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The Economics of Ecosystems and Biodiversity (TEEB)

Synthesis note

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Introduction: TEEB objectives and rationale

Objectives

The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on “making nature’s values visible”. Its principal objective is to promote a better understanding of the **economic values associated with biodiversity and ecosystem services** and thereby support their mainstreaming into decision making at all levels. It aims to achieve this by following a structured approach to valuation that helps policy and decision makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms, and use tools for capturing those values in decision making processes.

Rationale

“Natural capital”, i.e. the physical and biological resources available on earth, underpins all economic activities. Biodiversity and ecosystem services, which make up a significant share of this natural capital, directly and indirectly support most human activities. However, the understanding of their roles and functioning remains limited and, even more importantly, the economic and political institutions that drive development planning and investments generally fail to recognize their true value (TEEB 2008, TEEB 2009 Ch. 10).

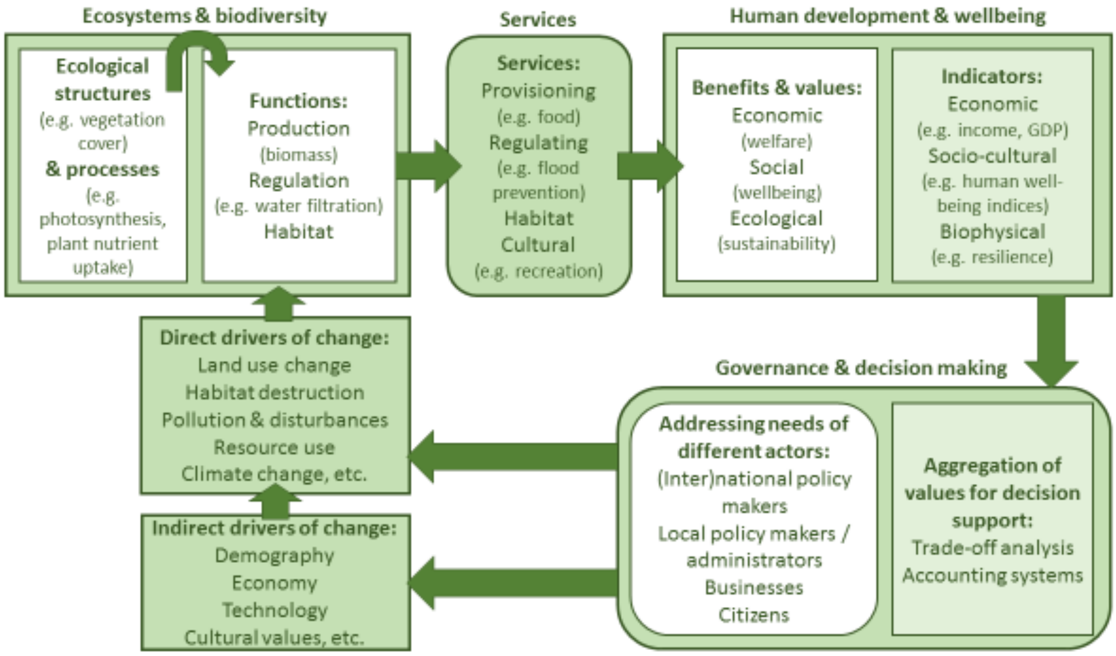
With some exceptions, **biodiversity and ecosystem services do not have a market value** – so they usually fail to be captured in the calculation of the costs and benefits of economic development and in decision-making frameworks and processes. This in turns leads to policy inaction and “policy failure”, i.e. a situation in which policies providing inadequate incentives end up encouraging harmful behaviour, while failing to reward sustainable practices (TEEB 2008). This results in inappropriate regulation, suboptimal allocation of resources and depletion of the natural capital on which humanity’s current and future prosperity and wellbeing depend.

TEEB’s response is to **make ecosystem service values more explicit and more visible**, and provide practical tools for incorporating them in the decision-making processes of development planners, landowners, investors, businesses and local communities. These tools notably support improved **assessment of trade-offs** between economic growth and biodiversity / ecosystem services or between competing uses of ecosystems – and help highlight **synergies** as well.

Section 1: Linkages between biodiversity, ecosystem services and development

Biodiversity and ecosystems generate multiple services that support life and provide a foundation for economic development and human wellbeing. In turn, human activities and especially economic development have a significant impact on biodiversity and ecosystems – more often than not taking the form of degradation and loss. **Figure 1** shows how ecological structures and processes are linked to the various aspects of human development and wellbeing, and how monitoring the benefits and values we derive from biodiversity and ecosystems can influence governance and decision making with a view to addressing the direct and indirect drivers of change in biodiversity and ecosystems.

Figure 1: From ecosystems to human wellbeing – TEEB conceptual framework



Source: Adapted from TEEB 2010a, Figure 1.5, Ch. 1:21

Economic valuation takes place primarily at the level of benefits and values – building on the understanding and, to the extent possible, the quantification of the links between ecosystems, ecosystem services and the associated benefits. **Table 1** shows the typology of ecosystem services used in TEEB studies and examples that illustrate how these services contribute, directly or indirectly, to human wellbeing.

Table 1: Typology and examples of ecosystem services

Main types of services	Examples
Provisioning services	
Food	Fish, livestock, game, fruit, cultivated crops
Water	Water for drinking, irrigation, cooling
Raw materials	Fibre, timber, woodfuels, fodder, fertilizer
Genetic resources	For crop improvement / resilience, pharmaceuticals, biotechnology, personal care
Medicinal resources	Biochemicals, models, test organisms
Ornamental resources	Decorative plants, materials for handicrafts
Regulating services	
Air quality regulation	Removal of fine dust and pollutants from the atmosphere, gas regulation
Climate regulation	Local: influence on rainfall, temperatures (shade)

Main types of services	Examples
	Global: carbon sequestration
Moderation of extreme events	Storm protection, flood and landslide prevention
Water flow regulation	Natural drainage, drought mitigation, irrigation
Wastewater treatment	Water purification
Erosion prevention	Soil stabilisation
Soil fertility maintenance and nutrient cycling	Soil formation and structure, nutrient retention
Pollination	Pollination
Biological control	Pest control, disease vector control
Habitat services	
Habitat for species	Food, water and shelter for plant and animal species including migratory species
Maintenance of genetic diversity	Through gene pool protection
Cultural services	
Aesthetic information	
Recreation and tourism	
Inspiration for culture, art and design (including engineering design)	
Spiritual experience	
Information for cognitive development	

Source: Adapted from TEEB 2010a, Table 1.2, Ch. 1:26 and TEEB 2010b, Box 1.4, Ch. 1:18-19

Governance mechanisms and institutions determine how ecosystem services are used, how human activities impact biodiversity and ecosystems, and which measures are adopted for their management, protection or restoration. The **monitoring** of ecosystem services and the **valuation** of benefits derived from their existence is expected to promote improved governance of natural resources and improved decision making by a large range of actors, from the international to the local level, and across sectors in both the public and the private sphere. In turn, improved information and the capture of at least part of the economic values associated with ecosystem services in **decision-making processes** should promote positive action on the **direct and indirect drivers** of biodiversity and ecosystem degradation and loss.

