Lecture 11: Ecosystem Services

ECON7720: Ecological and Environmental Economics

Dr Juan Soto-Diaz[1,2]

[1]School of Economics
[2]Sustainable Minerals Institute (SMI)
The University of Queensland

Semester 2, 2026 | Required reading: Tietenberg & Lewis, Ch. 16

Recap of Lecture 10

- Valuing the environment. Total Economic Value framework, WTP vs WTA, classifying valuation methods.
- Revealed preference methods: hedonic pricing, hedonic wages and the Value of a Statistical Life (VSL), the travel cost method (single-site, multi-site, and random utility models).
- Stated preference methods: contingent valuation (biases, warm glow), choice experiments, benefit transfer and meta-analysis.
- Aggregation challenges, emerging frontiers, and natural capital accounting.

Lecture Outline

1. What are ecosystem services?
2. Policy tools for ecosystem services

Example 1: pollination and agriculture

- 75% of food crop types rely on animal pollination (35% of production volume), valued at US$ 235–577 bn/yr (IPBES 2016).
- US beekeepers lose ∼30% of colonies each winter since 2006 (vs. ∼15% historically).
- In Sichuan (China), farmers pollinate apple and pear trees by hand after wild pollinators disappeared.



Source: Wikimedia Commons (CC BY 2.0).

Pollination is a regulating service: non-excludable, non-rival, and unpriced. When it collapses, the cost falls on farmers and consumers.

Example 2: mangroves and coastal protection

- Natural barriers against storm surges: reduce wave height by 13–66% over 100 m (McIvor et al. 2012).
- Also provide fisheries nursery habitat and sequester carbon at 3–5× the rate of terrestrial forests.
- ∼20% of global mangrove area lost between 1980 and 2005 (FAO 2007).



Mangrove forest, Philippines.

Source: Wikimedia Commons (CC BY-SA 4.0).

Engineered coastal defences cost ∼US$ 65,000/ha/yr; conserving existing mangroves costs $150–750/ha (Barbier 2015). Villages shielded by mangroves suffered fewer casualties in the 2004 Indian Ocean tsunami (Danielsen et al. 2005).

Example 3: India's vulture crisis

- Vultures consumed millions of tonnes of livestock carcasses per year, a critical waste-disposal service.
- The veterinary drug diclofenac caused a 99.9% population collapse in the 1990s (Oaks et al. 2004).
- Feral dogs surged by ∼5.5 million, causing a spike in rabies deaths: estimated cost of US$ 34 billion over 1993–2006 (Markandya et al. 2008).



Indian vultures, Orchha, Madhya Pradesh.

Source: Wikimedia Commons (CC BY-SA 4.0).

The loss of a single species eliminated a regulating service worth billions. Ecosystem services often go unnoticed until they disappear.

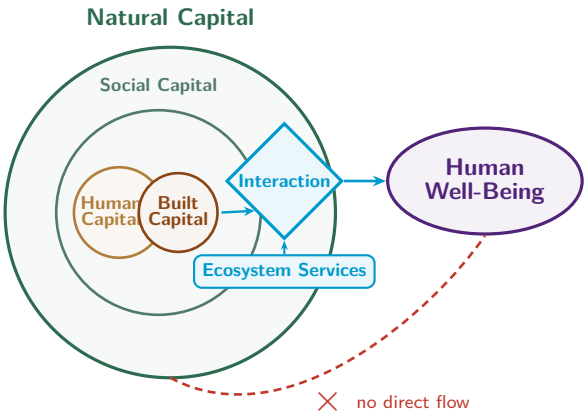
Part 1: What Are Ecosystem Services?

What are ecosystem services?

Ecosystem services are the benefits that humans derive from the natural functioning of ecosystems.

- Nature provides a vast array of goods and services (clean air, water filtration, pollination, climate regulation, recreation) that underpin human well-being.
- Most of these services are public goods or common-pool resources: they are non-excludable and/or non-rival, so markets fail to allocate them efficiently.
- The concept reflects a core insight of ecological economics: the economy is a subsystem of the biosphere (Daly 1996; Costanza et al. 2014).
- The term gained prominence in the 1990s (Daily 1997; Costanza et al. 1997) and was consolidated by the Millennium Ecosystem Assessment (2005).

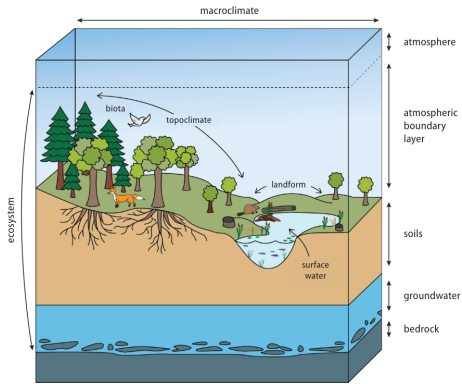
How ecosystem services generate well-being



Based on Figure 1 of Costanza et al. (2014), *Global Environmental Change*, 26, 152–158.

- Ecosystem services arise from the interaction of all four forms of capital, not from natural capital alone.
- The economy (built + human capital) is embedded in society, which is embedded in the rest of nature.
- A wetland's flood-protection value depends on the people, infrastructure and institutions nearby.
- There is no direct flow from natural capital to well-being: benefits require human, social and built capital to be realised.

