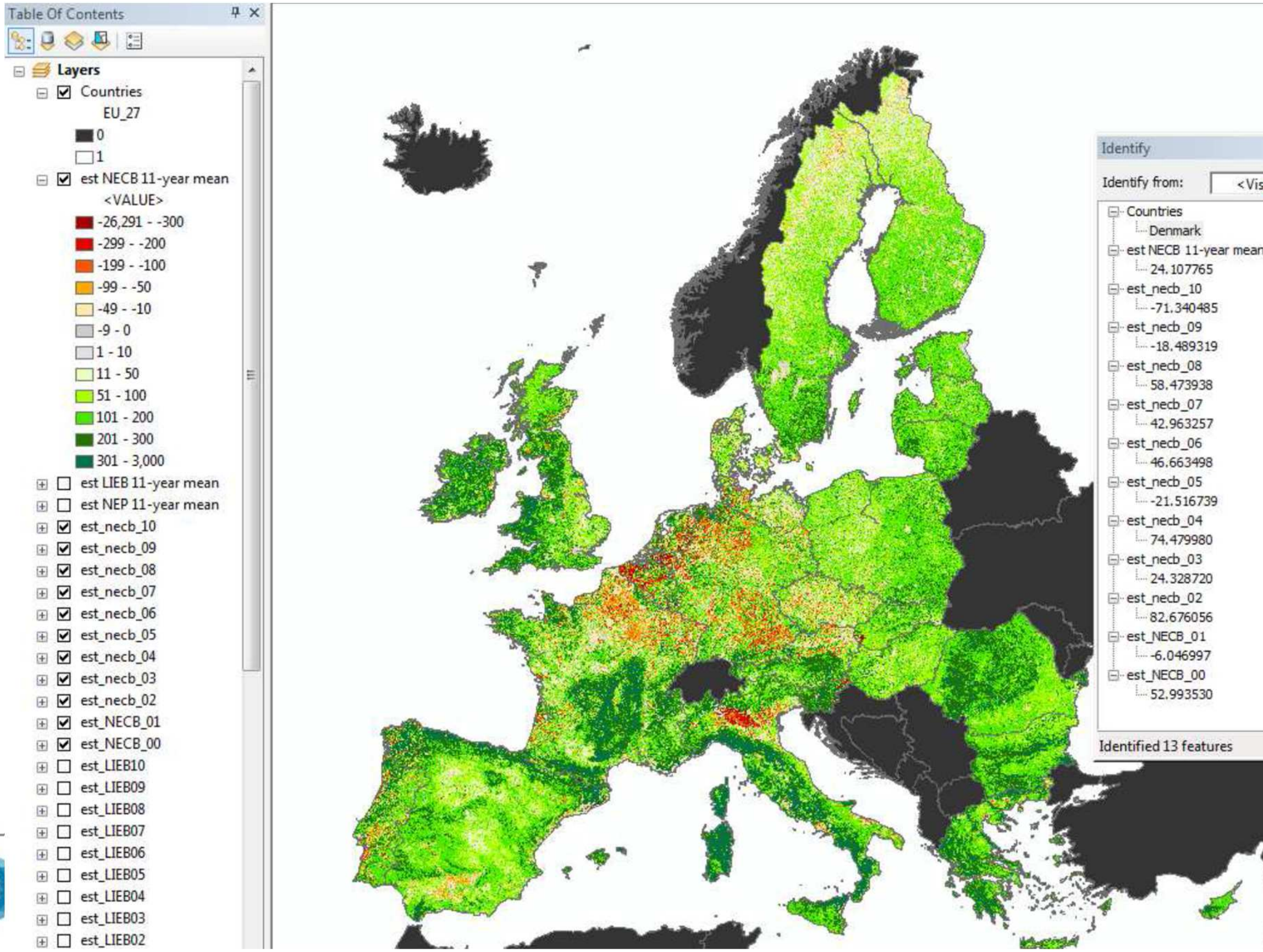
Terrestrial Carbon Management Data Sets and Analyses	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/carbonmanagement/
Land use and ecosystems	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/land_use.html
Global carbon biomass look-up table	Carbon Dioxide Information Analysis Centre (CDIAC)	http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_tables.pdf
National Biomass and Carbon Dataset	Woods Hole Research Centre	http://www.whrc.org/mapping/nbcd/
Project Carbon Sequestration	Forestry Commission (UK)	http://www.forestry.gov.uk/forestry/INFD-8JUE9T

International data sources – carbon sequestration and storage

Carbon and biodiversity calculator	CBD Secretariat, LifeWeb and UNEP-WCMC	http://carbonbiodiversitycalculator.unep-wcmc.org/
UNEP-WCMC Ecosystem Services Toolkit	Climate regulation	UNEP-WCMC, 2011
Envision	Oregon State University	http://envision.bioe.orst.edu/Default.aspx
InFOREST	Virginia Department of Forestry	http://inforest.frec.vt.edu/
REDD+ (Reduce Emissions from Deforestation and Forest Degradation).		https://www.forestcarbonpartnership.org/
Guidelines for National Greenhouse Gas Inventories Vol. 4. Agriculture, Forestry and other Land Use (AFOLU)	IPCC (Intergovernmental Panel on Climate Change). 2006.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html
Greenhouse gas emissions from Agriculture, Forestry and other Land Use	FAO	http://www.fao.org/faostat/en/#data