To further explore these aspects: **Section 2** of this note provides an overview of ecosystem and biodiversity valuation methods and the challenges associated with their use. **Section 3** and **Annex 2** provide concrete illustrations of the benefits of biodiversity and ecosystem conservation and sustainable use. **Section 4** reviews options for monitoring biodiversity and ecosystem services in support of decision making, with a few illustrations of decision support frameworks provided in **Annex 3**. To conclude, **Section 5** and the related **Annex 4** give an overview of practical instruments for better stewardship of natural capital in policy and management processes. Practical, sector-specific guidance on mainstreaming biodiversity and ecosystem services in development planning and interventions is available in a separate document.

Section 2: Ecosystem and biodiversity valuation methods and challenges

TEEB valuation framework

As shown in **Figure 2**, estimating the economic value of ecosystem services and changes in their availability is the last step in an evaluation sequence that starts with examining the impacts of policy change (or specific actions) on ecosystems, and builds on scientific understanding of the impacts of changes in ecosystem condition on ecosystem service provision and human welfare:

Figure 2: Evaluation sequence from policy change to economic value

Source: TEEB 2009, Figure 10.1, Ch.10:4, based on Stephen White

TEEB's approach to the valuation of biodiversity and ecosystem services rests on **bringing together ecological and economic aspects** along this evaluation sequence, and on quantifying and mapping the economic consequences of policy changes.

To interpret the results of economic assessments of biodiversity and ecosystem services, we need to understand and keep in mind a few key considerations:

- First, we must recognize that "both ecological functioning and economic values are **context-, space- and time-specific**" (TEEB 2010a Ch. 1:11). For this reason, caution must be exercised when aggregating values (moving from the valuation of services at a specific site to the macro policy scale), transferring them from one context to another, or using values that were estimated a long time ago (they may need updating to take account of changes in the socioeconomic and environmental context).
- Second, **different stakeholders** "often attach **different values** to ecosystem services depending on cultural background and the impact the service has on their living conditions" (TEEB 2010a Ch. 5:226). Identifying and involving all stakeholders is crucial for the validity of the valuation exercise and the ability to assess the impacts of changes in service provision across various groups. We should also remember that the economic values attached to ecosystem services are never entirely objective; they depend in part on the perceptions of their beneficiaries, which are determined by a sociocultural context (TEEB 2010a Ch. 4).
- Third, reducing or preventing biodiversity loss and protecting ecosystems usually involves **costs[1] as well as benefits**. To be meaningful and support the assessment of trade-offs between conservation and development, economic assessments must value the costs as well as the benefits of all considered policies or scenarios (TEEB 2008).

For those interested in further information on methods, **Annex 1** provides an overview of the TEEB economic valuation framework, as well as the components of **total economic value (TEV)**, an economic framework that seeks to capture all the various elements that contribute to the economic value of an asset. TEV underpins the range of **valuation methods** traditionally applied to biodiversity and ecosystem services, which are also briefly presented in this annex.

[1] These include: (i) management costs, i.e. the costs of actively implementing biodiversity and ecosystem protection and conservation measures; (ii) opportunity costs, i.e. the costs of foregone economic development); and (iii) transaction costs, i.e. costs associated with the design, implementation and control of biodiversity conservation policies (TEEB 2008).

Challenges and limitations

Even applying best practices, economic valuation of biodiversity and ecosystem services involves significant challenges and limitations. These notably include:

- **Scientific uncertainties**, e.g. with regard to ecosystem dynamics, ecosystem resilience, and the ecological "thresholds" beyond which changes in ecosystem condition trigger a change to a new state (which may or may not be irreversible).
- **Measurement difficulties**, e.g. with regard to the quantity and quality of some ecosystem services, in particular cultural services, and with regard to human preferences including risk tolerance.
- Uncertainties in the **application of valuation methods**. To keep it short, the ability of economic science to meaningfully attribute monetary values sharply decreases as we move from economic benefits (measurable although with varying degrees of accuracy depending on their nature) to socio-cultural benefits (only partly measurable) to ecological benefits (hardly measurable due to their complexity and more indirect contribution to human welfare and wellbeing).
- Disagreements over how far we should be ready to accept trade-offs between natural, human and physical capital, resulting from different views on the definition of **sustainability** and on the rights of present and future generations.[2]
- The failure of economic valuation tools and techniques to account for **irreversible environmental losses, resilience and abrupt changes** in the state of ecosystems, and in many cases to model non-linearity in the provision of ecosystem services.
- The failure of traditional economic methods, which aggregate costs and benefits, to account for their **unequal distribution and impacts** across stakeholders (TEEB 2008, TEEB 2010a Ch. 1, 5 and 6, TEEB 2010b Ch. 3).

In spite of these issues, economic valuation is becoming **increasingly reliable**, and usefully supports the **integration of at least some ecosystem service values in economic decision-making frameworks and processes**. The challenges and limitations described above should be acknowledged when presenting the results of economic valuation, but can be addressed by **combining economic valuation with other qualitative and quantitative information** to support informed decision (see Section 4 of this note).

[2] For economically minded readers, these "philosophical" differences result in disagreements between economists over the choice of appropriate discount rates.

Section 3: Benefits of biodiversity and ecosystem conservation and sustainable use

Biodiversity and ecosystem protection, conservation and sustainable use involve a wide range of benefits that frequently exceed the direct and short-term financial and economic benefits derived from ecologically destructive human activities. This is not to say that economic development should systematically be sacrificed to the conservation of nature – but incorporating the multiple values derived from nature in decision-making processes and frameworks can lead to better assessment of the trade-offs between development and conservation, more sustainable development planning, and much higher levels of human welfare and wellbeing in the medium and long term.

This section illustrates the benefits associated with the protection and sustainable use of biodiversity and ecosystem services in a variety of ecological and geographical contexts – as well as the large costs generated by the degradation or destruction of ecosystems. The examples provided are derived from a wide range of scientific publications that were reviewed, assessed and summarized in the context of the TEEB initiative, as well as some original TEEB research. **Annex 2** provides a few additional, more detailed case studies. Readers interested in further details or in search of a wider range of illustrations are invited to consult directly the TEEB web page dedicated to case studies[3] and the underlying publications.

Agro-ecosystems

Biodiversity and ecosystem services provide the foundation for all food production, underpinning production systems for crops, livestock, fisheries and aquaculture. Nine types of ecosystem services support agriculture and food systems: nutrient cycling, soil formation, erosion control, pollination, pest control, climate regulation, water provisioning, genetic diversity and moderation of extreme events. However, agriculture and food systems also have significant negative impacts on biodiversity and ecosystems through habitat encroachment, loss of ecosystem complexity, species reduction, soil erosion, pollution of air, land and water, and greenhouse gas emissions (TEEB 2015a Ch. 2).