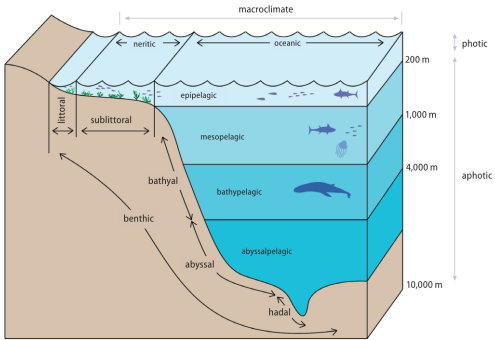
Structure of terrestrial ecosystems



Source: SEEA-EA (2021), adapted from Bailey (1996).

- Ecosystems are three-dimensional: abiotic layers (atmosphere, soils, groundwater, bedrock) interact with biotic components (flora, fauna, microorganisms).
- Ecosystem services emerge from these interactions, e.g. vegetation filters rainfall into groundwater (water purification), soil biota recycle nutrients.

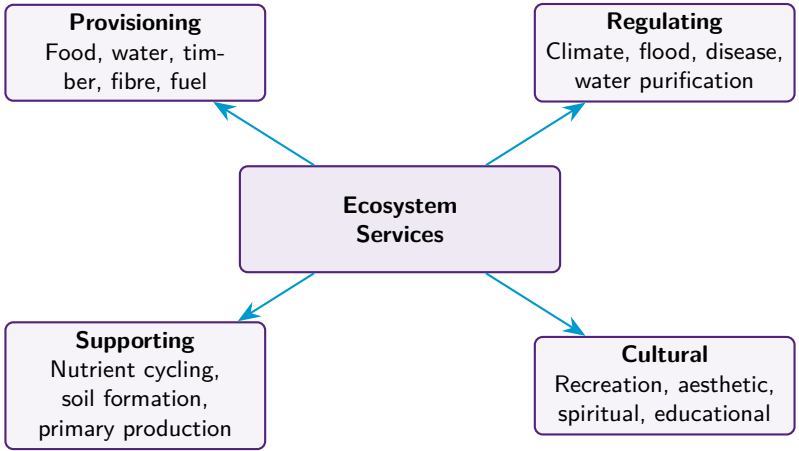
Structure of marine ecosystems



Source: SEEA-EA (2021), adapted from Kingsford (2018).

- Marine ecosystems are layered by depth and light: the sunlit surface (<200 m) supports most life, fisheries, and carbon absorption; deeper zones cycle nutrients back up.
- Shallow coastal waters (reefs, mangroves, seagrass) are far more productive per unit area than open ocean, making them disproportionately valuable.

The four categories of ecosystem services



Note: these categories are not mutually exclusive. A forest provides provisioning (timber), regulating (climate), supporting (nutrient cycling), and cultural (recreation) services simultaneously. This overlap creates risks of double counting in valuation.

Provisioning services

Definition

Products obtained directly from ecosystems.

- **Food**: crops, livestock, fisheries, bush tucker
- **Fresh water**: rivers, aquifers, wetland filtration
- **Fibre and timber**: hardwoods, cotton, wool
- **Fuel**: biomass, peat, wood fuel
- **Genetic resources**: crop wild relatives, medicinal compounds
- **Biochemicals**: natural medicines, pharmaceuticals

Example

The Murray–Darling Basin accounts for $\sim$40% of Australia's agricultural output (MDBA). Irrigated agriculture, which depends directly on river water as a provisioning service, represents roughly one-third of the Basin's GVAP (Gross Value of Agricultural Production). Over-extraction has caused severe ecological degradation.

Regulating services

Definition

Benefits obtained from regulation of ecosystem processes.

- **Climate regulation**: carbon sequestration by forests, oceans, and soils
- **Flood regulation**: wetlands, mangroves, floodplains absorb peak flows
- **Disease regulation**: biodiversity controls pathogen prevalence
- **Water purification**: riverbank vegetation filters sediment and nutrients
- **Pollination**: bees, butterflies, bats, birds pollinate
- **Erosion control**: root systems stabilise soils

Example

Globally, mangroves provide ∼US$65 billion/yr in flood protection benefits, averaging ∼US$4,700/ha/yr (Menéndez et al. 2020). In Australia, coastal wetlands reduced cumulative storm damages by an estimated A$29.6 billion over 54 recorded events (Mulder et al. 2020).

Supporting services

Definition

Services necessary for the production of all other ecosystem services.

- **Nutrient cycling**: decomposition returns nitrogen, phosphorus, and potassium to soils
- **Soil formation**: biological, chemical, and physical weathering
- **Primary production**: photosynthesis by plants and algae
- **Water cycling**: evapotranspiration, infiltration, groundwater recharge

Example

The Great Artesian Basin's water cycle (infiltration, groundwater recharge) sustains pastoral grazing across 1.7 million km^2 of arid Australia. Without this supporting service, cattle and sheep production in outback Queensland, NSW, SA and the NT would not be viable.