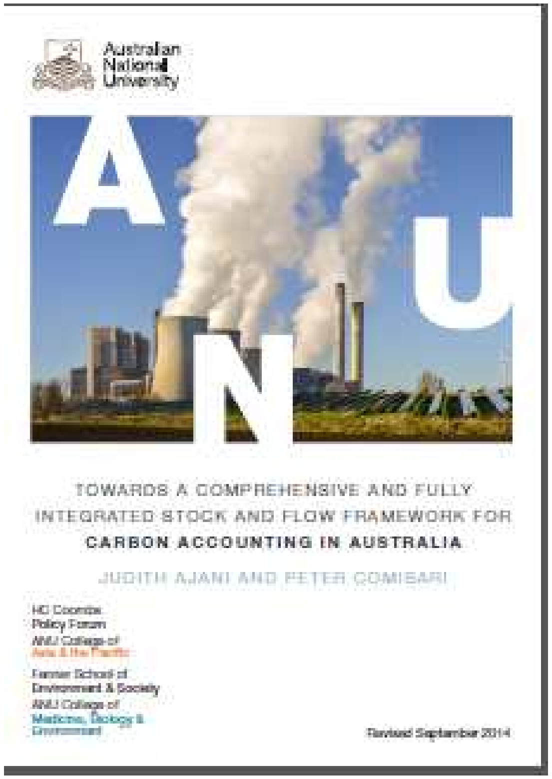
Carbon accounting: examples

European Union – Map of carbon sequestration



Carbon accounting in Australia

- The goal of the carbon accounting project in Australia was to study the feasibility of creating comprehensive carbon accounts.
- Background: November 2012, the Australian Bureau of Statistics, Department of Environment and Australian National University began a project to:
  - > Identify the need for carbon stock information and potential data
  - > Populate the SEEA carbon stock account for Australia.
  - > Assess what is needed for regularly producing a carbon stock account for Australia.



Judith Ajani and Peter Comisari (2014). Towards a Comprehensive and Fully Integrated Stock and Flow Framework for carbon Accounting in Australia: https://coombs-forum.crawford.anu.edu.au/publication/hc-coombs-policy-forum/4708/carbon-accounting-australia

Results of the study

- Biocarbon 31,081 Mt C
- Geocarbon 239,581 Mt C (fossil fuel only)
- Total 270,662 Mt C

- Geocarbon (fossil fuel only) is overwhelming majority of carbon
- Biocarbon 11.5% and geocarbon 88.5% of total carbon estimate

Primary reservoir	Geocarbon (Mt C)	Hectares (million)	Biomass carbon (Mt C)	Soil organic carbon (Mt C)	Total biocarbon (Mt C)
Geocarbon					
Fossil fuel					
Black coal	97,400				
Brown coal	58,100				
Crude oil[b]	145				
LPG[c]	90				
Natural gas	1,559				
Shale oil	82,287				
Total fossil fuel	**239,581**				
Carbonate rocks					
Limestone	n.r.				
Other carbonate rocks	n.r.				
Total carbonate rocks	n.r.				
Other (includes methane clathrates)	n.r.				
Biocarbon					
Natural ecosystems					
Rangelands		596.3	6,374	6,603	12,977
Non rangelands:					
Eucalypt native forests		16.7	4,671	3,753	8,424
Shrub lands & woodlands		14.7	500	636	1,137
Grass, shrub & heath lands		1.6	37	51	87
Rainforests		2.3	1,225	252	1,477
Other		0.7	15	16	32
Marine ecosystems		1.8	114	1,084	1,198
Fresh water ecosystems		9.9	4	7	11
Total Natural ecosystems		**644.0**	**12,941**	**12,402**	**25,343**
Semi-natural ecosystems					
Highly modified rangelands		50.0	750	1,500	2,250
Grazing in modified pastures outside rangelands		32.9	132	1,315	1,447
Total Semi-natural ecosystems		**82.9**	**882**	**2,815**	**3,697**
Agricultural ecosystems					
Cropping		25.5	102	1,022	1,124
Irrigated agriculture		2.6	12	105	117
Plantation wood		2.4	177	120	296
Reservoir/dam		0.6	1	6	7
Other		6.3	120	244	363
Total Agriculture ecosystems		**37.4**	**412**	**1,497**	**1,907**
Settlements		2.6	30	79	108
Other		0.5	7	19	26
Total Settlements and Other		**3.1**	**37**	**98**	**134**
Total biocarbon[d]		**767.4**	**14,270**	**16,811**	**31,081**

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Key points from Australian carbon accounts

1. It is **possible** to construct carbon stock accounts for Australia with current information.
2. Having comparable information on carbon stocks in fossil fuels and ecosystems (terrestrial and marine) linked to economic information enables **past policies and future policy options** to be assessed (including scenario analysis).
3. Different parts of government and academia can successfully **work together** to assess the usefulness and feasibility of producing environmental or ecosystem accounts

Concepts group exercise (15m)

- In groups of 3-5:

1. In your country, what are some important **land cover types** for carbon sequestration?
2. What are some main sources of change in their capacity to sequester carbon? (positive and negative)
3. Are **national** data available in your country on the extent and change in these ecosystem types?
4. Report your results

Concepts group exercise

- Group reports
  - The **land cover types** you selected
  - Main sources of **change** (positive and negative)
  - Are **national data** available in your country on the extent and change in these ecosystem types?
- Discussion
  - What other land cover types would be important to measure?
  - What other data sources could you suggest?

Concepts group exercise

- Discussion and questions
- Take home points
  - Data on biocarbon may be limited, but much can still be used in ecosystem accounting
  - There are some simple methods to calculate carbon storage and sequestration from land cover data
  - Testing will provide a better understanding of data opportunities and constraints
  - Focus on available data and priority services

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Acknowledgements

These materials have been developed in partnership with various organizations including the United Nations Statistics Division, UN Environment, the Convention on Biological Diversity, supported by the Norwegian Ministry of Foreign Affairs, and the European Union.