Well-functioning ecosystems make significant contributions to the livelihoods of rural populations, and also support crop and livestock productivity. Considering the need to increase global food production in coming decades, applying techniques that promote sustainable use of ecosystems while enabling sustained and diversified food production is essential. Among such techniques is agroforestry, "a collective name for land use systems in which trees and shrubs are grown in association with crops and pasture and/or livestock, (…) and in which there are both ecological and economic interactions between the tree and non-tree components of the system" (TEEB 2015a:xvi). Agroforestry systems, besides being generally considered quite productive, "provide almost half of the biodiversity services found in intact forests and store substantial carbon stocks" (TEEB 2015a:69).

In **Ethiopia** for example, coffee agroforestry systems store carbon stocks with an overall monetary value of US$ 865 million. They generate provisioning services including coffee yield, food, fuelwood and non-timber forest products worth an annual per hectare value of US$ 1 100–2 500. In comparison maize systems generate a value of only US$ 450 per hectare per year. The agroforestry systems also provide regulating ecosystem services including soil fertility enhancement, pollination, biodiversity support, soil erosion control, water purification, water flow regulation and carbon sequestration. Over 20 years, the overall net present value of baseline coffee agroforestry is estimated at US$ 2 750–29 300/ha compared with only US$ 900–3 000/ha for maize systems (TEEB 2015b). Economic analysis has shown that conversion of coffee agroforestry systems to maize cultivation would not only reduce the value of the crop production, but also entail significant losses in regulating services. Conversely, increasing forest cover to 30% in such ecosystems would not significantly reduce provisioning services, but would increase carbon stocks and water yields and reduce soil erosion and runoff.

[3] Over 120 case studies, classified by region, are available on http://www.teebweb.org/resources/case-studies/.

The livestock sector also offers opportunities for combining increased productivity with improved management of biodiversity and ecosystems. In **Nicaragua**, "large-scale deforestation (…) is being driven by clearance for livestock grazing. However traditional grazing regimes on deforested land are often unsustainable. In Matiguas, silvo-pastoral systems have been introduced, and degraded pastures planted with improved grasses, fodder shrubs and trees. This improved habitat reduces surface runoff and soil erosion on steep slopes, benefits local wildlife and, crucially, is also able to support a much higher density of cattle per hectare" (TEEB 2010b:13, Box 1.1, based on FAO 2006).

Case study 1 (Annex 2) illustrates how unsustainable irrigation for cotton production led to an ecological disaster in the Aral Sea region of **Central Asia**, resulting in huge economic, social and environmental costs.

Coastal ecosystems

Coastal ecosystems include shallow seas, estuaries, coral reefs, mangroves, coastal marshes, seagrass beds and other systems. They provide a wide range of ecosystem services, including provisioning services (e.g. seafood, timber and other raw materials), regulating services (e.g. coastal protection through the dissipation of waves and the buffering of winds, flood prevention through the absorption of sea surges), habitat services (including an important role as a nursery for fish supporting local fisheries), as well as aesthetic and recreational values.

In **Belize**, the contribution of coral reefs and mangroves to the national economy was estimated for 2007 at US$ 150-196 million for tourism (12-15% of GDP), US$ 14-16 million for fisheries, and US$ 231–347 million for protection from erosion and wave-induced damage. These values were used by local NGOs to advocate for stricter fishing and mangrove protection regulations, and also to calculate compensation for damages caused by the grounding of a container ship on the barrier reef in 2009. *(Source: Russi et al. 2013:28, Box 3.4, based on Cooper et al. 2008 and Humes 2010)*

Maldives has the seventh largest coral reefs in the world. Coastal and marine biodiversity underpin the two largest sectors in the economy: fisheries and tourism, which account respectively for approx. 8.5% and 67% of gross domestic product. The tourism sector employs 64 000 people or 58% of the workforce. In addition to their direct contribution to economic activity, coral reefs produce regulating and supporting services (e.g. in the form of shoreline protection, storm protection and sand formation). The cost of artificial replacement of coral reefs for these purposes was estimated at rufiyaa 20–34 billion (EUR 1.5–2 billion at current exchange rates), depending on the type of replacement measure. Coral reefs also generate spiritual, cultural and aesthetic values. "Existence value" was estimated at rufiyaa 1.8 million (EUR 0.1 million) per year among residents, and rufiyaa 230 million (EUR 13.2 million) per year internationally. *(Source: TEEBcase by S. Baig (2010) Tourism more valuable than fisheries, Maldives, based on Emerton et al. 2009)*

Case study 4 (Annex 3) illustrates how the economic costs of mangrove conversion far exceed the benefits of coastal shrimp farming in Southern **Thailand**.

Fisheries

Marine ecosystems as well as coastal and inland wetlands are major source of provisioning services. Fish is an essential source of protein and other nutrients. In developing countries, fishing makes an important contribution to the livelihoods of poor people, providing both food and cash income. Yet marine and inland fisheries in most parts of the world tend to be over-exploited. As a result, fish populations dwindle, the size but also the value of the catch decreases as the most valuable species tend to disappear first, and economic returns from the sector go down as more time and increasingly sophisticated equipment are allocated to a less and less profitable activity.

Globally, a World Bank study has estimated the lost economic benefits resulting from the over-exploitation of marine fisheries at US$ 50 billion annually. In other words, more sustainable management of fisheries (allowing fish stocks to recover) combined with the downsizing of fishing fleets would make the global marine fishing industry more profitable by US$ 50 billion every year – while also entailing ecological and social benefits not accounted for in these estimates. *(Source: TEEB 2009, Box 10.19, based on World Bank and FAO 2008)*

The establishment of more **marine protected areas** (MPAs) is one of the options for allowing fisheries to recover. It has been estimated that extending MPAs to 20-30% of the surface of the world's oceans[4] would increase the sustainability of a global fish catch worth US$ 70-80 billion/year in 2004. In comparison, running costs for a global MPA system were estimated at US$ 12.5 billion per year for 20% coverage and US$ 18.8 billion per year for 30% coverage – an amount which could be offset or more than offset by the removal of harmful subsidies to industrial fisheries, estimated at between US$ 15–30 billion per year. Besides supporting or enhancing the global fish catch, an MPA system of the scope envisaged here "would also help ensure the continued delivery of largely unseen marine ecosystem services with a gross value, according to one estimate, of roughly US$ 4.5–6.7 trillion each year". *(Source: TEEB 2009, Box 10.14, and Balmford et al. 2004)*

Forests

Forests all over the world provide a wide range of provisioning services (e.g. timber and other fibrous materials, woodfuels, non-timber forest products such as honey, wild plants, fruit, nuts, oils and mushrooms for human consumption, game, insects, caterpillars, fodder, medicinal plants, rubber, latex, materials for producing pigments and dyes), important regulating services (in particular erosion prevention, soil formation and conservation, water retention, water flow regulation, water purification, air quality regulation, local climate regulation and carbon sequestration), habitat services for multiple plant and animal species including pollinators, as well as a range of recreational, aesthetic and spiritual benefits. They also support the livelihoods of forest-dwelling people, neighbouring communities and more remote people involved in forest product value chains.