Cultural services

Definition

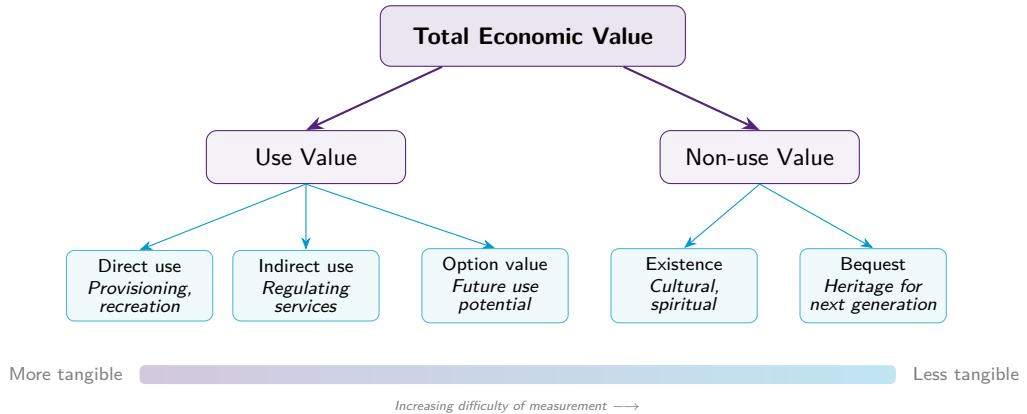
Non-material benefits people obtain from ecosystems.

- **Recreation and ecotourism**: national parks, diving, bushwalking
- **Aesthetic values**: scenic landscapes, birdwatching
- **Spiritual and religious significance**: sacred sites, totemic species
- **Educational and scientific value**: field research, citizen science
- **Sense of place and identity**: cultural landscapes, Indigenous Country

Example

Deloitte Access Economics (2017) estimated the Great Barrier Reef's total asset value at A$56 billion, contributing A$6.4 billion/yr to the Australian economy and supporting 64,000 jobs, largely through tourism.

Total Economic Value and ecosystem services



Recall from Lecture 10: ecosystem services map directly onto TEV categories. Provisioning and cultural services involve direct use; regulating and supporting services generate indirect use value; biodiversity underpins option, existence and bequest values.

Costanza et al. global valuations

- **Costanza et al. (1997)**: first attempt to value all global ecosystem services.
  - Estimated value: $33 trillion/yr (1995 USD).
  - Compared to global GDP of $18 trillion.
- **Costanza et al. (2014)**: updated estimate using more studies and revised land-cover.
  - New estimate: $125 trillion/yr (2007 USD).
  - Estimated losses from land-use change (1997–2011): $4.3–20.2 trillion/yr.

Method: benefit transfer

Synthesised unit values ($/ha/yr) from 100+ existing valuation studies, then multiplied by global area of each ecosystem type.

Classifying land into ecosystem types

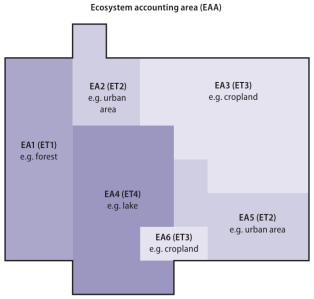


Table 3.1
Tabular presentation of spatial units

Spatial unit	Size[a]
Ecosystem type 1 (EA1)	12
Ecosystem type 2 (EA2 and EA5)	13
Ecosystem type 3 (EA3 and EA6)	15
Ecosystem type 4 (EA4)	14
EAA	**54**

Source: SEEA-EA (2021).

- The first step is to classify land into ecosystem types (e.g. forest, cropland, urban, lake) and measure their area.
- Each spatially distinct patch is an ecosystem asset (EA); multiple assets can share the same type (e.g. EA3 and EA6 are both cropland).

Costanza et al. (1997)

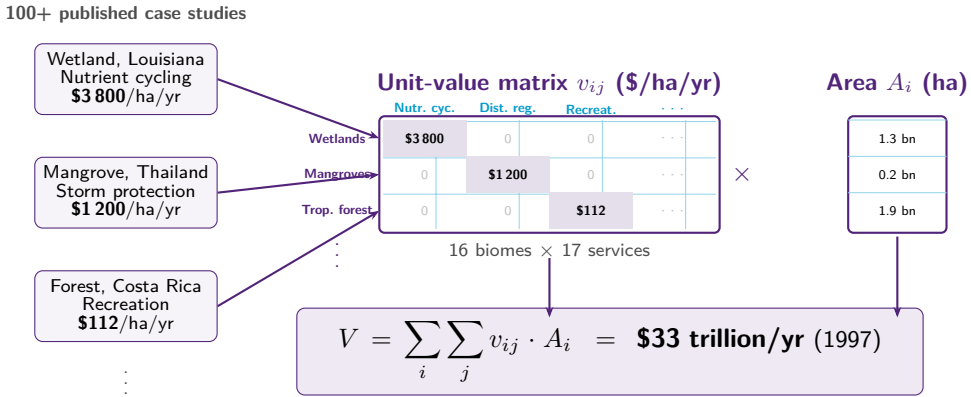
Let v_{ij} be the unit value (\$/ha/yr) of service j in ecosystem type i, and A_i the global area (ha) of type i. Then:

$$V = \sum_i \sum_j v_{ij} \cdot A_i$$

where V is the total annual value of global ecosystem services.

- Basic benefit transfer: per-hectare value from one site applied to all hectares of that ecosystem type globally (analogous to GDP's price $\times$ quantity).
- Unit values v_{ij} averaged from 100+ published studies; cells with no study set to zero.
- Valuation hierarchy: (1) consumer + producer surplus, (2) net rent, (3) $p \times q$ as conservative proxy.

How benefit transfer extrapolates to the global scale



Costanza et al. (1997) – valuation matrix

17 ecosystem services

1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Erosion control
7. Soil formation
8. Nutrient cycling
9. Waste treatment
10. Pollination
11. Biological control
12. Habitat/refugia
13. Food production
14. Raw materials
15. Genetic resources
16. Recreation
17. Cultural

16 ecosystem types

Marine: open ocean, coastal, estuaries, seagrass/algae beds, coral reefs, continental shelf

Terrestrial: tropical forest, temperate/boreal forest, grass/rangelands, wetlands (tidal marsh/mangroves, swamps/floodplains), lakes/rivers, desert, tundra, ice/rock, cropland, urban

Key limitations

- Many cells left blank: no studies available
- No values for desert, tundra, ice/rock, or urban
- Excludes non-renewable resources and the atmosphere

$\Rightarrow$ Estimate explicitly a *minimum*

Costanza et al. (1997) – results

Global ecosystem services ≈ **US$33 trillion/yr** (range $16–54 trillion), vs. global GNP ≈ US$18 trillion/yr. All values in 1994 US$.

By ecosystem type (total, $bn/yr):

Marine (total)	20,949
Open ocean	8,381
Coastal	12,568
Terrestrial (total)	12,319
Forest	4,706
Wetlands	4,879
Grass/rangelands	906
Lakes/rivers	1,700
Global total	**33,268**

Top services ($bn/yr):

Nutrient cycling	17,075
Cultural	3,015
Waste treatment	2,277
Disturbance regulation	1,779
Water regulation	1,115
Food production	1,386
Gas regulation	1,341

Highest values *per hectare*: estuaries ($22,832), swamps ($19,580), seagrass beds ($19,004).

Costanza et al. (2014) – updated data and method

Now with ∼665 data points from 300+ case studies, drawn from the TEEB (The Economics of Ecosystems and Biodiversity) / ESVD (Ecosystem Services Valuation Database). Values in 2007 international $/ha/yr (PPP-adjusted).

Decomposing the change

The total change $V^{2011} - V^{1997}$ mixes two effects. The authors separate them by holding one factor constant at a time:

- **Effect of revaluation**: update unit values v_{ij} while keeping areas fixed. Updated v_{ij} averaged ∼8× higher than 1997, mostly reflecting *more complete* valuation (more studies, more services covered), not real appreciation.
- **Effect of land-use change**: update areas A_i while keeping unit values fixed. Losses concentrated in high-value biomes (tropical forests, wetlands, coral reefs).

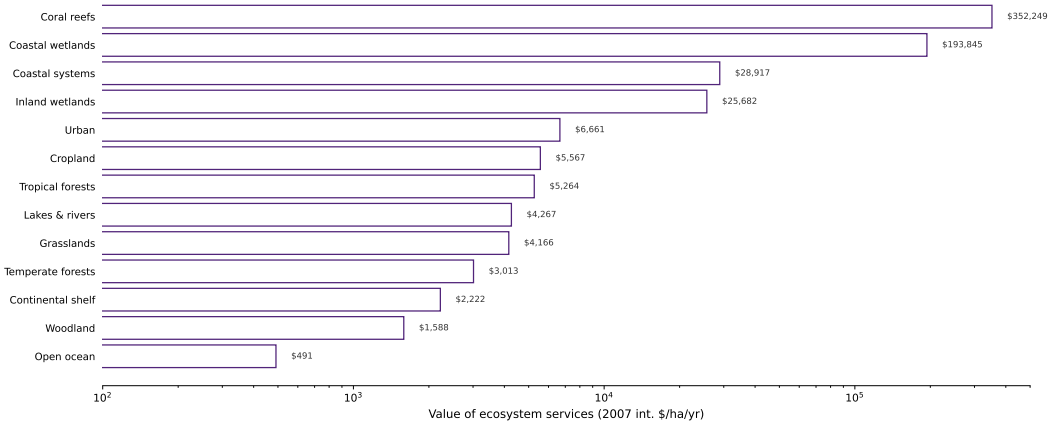
Costanza et al. (2014) – results

- Largest unit-value revisions driven by *new studies*:
  - Tidal marsh/mangroves: \$14k $\rightarrow$ \$194k/ha/yr (storm protection, erosion control)
  - Coral reefs: \$8k $\rightarrow$ \$352k/ha/yr (storm protection, recreation)
- Losses concentrated in high-value ecosystem types whose area *shrank*: tropical forests, wetlands, coral reefs
- For comparison: global GDP was \$46 trillion (1997) and \$75 trillion (2011), both in 2007 \$US

Interpretation

- Estimate is a *minimum*: many cells had no data; consumer surplus understated for essential services
- An *accounting measure*: useful for awareness and national accounts, not for pricing in markets

Ecosystem service values by ecosystem type



Data: Costanza et al. (2014), based on de Groot et al. (2012). Log scale.

Challenges in measuring ecosystem services

1. **Double counting**: if we count pollination (regulating) *and* crop yields (provisioning), we count the same benefit twice.
   - Solution: distinguish intermediate (supporting) from final (provisioning, regulating, cultural) services (Boyd & Banzhaf 2007).
2. **Spatial heterogeneity**: the value of a wetland depends on its location: proximity to population, downstream infrastructure, substitutes.
3. **Threshold effects and non-linearities**: ecosystem functions may collapse suddenly (coral bleaching, desertification).
4. **Respondent knowledge**: stated-preference surveys require respondents to understand complex ecological relationships, which they often do not.
5. **Temporal dynamics**: ecosystem services change over time (seasonal, successional, climate-driven).
6. **Marginal vs. total value**: policy decisions require marginal values; many studies estimate average or total values.