In the Shinyanga Region in central **Tanzania**, a traditional natural resource conservation system called *Ngitili* (meaning "enclosure" or "fodder reserve") has been promoted to create and restore forests while improving the livelihoods of local communities. Between 1986 and 2002, between 300 000 and 500 000 hectares of *Ngitili* were restored in 833 villages. A study of the outcomes of this programme found that the economic value of restored Ngitili was US$ 14 per person per month – a significant amount when compared with average national rural consumption, amounting to US$ 8.50 per person per month at the time of the study. The average value derived from the use of 16 natural resource products was estimated at US$ 1 200 per household per year – in comparison of which the cost of wildlife damage due to forest restoration, approx. US$ 65 per family per year, seems quite acceptable. Forest restoration close to villages also reduced the time spent (in particular by women) collecting fuelwood, poles, thatch, water and fodder. *(Source: Barrow, E. and A. Shah (2011) TEEBcase: Traditional forest restoration in Tanzania, based notably on Monela et al. 2005)*

In Aceh province in **Indonesia**, a study was undertaken in 2003 to determine the economic value of the Leuser forest ecosystem in the Leuser National Park and surrounding areas. It compared the benefits from 11 different ecosystem services over a period of 30 years under three scenarios: "deforestation" (a continuation of the current trend); "selective use" (involving a substantial reduction in primary forest logging and compulsory reforestation); and "conservation" (involving a total ban on logging). The net present value of services was calculated separately for five stakeholder groups, including local communities, local government, the national government, the logging industry and the international community. The conservation and selective use scenarios were found to provide the highest benefits for the region (respectively US$ 9.1 and 9.5 billion over 30 years, using a 4% discount rate), against less than US$ 7 billion for the continued deforestation scenario. Local communities gain most from the conservation scenario, with benefits estimated at US$ 5.32 billion. These results led the governor to declare a moratorium on logging activities (very recently extended to palm oil production), and to commission the development of a Green Economic Development and Investment Strategy for Aceh (2008) as well as a study update extending to the ecosystem services of the entire province. *(Source: J. Förster and A. Berghöfer (2010) TEEBcase: Forest valuation stimulates green development policies in the Province of Aceh, Indonesia, based on van Beukering et al. 2003 and 2008)*

[4] Against approx. 2% in 2016, based on MP Atlas (http://www.mpatlas.org/explore/).

Case study 2 (Annex 2) illustrates how deforestation driven primarily by the needs of the construction industry resulted in the catastrophic loss of ecosystem services in **China**, caused a rise in the price of timber and required the spending of billions of dollars to attempt to restore ecosystems. In contrast, **case study 12** (Annex 4) shows how a forest certification scheme supports more sustainable forest management in Sumatra, **Indonesia**.

River basins and watersheds

River basins and watersheds[5] are very important functional ecological units, considering their role in collecting and draining water. They are generally taken to be the natural geographical unit for water resources planning and management. River basin and watershed managers must take into account the needs of various, frequently competing water users including natural ecosystems. Sustainable watershed management involves providing minimum essential supplies to all users, optimizing the economic value of water across uses, managing water abstraction to avoid water resource depletion, monitoring and protecting water quality, minimizing flood risk and drought impacts. The maintenance or restoration of adequate vegetation cover, including forests, in upstream areas and on hillsides helps sustain key ecosystem services such as water retention and release, erosion prevention and flood prevention, and is generally the most cost-effective way of achieving these various objectives.

From the late 1970s to the early 1990s, Hiware Bazaar in the state of Maharashtra, **India**, had all the problems of a typical semi-arid village. Most of its natural assets had been lost: forests had been cut, water sources ran dry, water storage systems were dilapidated, and by 1990 the land was so degraded that only 12% of it was cultivable. Over 90% of families were below the poverty line. This changed with the election of a new mayor in 1989. Taking inspiration from the experience of a nearby village, Hiware Bazaar adopted a five-year plan based on an integrated watershed management approach with water conservation as its core. Another five-year plan targeting ecological regeneration of the local watershed was adopted in 1995, and was implemented with support from the government's Employment Guarantee Scheme. Trees were planted, watershed ecosystems restored, erosion prevention and rainwater harvesting infrastructure built, irrigation practices improved. By 2006, irrigated land had increased from 20 to 260 hectares. The number of wells more than doubled. Grass production went up from 100 tonnes in 2000 to 6 000 tonnes in 2004, supporting a large increase in livestock units and milk production. By 1998, the number of families living below the poverty line had fallen from 168 just 3 years before to 53 – and the trend continued. The per capita income of the village is now twice the average of the top 10% in rural areas nationwide. *(Source: S. Singh (2010) TEEBcase: Enhancing agriculture by ecosystem management in Hiware Bazaar, India)*

In **Tanzania**, the Pangani river is a source of drinking for people and livestock. It supports irrigation agriculture, fisheries, and the livelihoods and income of riparian populations – but also essential hydropower generation for the town of Pangani and surrounding coastal area. Wetlands in the river basin support biodiversity as well as water flow regulation and water quality. Population growth and the intensification of land use have led to over-exploitation of water resources and increased the demand and competition for water among farmers, industry, city dwellers and ecosystems. In a vicious circle, the degradation and loss of forests and wetlands increases water stress, causing conflicts between water users. To resolve them, a strategy for the sustainable management of water resources, forests and wetlands across the entire Pangani river basin is required. Environmental flow assessment combined with economic valuation of various water uses and ecosystem services was used to create a better understanding of the trade-offs between water development and natural resource protection. The assessment of gains and losses for different sectors (including hydropower, agriculture and natural resources) across different water allocation scenarios showed that trade-offs are involved in every scenario – in other words, none of the envisaged scenarios can be beneficial simultaneously from an economic, social and environmental perspective. Quantifying and valuing these trade-offs supports decisions with regard to water resource management and water allocation. *(Source: K. Cross and J. Förster (2011) TEEBcase: Environmental flow assessment taking into account the value of ecosystem services, Pangani River Basin, Tanzania, mainly based on PBWO/IUCN 2009 and Turpie et al. 2005)*

[5] Watersheds are sub-entities in a river basin, typically corresponding to a tributary to a larger river.

Case study 11 (Annex 4) shows how payment for ecosystem services supports sustainable watershed management in South America.

Wetlands

Wetlands, which are among the most threatened ecosystems around the globe, are found both in coastal areas (e.g. estuaries, mangroves, tidal marshes, coral reefs) and inland (rivers, lakes, floodplains, marshes and peatlands). They provide provisioning services (e.g. water supply for domestic use, agriculture and industry, food from fish, other animals and plants, plants used as fertiliser, raw materials such as timber, fibres and peat fertilizer, woodfuels, transport services), regulating services (e.g. water purification, water pollution control, water flow regulation through groundwater recharge and discharge, flood prevention through the absorption of storm water and sea surges, soil formation and conservation through sediment retention and accumulation, carbon sequestration particularly in peatlands), habitat services for multiple plant and animal species including pollinators, as well as a range of recreational, aesthetic and spiritual benefits.