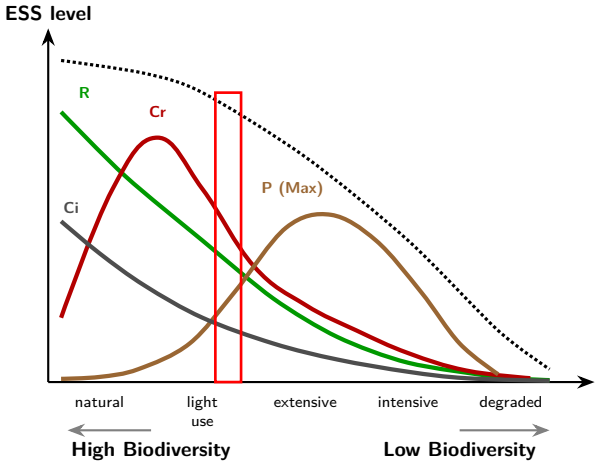
The Millennium Ecosystem Assessment (2005)

- Launched by the United Nations in 2001; published 2005.
- Involved 1,360 experts from 95 countries.
- Goal: assess the consequences of ecosystem change for human well-being and establish the scientific basis for conservation.
- Key finding: **60%** of ecosystem services examined are being degraded or used unsustainably.
- Introduced the now-standard four categories of ecosystem services.

Other global policy frameworks

1. **TEEB** (The Economics of Ecosystems and Biodiversity, 2007–2010):
   - UN-led initiative to make the economic case for conservation.
   - Provided valuation estimates across **biomes** (large-scale ecosystems defined by climate, vegetation, and fauna, e.g. tropical forests, coral reefs, wetlands) and services, feeding into national policy design worldwide.
2. **IPBES** (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, est. 2012):
   - Produces periodic global assessments; its 2019 report warned that 1 million species face extinction.
3. **UN SEEA-EA** (System of Environmental-Economic Accounting – Ecosystem Accounting, adopted 2021):
   - First international statistical standard for measuring ecosystem services in national accounts.
   - Allows countries to track changes in natural capital alongside GDP, closing the gap between economic and environmental reporting.

Land use, biodiversity, and ecosystem service trade-offs



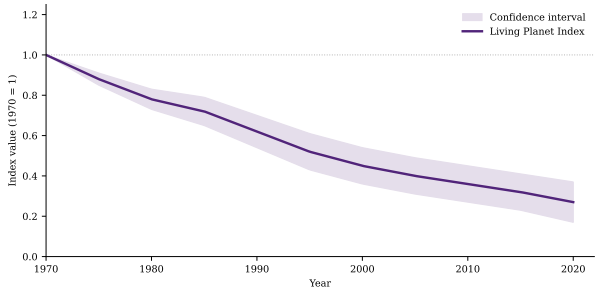
Source: Braat & de Groot (2012), after Braat & ten Brink (2008).

- **P**: Provisioning services
- **R**: Regulating services
- **Cr**: Cultural (recreation)
- **Ci**: Cultural (information)
- ☐ Multiple services per land-use type

Key insight: maximising **one** service (e.g. provisioning via intensive agriculture) comes at the cost of **all others**. Total ESS (dotted) declines with land-use intensity.

The biodiversity crisis

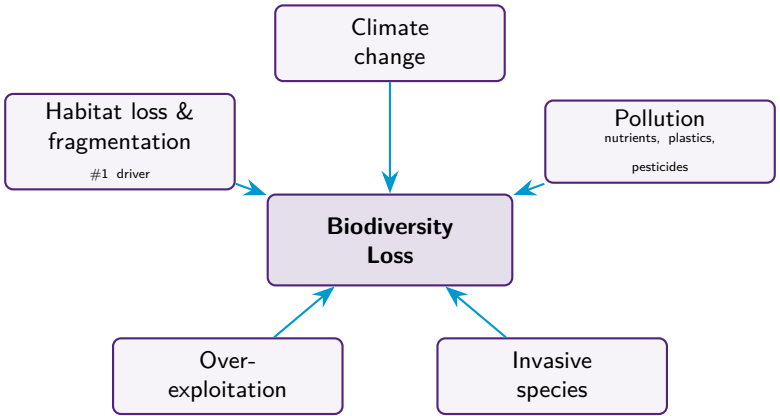
- Current extinction rate: 100–1,000× higher than the pre-human background rate.
- The Living Planet Index (WWF 2024) documents a 73% decline in monitored wildlife populations since 1970.
- Freshwater: −85%; terrestrial: −69%; marine: −56%.



Source: WWF/ZSL Living Planet Report 2024.

Biodiversity is part of the **natural capital stock**; ecosystem services are the **flow of benefits** it generates.

Drivers of biodiversity loss



Source: IPBES (2019). These five direct drivers are ranked by global impact; their relative importance varies regionally.

Connection to natural capital accounting

- Recall from Lecture 11: the UN SEEA provides the framework for natural capital accounts.
- The **SEEA Ecosystem Accounting** (SEEA-EA, 2021) extension specifically measures:
  - Ecosystem extent (area by type)
  - Ecosystem condition (quality indicators)
  - Ecosystem services (physical and monetary flows)
  - Ecosystem assets (present value of expected service flows)
- Australia was an early adopter: the ABS published experimental ecosystem accounts from 2017.
- The link: ecosystem services valuation provides the monetary layer that sits atop biophysical accounts.
- This connects our Lecture 11 discussion of SEEA with today's focus on ES.

The economics of ecosystem service provision

Why markets fail to protect ES

- Most ecosystem services are public goods (non-rival, non-excludable) or common-pool resources (rival but non-excludable).
- $\Rightarrow$ No market price; no incentive for private provision or conservation.
- Externalities: land clearing provides private benefits (agriculture) but destroys public ES (carbon storage, biodiversity, water filtration).
- Information failures: landholders and policymakers often do not know the value of ES on their land.
- Property rights: who "owns" the pollination service provided by wild bees? The carbon stored in a forest?
- These market failures justify policy intervention: regulation, PES, taxes/subsidies, property rights creation.

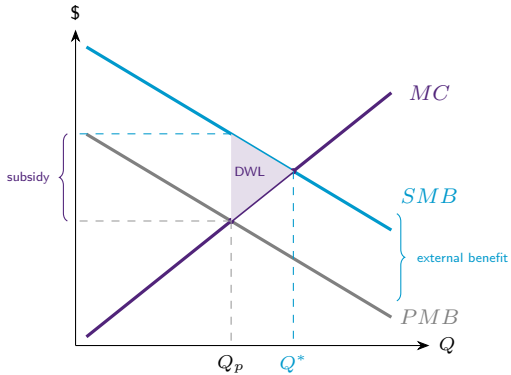
Part 2: Policy Tools for Ecosystem Services

Why do ecosystems need policy intervention?

- Most ecosystem services are positive externalities: landholders who maintain habitat provide benefits to society but bear the costs privately.
- The conditions for Coasean bargaining are not met:
  - Transaction costs are high (many dispersed beneficiaries).
  - Property rights over ES flows are poorly defined.
  - Information asymmetry: landholders know their costs, society does not.

Under-provision of ecosystem services

- Result: **under-provision** of ecosystem services and **over-conversion** of natural land.
- The private market produces Q_p, but society would be better off at Q^*. The gap is a deadweight loss.
- Policy instruments can correct this by paying landholders for the services they provide (Pigouvian subsidy logic).



Recall Lecture 3: a positive externality leads to under-provision ($Q_p < Q^*$). A Pigouvian subsidy closes the gap.

Ecosystem services and market failures

- Are *all* ecosystem services positive externalities? Not quite. The type of market failure depends on the category of service.

Category	**Examples**	**Market failure**
Regulating	pollination, flood control, climate regulation	positive externality (under-provision)
Supporting	nutrient cycling, soil formation	positive externality (under-provision)
Cultural	recreation, aesthetic, spiritual values	mixed: partly captured (fees, property premia)
Provisioning	food, timber, water, fisheries	common-pool resource (over-exploitation)

Regulating, supporting, and cultural services ⇒ positive externalities (under-provision). Provisioning services ⇒ common-pool resource problems (over-exploitation). Different failures require different instruments.

Policy tools for ecosystem services

Market-based instruments

1. **Payments for Ecosystem Services (PES):** voluntary payments to landholders who conserve or restore ES (e.g. BushTender).
2. **Pigouvian subsidies / taxes:** corrective prices that internalise external benefits or costs (e.g. agri-environment subsidies, carbon tax).
3. **Cap-and-trade / tradable permits:** quantity-based instruments for rivalrous resources (e.g. ITQs in fisheries, emissions trading, Lecture 2).
4. **Conservation banking and offsets:** tradable credits for species-specific habitat protection (e.g. US conservation banks, biodiversity offsets).

Command-and-control instruments

5. **Regulation:** protected areas, species listings, land-use zoning (e.g. EPBC Act, Endangered Species Act, MPAs).
6. **Public provision:** government supply of non-excludable services (e.g. national parks, urban green spaces).

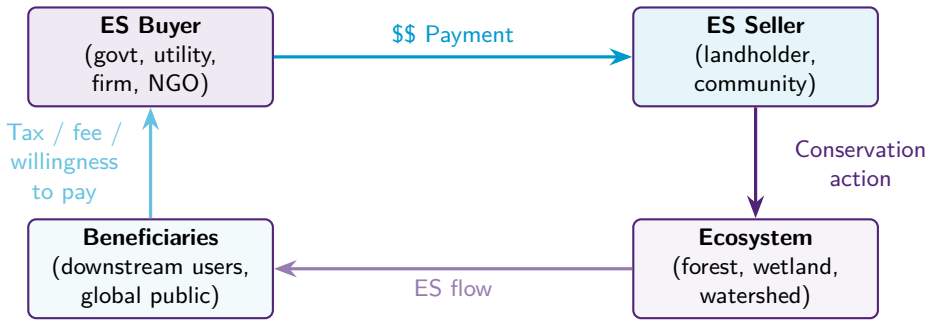
Payments for Ecosystem Services (1)

A PES is a voluntary transaction where a well-defined environmental service is "bought" by at least one service buyer from at least one service provider, *if and only if* the provider secures service provision (conditionality) (Wunder 2005, revised 2015).

- **Buyer**: govt, utility, firm, or NGO.
- **Seller**: landholder, community, or Indigenous group.
- **Service**: specific ES (e.g. watershed protection, carbon sequestration).

Estimated more than 550 active PES programmes globally (Salzman et al. 2018). Payment must lie between the landholder's opportunity cost and the beneficiaries' WTP.