Globally, an economic assessment of 63 million hectares of wetlands estimated their value at US$ 3.4 billion per year – with the highest benefits found in Asia, which accounts for US$ 1.8 billion per year. *(Source: L. Brander and K. Schuyt (2010) TEEBcase: The economic value of the world's wetlands, mainly based on Schuyt and Brander 2004)*

In **Uganda**, the Nakivubo Swamp (covering an area of 5.5 km² between Kampala and Lake Victoria) provides water purification services to the city of Kampala, treating and purifying domestic and industrial wastes and effluents. An economic valuation study concluded that the wastewater purification and nutrient retention ecosystem services provided by the swamp were worth between US$ 1 million and 1.75 million per year, depending on the valuation method used. Another study showed that a sewage treatment plant providing the same service would cost over US$ 2 million in maintenance each year. In comparison, the estimated cost of managing the wetland to simultaneously optimize its waste treatment potential and maintain its ecological integrity is only US$ 235 000 per year. As a result, plans to drain and reclaim the wetland were abandoned and it was incorporated in the city's green belt. Besides water purification, the swamp provides benefits in terms of biodiversity conservation and support for the livelihoods of riparian slum dwellers. *(Sources: Almack K. (2010) TEEBcase: Protected wetland for securing wastewater treatment, Uganda; TEEB 2010b, Box 4.1; Russi et al. 2013, Box 3.4; based mainly on Emerton et al. 1999, Emerton 2003 and Emerton and Bos 2004)*

Case study 3 (Annex 2) and **case study 6** (Annex 3) provide further examples of the assessment and valuation of wetland ecosystem services in, respectively, **Burkina Faso** and **Sri Lanka**.

Section 4: Monitoring biodiversity and ecosystem services to support decision

Improved governance of biodiversity and ecosystems is only possible if policy and decision makers have access to monitoring systems and a range of relevant indicators presented in ways that are accessible to them.

Referring back to the TEEB conceptual framework (see Figure 1), data are needed regarding:

- The extent and condition of ecosystems, including the status of species and biodiversity, and their evolution over time; early warning systems are also needed to alert decision makers before "tipping points" or critical "ecological thresholds" are reached.
- The status of and trends in the provision of ecosystem services.
- The benefits derived from ecosystem services.
- The direct and indirect drivers of ecosystem change and related pressures, and their evolution over time (TEEB 2009 Ch. 3).

Table 2 provides an overview of the complementary tools and data needed to monitor biodiversity and ecosystem service benefits and guide decisions with regard to their protection and conservation.

Table 2: Tools and data needed to monitor ecosystem service benefits

Tools and/or data needed	Examples
Qualitative data, in particular to describe values and benefits that are not easily translated into quantitative information	▪ Descriptions and photos of remarkable landscapes ▪ Description of the cultural and spiritual values local communities attach to specific natural assets ▪ Description of livelihood systems based on natural resources
Quantitative data representing the state of, and changes in, ecosystems and the services they provide	▪ Physical stock indicators (e.g. forest cover, freshwater stock, water quality indicators, fishing stocks, species diversity, species abundance, total carbon sequestration) ▪ Flow indicators (e.g. sustainable livestock / fisheries / crop / woodfuel production, water flows in a watershed, annual incremental carbon sequestration, soil erosion rate by land use type) ▪ Social indicators (e.g. proportion of households with access to clean water, annual number of visitors to a site)
Geospatial mapping linking quantitative and/or qualitative data with geographical information	▪ Maps of ecological infrastructure supporting the assessment of ecosystem connectivity and/or fragmentation ▪ Maps of forest cover and changes in forest cover ▪ Maps showing how the projected impacts of climate change (e.g. change in temperature or rainfall) might affect key ecosystems such as agro-ecosystems
Monetary valuation building on biophysical information on ecosystem service provision	▪ Value of crops, livestock, fish, timber produced in a given area or ecosystem ▪ Value of water purification and flood mitigation services in a watershed ▪ Value of "carbon credits" generated by a carbon sink ▪ Local income from ecotourism
Environmental accounting and reporting	▪ At the macroeconomic level: National Accounts Matrix including Environmental Accounts (NAMEA), System of Economic Environmental Accounting (SEEA) of the UN system of standard national accounts ▪ At the local level: Singapore Index on Cities Biodiversity ▪ At the corporate level: Environmental Management Accounting (EMA), Global Reporting Initiative (GRI) biodiversity and environmental performance reporting

Source: Russi et al. 2013 Ch. 3, with inputs from TEEB 2010a Ch. 3, TEEB 2010b Ch. 4 and TEEB 2010c Ch. 3

Systems for monitoring biodiversity and ecosystem condition and services, the factors and pressures that drive their degradation and the multiple benefits they provide in support of human welfare and wellbeing should be available to policy and decision makers at the **international, national, subnational and local levels**. Their users include stakeholders in the public sector but also in business and civil society.

The three most widely used decision support frameworks by which the appraisal and valuation of ecosystem services can directly inform policy choices are the following:

- **Cost-benefit analysis:** this is a method that values all the benefits and costs expected to arise from a policy or project over its life cycle, discounts them as appropriate to take account of their distribution over time[6], and compares them to determine whether the policy or project is economically advantageous.
- **Participatory appraisal:** this includes a range of techniques that support the collection of qualitative as well quantitative information from various stakeholders; they can notably help highlight relationships between livelihoods, socioeconomic and environmental factors, and are generally good at mobilizing the knowledge and skills of local people.
- **Multi-criteria analysis:** this is a decision-support tool that allows incorporating different types of criteria (e.g. financial, socioeconomic, technical and environmental ones) into a coherent, structured framework for assessing the relative merits of various policy or project options (e.g. various alternative management and development options for a river basin) (TEEB 2010b Ch. 3).

Annex 3 illustrates the use of these decision support frameworks with short case studies focused on, respectively, cost-benefit analysis applied to mangrove conversion for fish farming in **Thailand**; participatory appraisal to determine the location of protected areas in **Solomon Islands**; and multi-criteria analysis applied to the assessment of man-made wetland management options in **Sri Lanka**.

In business, integration of biodiversity and ecosystem service information in life cycle assessment methods is a promising approach (TEEB 2010c Ch. 3).

[6] Discounting is an economic technique that converts costs and benefits that occur at the different times in the future to their value from the perspective of the present. Discounting implies that future costs and benefits are considered to be worth less than their equivalent in the present time. The higher the discount rate, and the further one goes into the future, the smaller the present value.

Section 5: Practical options for better stewardship of natural capital

Biodiversity and ecosystem services need to be integrated in development planning. **Table 3** gives an overview of some practical options and instruments for integrating these themes in policy and management processes at the local / regional as well as the national / international levels. These instruments are briefly described in the text that follows, while **Annex 4** provides illustrations of the use of some of them in the form of short case studies.

Table 3: Key instruments for better stewardship of biodiversity and ecosystem services

Options / Instruments	Decision level	
	Local / Reg'l	Nat'l / Int'l
Planning and regulatory instruments		
Regulation including environmental standards	√	√
Spatial planning	√	(√)
Environmental assessment	√	√
Protected areas	√	√
Investment in ecological infrastructure	√	√
Biodiversity offsets	(√)	√
Pricing and other market-based instruments		
Reform of subsidies	(√)	√
Pricing and taxes	√	√
Commercial licences and tradable permits	√	√
Compensation payments (e.g. for wildlife damage)	√	√
Payment for ecosystem services (PES)	√	√
Green markets: certification and labelling	√	√

Source: Based on TEEB 2009 and TEEB 2010b

The use of these instruments can be promoted through development cooperation programmes, in the context of general and sector support for policy and regulatory reform and as part of environment- and climate change-focused interventions.

Planning and regulatory instruments

Regulation including environmental standards is and remains the most widely used instrument for protecting biodiversity and ecosystems from excessive damage from development. A strong regulatory baseline is key to establishing environmental protection objectives, reducing pollution, providing clear guidelines for private sector operations, and establishing a foundation for the use of pricing and market-based instruments. The "regulatory toolkit" includes the regulation of emissions and products (environmental standards), land uses (see "spatial planning") and other use of natural resources (e.g. regulation of water abstraction, fishing quotas, timber quotas in forestry concessions). Regulation is best used in conjunction with other instruments and is not always the most cost-effective manner of achieving environmental objectives – hence the development of complementary market-based instruments expected do better in this regard. Furthermore, if regulation is to be effective at all, specific attention must be paid to **enforcement**, which in many developing countries remains weak (TEEB 2009 Ch. 7).

Spatial planning, i.e. planning with a view to optimizing land use and the distribution of people, infrastructure and activities across space at various scales, is particularly useful for integrating sustainable ecosystem management with socioeconomic development, since it can take account of the cumulative impacts of development on ecosystems and the services they provide. It can be used, for example, to secure the continued provision of essential ecosystem services such as water flow regulation in watersheds. It can also help avoid the excessive fragmentation of natural ecosystems, which is essential for their resilience and the long-term conservation of biodiversity (TEEB 2010b Ch. 6). Two related concepts support a proactive approach to biodiversity and ecosystem conservation in spatial planning:

- *Green networks* “promote linked spaces and corridors of biodiversity resources, sustainable transport networks and formal and informal public open-spaces. This enables the identification of network ‘gaps’ and implementation of management priorities with a focus on linked networks rather than individual sites”.
- *Green infrastructure* “is a strategically planned and delivered network of ecosystems and green spaces including parks, rivers, wetlands and private gardens. It focuses on ecosystems that provide important services such as storm water protection, water and air quality improvement as well as regulation of local climate” (TEEB 2010b:113).

The interconnection of natural ecosystems and their organisation as a network is indeed essential to preserve ecosystem services and biodiversity on an adequate scale, notably in the context of climate change. “Connecting elements” such as conservation corridors and buffer zones around protected areas allow the migration of plant and animal species across natural habitats, and enable them to maintain genetic diversity and gradually modify their range in response to climate change. They also support the maintenance of critical services such as water absorption and release, pollination and seed dispersal (TEEB 2009 Ch. 8 and 9, TEEB 2010b Ch. 6 and 7).

From the perspective of sustainable development, **environmental assessment** is the indispensable complement to spatial planning. It can be conducted at the level of projects (environmental impact assessment or EIA) as well as policies, plans and programmes (strategic environmental assessment or SEA). EIA and, even more effectively, SEA can help spatial planning in various ways, by:

- Identifying and preventing or mitigating changes that create excessive pressures or involve irreversible negative impacts on biodiversity and ecosystems.
- Identifying opportunities for sustaining and enhancing the provision of ecosystem services and their contribution to socioeconomic welfare and quality of life, in both rural and urban settings.
- Supporting compliance with national and international legal obligations concerning protected areas, protected species and key ecosystem services (including carbon sequestration) (TEEB 2010b Ch. 6).

Marine and terrestrial **protected areas** are a cornerstone of biodiversity conservation policies and provide multiple benefits from the local to the global level. Generally speaking, these benefits far outweigh the costs of setting up and managing protected areas, even taking account of the “opportunity costs” associated with foregone development or exploitation – but two issues need to be addressed:

- The costs involved are frequently more direct, visible and short-term than the benefits, which tend to be more dispersed, non-traded and long-term – so that the balance of costs and benefits may not be clear. Ecosystem service assessment and valuation can help build political support for conservation, make better-informed planning and management decisions, manage conflicts between various groups of stakeholders, and raise funds.
- Costs and benefits are not always fairly distributed. Distant users (from downstream water users to foreign tourists and TV watchers to global beneficiaries of greenhouse gas emission reductions) may enjoy the most significant benefits, while local communities impacted by restricted access to or use of some resources bear the bulk of the costs. This can be addressed through the use of pricing and market-based instruments (see below) that support a more equitable distribution of costs and benefits, and by allowing or developing sustainable income-generating activities for local communities in and/or around protected areas (TEEB 2009 Ch. 8, TEEB 2010b Ch. 7).

Ecological infrastructure “refers to nature’s capacity to provide freshwater, climate regulation, soil formation, erosion control and natural risk management, amongst other services” (TEEB 2009 Ch. 10:15). Investing in ecological infrastructure is frequently more cost-effective than investing in man-made technological solutions, especially if the multiple benefits derived from natural capital are taken into account. Preventive maintenance and conservation of ecological infrastructure is clearly the best option – but where it has been damaged ecosystem restoration, even if expensive, can still be better value for money than replacement with man-made infrastructure (TEEB 2009 Ch. 9). The spatial dimension of ecological infrastructure requires specific attention. For example, water-related ecosystem services must be managed at the river basin and watershed levels. Aspects related to green infrastructure and maintaining connectivity between ecosystems are addressed above in relation to spatial planning.

Biodiversity offsets refers to arrangements by which damage to biodiversity or ecosystems due to development in one place can be compensated by habitat restoration, creation or enhancement somewhere else. Such arrangements can be voluntary or mandated by regulation. Offsetting generally aims to achieve no net loss or if possible a net gain in biodiversity based on criteria such as species composition, the size of specific habitats or the provision of specific ecosystem services. There are limits to offsetting and some risks that offsets fail to achieve their goals – but if well managed, they can provide a flexible way of reconciling development and conservation objectives (TEEB 2009 Ch. 7, TEEB 2010b Ch. 8).

Case study 7 (Annex 4) illustrates the integration of ecosystem services in spatial planning in Sumatra, **Indonesia**. **Case study 8** shows how SEA encompassing ecosystem service assessment led to the downscaling of a water diversion project in **Egypt**. **Case study 9** describes the costs and benefits associated with protected areas in **Namibia**, and **case study 10** the use of ecosystem service assessment to locate an ecological corridor in a biodiversity reserve in **Paraguay**.

Pricing and other market-based instruments

We have seen that the failure of market prices to reflect the environmental costs associated with the production of goods and services is a significant driver of ecosystem degradation and biodiversity loss. Various instruments are available to:

- "Correct" prices, thus bringing private incentives more in line with society's interests (in application of the "polluter pays principle").
- Redistribute costs and benefits so that the beneficiaries of ecosystem services pay for their use (in application of the "full cost recovery principle") while those who help sustain and protect them get rewarded for their efforts.