Payments for Ecosystem Services (2)



Example 1: New York City's watershed

- NYC's drinking water comes from the Catskill–Delaware watershed, ∼200 km north of the city.
- In the 1990s, the city faced a choice:
  - Filtration plant: **US$ 6–8 bn** capital + $300–500 M/yr operating.
  - Watershed protection: US$ 1.5 bn over 10 years.
- NYC chose to pay upstream landholders to conserve forests and wetlands that naturally filter water for 9 million people.

Nature's water filtration service was 4–5× cheaper than engineered infrastructure.



Ashokan Reservoir, Catskill Mountains, NY. Source: Wikimedia Commons (CC BY-SA 3.0).

Conservation auctions

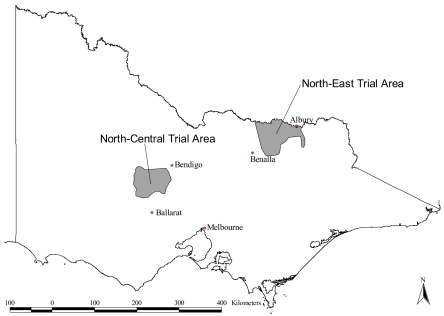
- A key challenge in PES: the government does not know each landholder's opportunity cost of conservation.
- **Fixed-price PES**: government sets a uniform payment.
  - Too low ⇒ few participate.
  - Too high ⇒ waste taxpayer money (informational rents).
- **Conservation auction** (reverse auction): landholders bid the payment they require to supply conservation.
  - The government selects the most cost-effective bids.
  - Competitive pressure drives down informational rents.
- Competition encourages bidders to reveal costs more truthfully, reducing informational rents.

Example 2: Victorian BushTender programme

Context

Victoria has cleared >60% of native vegetation since European settlement. Remnant vegetation on private land is critical for biodiversity conservation.

- Developed by the Victorian Department of Sustainability and Environment (DSE); piloted 2001–02.
- Goal: use a reverse auction to purchase biodiversity conservation from private landholders at lowest cost.
- Key innovation: combined an ecological scoring system with competitive bidding.



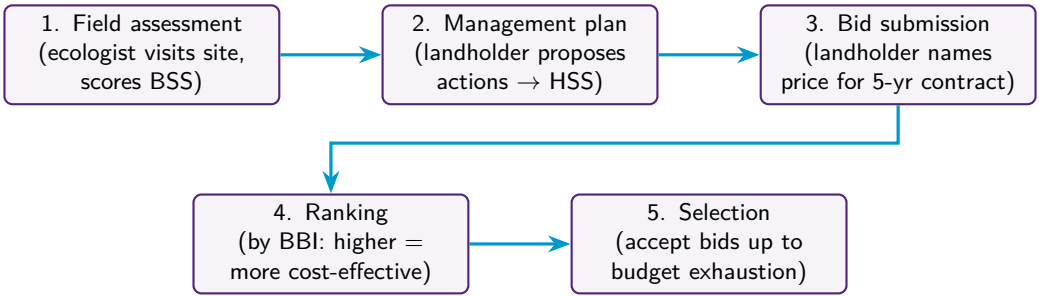
Source: Stoneham et al. (2003), Figure 1.

Example 2: Biodiversity Benefits Index (BBI)

$$\text{BBI}_i = \frac{\overbrace{\text{BSS}_i}^{\text{ecological quality}} \times \overbrace{\text{HSS}_i}^{\text{management gain}}}{\underbrace{b_i}_{\text{bid (\$)}}}$$

- **BSS**$_i$: biodiversity significance of the site (vegetation condition, landscape context, threatened species, bioregional rarity).
- **HSS**$_i$: the expected improvement in habitat from the proposed management actions (fencing, weed control, grazing management, revegetation).
- b_i: the landholder's bid, the subsidy they require for a 5-year management agreement.
- Higher BBI $\Rightarrow$ more biodiversity per dollar. Government ranks bids by BBI and accepts from the top down.

Example 2: auction design



- Each bidder submits one sealed bid; no information about others' bids.
- Government ranks all bids by BBI: higher BBI = more biodiversity per dollar spent.

Example 2: results

- Pilot round (2001–02): 192 expressions of interest, 97 landholders assessed, **73 contracts** awarded.
- Budget: A$400,000 for 5-year management agreements.
- Bids accepted down to a BBI cutoff set by budget exhaustion.
- Key finding: the auction achieved an estimated $7\times$ cost savings compared to a fixed-price scheme.
  - Under fixed price, the government would have paid the highest accepted bid to everyone $\Rightarrow$ massive informational rents.
  - Under pay-as-bid, each landholder receives only their own bid.
- Evidence that some landholders bid above their true costs. But competitive pressure limited this.
- Programme was subsequently scaled up statewide and inspired similar designs nationally and internationally.

Ecotourism

Ecotourism: responsible travel to natural areas that conserves the environment, sustains the well-being of local people, and involves interpretation and education.

- Economic logic: converts non-market ES values (aesthetic, recreational, cultural) into market revenues.
- Creates financial incentives for conservation: if wildlife/ landscapes generate tourist dollars, communities have reason to protect them.
- Global ecotourism market estimated at \$300+ billion/yr (2024).
- Can provide livelihoods in regions with limited alternatives (remote areas, developing countries).