Economic analysis and the valuation of biodiversity and ecosystem services play a role in the design of all these instruments, as they help determine the "right" level of prices.

Alongside regulation, **reforming subsidies** is one of the essential tools in the policy toolkit for protecting biodiversity and ecosystems. Subsidies can contribute to biodiversity and ecosystem degradation by artificially lowering the price of (and thus increasing demand for) some goods or services the production of which involves environmental damage, or encouraging the inefficient or excessive use of some natural resources (e.g. land, water, fish stocks). Examples of environmentally harmful subsidies include subsidies for unsustainable irrigation, those that encourage overcapacity in the fishing industry, and fossil fuel subsidies. Not all subsidies are harmful, and some can be used to support the transition towards more sustainable production and consumption patterns (e.g. subsidies for agro-environmental schemes). Economic analysis can help determine the adequate level of subsidies to reward sustainable practices without causing excessive distortions in prices. The phasing out of harmful subsidies can be politically delicate as it often entails a rise in the price of some essential goods and services such as water, food and transport – but these subsidies typically benefit primarily the better-off who could afford to pay more, and impacts on the poor can be alleviated by targeted measures financed by the freed up public resources (TEEB 2008, TEEB 2009 Ch. 6).

Pricing and taxes can help correct the failure of market prices to reflect environmental values by raising the price of some goods and services to a level that truly reflects their social and environmental costs. Examples include entrance fees in national parks and other conservation or recreation areas, charges for using water or cutting trees, and taxes on the production of waste or the use of plastic bags. Fines for breaching environmental regulations are also a way of sending price signals about the true value of natural capital. Again, economic analysis integrating the value of ecosystem services can help determine the right level of various types of charges (TEEB 2009 Ch. 7).

Commercial licences and **tradable permits** are other examples of market-based instruments for promoting sustainable management of biodiversity and ecosystems. They frequently combine an element of pricing (the cost of purchasing a licence or permit) with an element of quantitative regulation (limitations in the amount of natural resources that can be extracted, applied to individual permit holders and/or overall where quotas can be traded among those who hold them). Examples include hunting licences, fishing quotas and timber licences (TEEB 2009 Ch. 7).

Compensation payments for wildlife damage are another example of price-based instrument. They are typically set up to indemnify land owners and farmers in the vicinity of protected areas and other natural ecosystems that host animals (e.g. tigers, elephants) that can cause damage to livestock and/or crops. They can help raise acceptance of protected areas and prevent the illegal hunting of endangered species, but can also generate negative perceptions of wildlife (TEEB 2009 Ch. 5).

Payment for ecosystem services (PES) is defined as "an incentive-based approach to protect ecosystem services by compensating landowners or managers who adopt practices that are favourable to an ecosystem. Simply put, those who use ecosystem services pay those who provide them – and when providers are compensated, conservation becomes more attractive" (TEEB 2010b, Ch. 8:142). PES schemes can focus on a variety of services. They are most frequently used in the context of watershed management, to reward the application by farmers and cattle breeders of "good practices" that help regulate water flows and prevent erosion. Another application that is gaining ground is carbon sequestration and storage. The **REDD+** initiative for reducing emissions from deforestation and forest degradation[7] is in essence a PES scheme aimed at rewarding developing countries for not cutting down their forests, or slowing the rate of deforestation and forest degradation against an accepted baseline. PES schemes can be established at the regional, national or international level. They are one of the possible sources of funding for protected areas (TEEB 2009 Ch. 5, TEEB 2010 Ch. 8).

Promoting the development of **green markets** is another market-based option with promising perspectives. **Certification and labelling schemes** help producers signal that they have met recognized sustainability standards, and consumers identify products and services that meet specific environmental and/or social criteria. Certification schemes and labels now exist for a wide range of products and services, including organic food, sustainably produced timber and fish, fair trade products and sustainable tourism. Certified products and services are frequently (but not always) sold at a premium price, which rewards producers for implementing sustainable practices; certification and labelling can also support improved market access, increased market share and/or improved reputation for producers (TEEB 2009 Ch. 5, TEEB 2010b Ch. 9, TEEB 2010c).

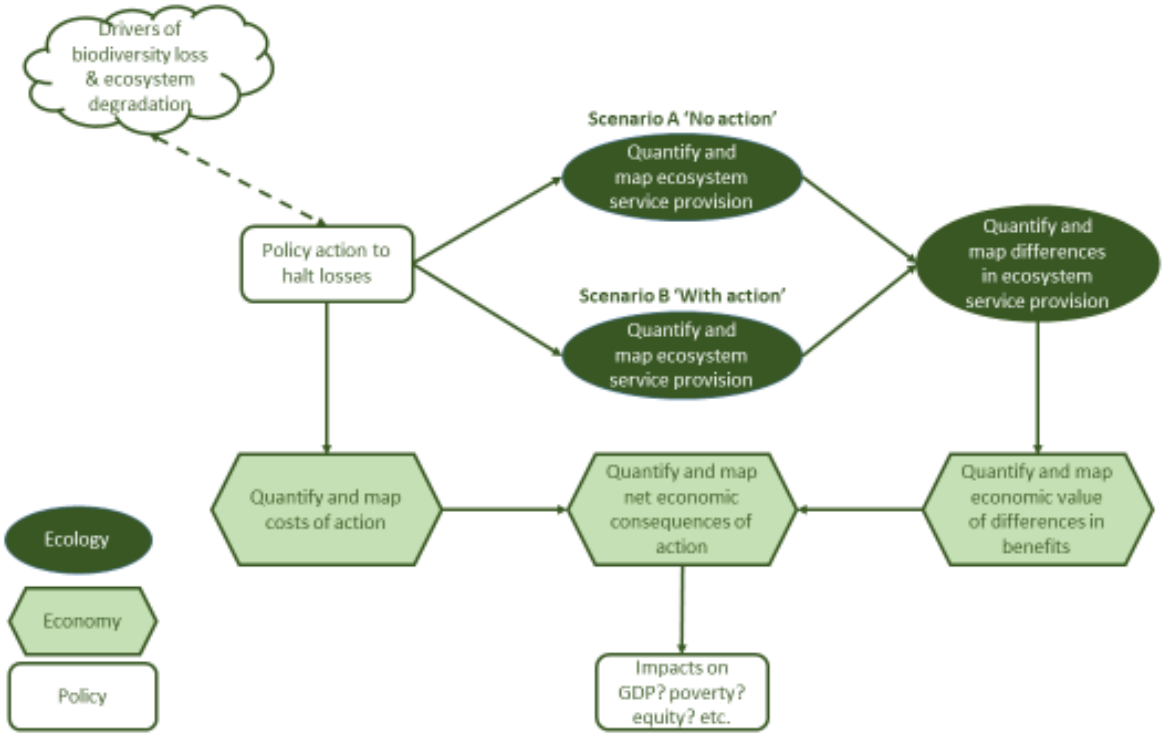
Case study 11 illustrates the application of PES schemes to watershed protection in **South America**. **Case study 12** describes the benefits but also the limitations of forest certification in **Solomon Islands**.