Note

Ecotourism is a direct market for cultural ES (partly excludable via fees), not strictly a PES. However, when tourism revenues are channelled to landholders *conditional on conservation*, it can function as a PES delivery mechanism.

Tradable entitlement systems for ecosystem services

- Extend the cap-and-trade logic (Lecture 3–4) to ecosystem services.
- Concept: set a cap on ecosystem degradation; issue tradable permits/credits for units of ES.
- Those who can maintain/enhance ES cheaply become sellers; those facing high costs become buyers.
- Trade ensures the conservation target is met at least cost.
- Examples:
  - Water quality trading (nutrient credits, Chesapeake Bay)
  - Salinity credits (Murray–Darling Basin)
  - Biodiversity offsets (see next slides)
  - Carbon markets: forest conservation generates tradable carbon credits (e.g. REDD+, ACCUs), turning avoided deforestation into a revenue stream

Conservation banking and biodiversity offsets

- Developers who damage ecosystems must purchase credits from sites that have conserved or restored equivalent habitat.
- Follows the mitigation hierarchy: avoid $\rightarrow$ minimise $\rightarrow$ restore $\rightarrow$ offset (last resort).
- Examples:
  - Conservation banks (US): species-specific habitat credits (130+ banks, mostly California).
  - Biodiversity offsets (AU): NSW Biodiversity Offsets Scheme (2017), QLD Environmental Offsets Act 2014.
- The market creates a financial incentive for private landholders to protect habitat voluntarily.
- Criticism: offsets can legitimise destruction; "like-for-like" replacement is ecologically difficult.

Individual Transferable Quotas (ITQs) for fisheries

- Fisheries are a classic common-pool resource problem: open access $\Rightarrow$ overfishing $\Rightarrow$ stock collapse.
- ITQ system:
  1. Set a Total Allowable Catch (TAC) based on stock assessment.
  2. Divide TAC into individual quota shares.
  3. Quota shares are tradable: efficient fishers buy quota from less efficient ones.
- Benefits:
  - Eliminates the "race to fish."
  - Reduces overcapitalisation.
  - Aligns private incentives with sustainability.

Marine Protected Areas (MPAs)

- MPAs: geographically defined marine areas with restrictions on human activity to protect ecosystems.
- Range from no-take zones (no extractive activity) to multiple-use zones (some fishing allowed).
- Benefits:
  - Protect breeding populations and nursery habitats.
  - "Spillover effect": fish populations rebuild inside MPA and migrate outward, benefiting adjacent fisheries.
  - Protect ecosystem structure and function.
- Global coverage: $\sim$8.3% of oceans in MPAs (2024), but only $\sim$3% in fully/highly protected areas.

Appendix

References (1/3)

- Barbier, E.B. (2015). Valuing the storm protection service of estuarine and coastal ecosystems. *Ecosystem Services*, 11, 32–38.
- Boyd, J. & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, 63(2–3), 616–626.
- Braat, L.C. & de Groot, R. (2012). The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. *Ecosystem Services*, 1(1), 4–15.
- Costanza, R. et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630), 253–260.
- Costanza, R. et al. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152–158.
- Costello, C., Gaines, S.D. & Lynham, J. (2008). Can catch shares prevent fisheries collapse? *Science*, 321(5896), 1678–1681.
- Daily, G.C. (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press.
- Daly, H.E. (1996). *Beyond Growth: The Economics of Sustainable Development*. Beacon Press, Boston.

References (2/3)

- Danielsen, F. et al. (2005). The Asian tsunami: a protective role for coastal vegetation. *Science*, 310(5748), 643.
- Deloitte Access Economics (2017). *At What Price? The Economic, Social and Icon Value of the Great Barrier Reef*. Report for the Great Barrier Reef Foundation.
- FAO (2007). *The World's Mangroves 1980–2005*. FAO Forestry Paper 153, Rome.
- IPBES (2016). *The Assessment Report on Pollinators, Pollination and Food Production*. IPBES Secretariat, Bonn.
- Markandya, A. et al. (2008). Counting the cost of vulture decline: an appraisal of the human health and other benefits of vultures in India. *Ecological Economics*, 67(2), 194–204.
- McIvor, A.L., Möller, I., Spencer, T. & Spalding, M. (2012). Reduction of wind and swell waves by mangroves. Natural Coastal Protection Series, Report 1. The Nature Conservancy.
- Menéndez, P., Losada, I.J., Torres-Ortega, S., Narayan, S. & Beck, M.W. (2020). The global flood protection benefits of mangroves. *Scientific Reports*, 10, 4404.
- Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington DC.

References (3/3)

- Mulder, O.J. et al. (2020). The value of coastal wetlands for storm protection in Australia. *Ecosystem Services*, 45, 101174.
- Oaks, J.L. et al. (2004). Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature*, 427(6975), 630–633.
- Salzman, J., Bennett, G., Carroll, N., Goldstein, A. & Jenkins, M. (2018). The global status and trends of Payments for Ecosystem Services. *Nature Sustainability*, 1(3), 136–144.
- Stoneham, G., Chaudhri, V., Ha, A. & Strappazzon, L. (2003). Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial. *Australian Journal of Agricultural and Resource Economics*, 47(4), 477–500.
- Wunder, S. (2015). Revisiting the concept of payments for environmental services. *Ecological Economics*, 117, 234–243.
- WWF (2024). *Living Planet Report 2024: A System in Peril*. WWF International, Gland, Switzerland.