[7] Implemented in the context of the UN Framework Convention on Climate Change.

Annex 1: TEEB valuation framework, total economic value and economic valuation methods

Figure 3 gives a schematic representation of the economic valuation framework used in TEEB.

Figure 3: TEEB economic valuation framework



Source: TEEB 2010a, Figure 1.2 Ch.1:15, after Balmford et al (2008) and TEEB (2008)

Total economic value (TEV) is a framework that attempts to capture all the various elements that contribute to the economic value of a natural asset. It includes the following components:

1) **Use values**, i.e. the benefits derived from using the asset and keeping options open for future use:
   - *Direct use values*, accruing from both consumptive uses (e.g. crops, wild and cultivated foods, fuel, raw materials) and non-consumptive uses (e.g. recreation, cultural and spiritual wellbeing).
   - *Indirect use values*, accruing primarily from regulating services (e.g. water regulation and purification, soil fertility, air quality regulation).
   - *Option value*, accruing from the preservation of the asset for securing the potential (optional) future use of benefits, including uses that might only be discovered in the future (e.g. natural medicinal substances derived from plant and animal biodiversity); this is sometimes assimilated with a form of "insurance premium" against the irreversible loss of benefits in a situation of imperfect knowledge.
2) **Non-use values**, i.e. the other benefits humanity derives from knowing the asset exists and will continue to exist:
   - *Bequest value*, i.e. the "value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (intergenerational equity concerns)".
   - *Altruist value*, i.e. the "value attached by individuals to the fact that other people of the present generation have access to the benefits provided by species and ecosystems (intragenerational equity concerns)".
   - *Existence value*, i.e. the "value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist" (TEEB 2010a, Table 5.1, Ch. 5:195).

TEV aggregates these various categories of values estimated on the basis of marginal (i.e. "small") changes in the current and future flows of benefits (appropriately discounted) for a given state of the considered asset or ecosystem – in other words, it is specific to a time and context.

Under the TEV approach, various valuation methods have been developed. They belong to three main categories, under each of which various methods exist[8] (see TEEB 2010a Ch. 5 for more details, and TEEB 2010b Ch. 3: for simple explanations and some illustrations):

1) **Direct market valuation approaches** use data from actual markets:
   - *Market price-based approaches* use values taken directly from markets (e.g. for food products, fuels and raw materials which are generally traded goods).
   - *Cost-based approaches* use estimates of the costs that would be incurred as a result of the loss of ecosystem services (avoided cost method), or the costs that would be incurred if currently "free" ecosystem services need to be generated by artificial infrastructure (replacement cost method) (e.g. for water regulation and purification).
   - *Production function-based approaches* estimate how much a given ecosystem service (typically a regulating service) contributes to the production of a traded good or service (typically a provisioning service) to assess the value of a change in ecosystem service provision.
2) **Revealed preference approaches** infer the demand for some types of environmental services by observing behaviour in existing "surrogate" markets that are related to the ecosystem service considered:
   - The *travel cost method* is used to estimate recreational values based on the expenses people incur to visit a site of interest, including the opportunity cost of the time dedicated to this visit.
   - The *hedonic pricing method* uses differences in property prices combined with data on the characteristics of properties – including specific environmental attributes such as proximity to a forest or a view on a nice landscape – to infer the value people allocate to specific ecosystem services such as recreational or aesthetic services.
3) **Stated preference approaches** simulate market conditions, using surveys and experiments to determine how much people are willing to pay to secure the continued provision of given ecosystem services:
   - The *contingent valuation method* uses questionnaires to directly assess people's willingness to pay to sustain or enhance the provision of an environmental good or service – or their willingness to accept payment in exchange for its loss or degradation.
   - *Choice modelling* or *choice experiments* infers value by making people choose between two or more alternatives of a policy or project that affects biodiversity or ecosystem service provision, among a set of alternatives that share attributes but offer different levels of these attributes, and are priced in a different manner (e.g. business-as-usual i.e. continued degradation of an environmental asset with no increase in taxes vs. two conservation policies characterized by different levels of protection and a more or less significant increase in taxes).

These methods all have advantages and disadvantages. Some are more complex than others. Some are more suitable than others for the estimation of certain categories of values, or for certain categories of ecosystem services. **Table 4** below summarizes key features of the most used valuation methods including the types of services to which they are typically applied.

[8] Only the most widely used are listed here.

Table 4: Comparison of economic valuation methods

Group	Methods	Summary	Statistical analysis	Services valued
Direct market prices	Market prices	Observe market prices	Simple	Provisioning services
Market alternative	i. Replacement costs	Finding a man-made solution as an alternative to the ecosystem service	Simple	Pollination, water purification
	ii. Damage cost avoided	How much spending was avoided because of the ecosystem service provided?	Simple	Damage mitigation, carbon sequestration
	iii. Production function	How much is the value-added by the ecosystem service based on its input to production processes?	Complex	Water purification, freshwater availability, provisioning services
Surrogate markets	i. Hedonic price method	Consider housing market and the extra amount paid for higher environmental quality	Very complex	Use values only, recreation and leisure, air quality
	ii. Travel cost method	Cost of visiting a site: travel costs (fares, car use etc.) and also value of leisure time expended	Complex	Use values only, recreation and leisure
Stated preference	i. Contingent valuation method	How much is the survey respondent willing-to-pay to have more of a particular ecosystem service?	Complex	All services
	ii. Choice experiments	Given a 'menu' of options with differing levels of ecosystem services and differing costs, which is preferred?	Very complex	All services
Participatory	Participatory environmental valuation	Asking members of a community to determine the importance of a non-marketed ecosystem service relative to goods or services that are marketed	Simple	All services
Benefits transfer	Benefits transfer (mean value, adjusted mean value, benefit function)	'Borrowing' or transferring a value from an existing study to provide a ballpark estimate for current decision	Can be simple or complex	Whatever services were valued in the original study

Source: TEEB 2010b, Table 3.1, Ch. 3:44

Various valuation methods can be combined in a study to assess various components of total economic value – as long as precautions are taken to avoid double counting (e.g. of provisioning services and the regulating services that contribute to their availability).

Benefit(s) transfer methods can build on any of the above methods. Benefit transfer refers to the practice of applying values calculated in a specific context to a different context and possibly at a different scale, as "an approach to overcome the lack of system-specific information in a relatively inexpensive and timely manner" (TEEB 2010a Ch. 5:229). There are various ways of doing this, involving more or less sophistication in the method used to account for differences in context between the "policy site" (i.e. the ecosystem to which values are transferred) and the "study site" (i.e. the ecosystem for which values were originally estimated) (TEEB 2010b Ch. 3). Benefit transfer is convenient considering the sometimes considerable time and costs involved in undertaking primary valuation studies, but it should be applied with great caution as it may otherwise result in errors and therefore poorly informed decisions. The same recommendation applies to the **scaling-up** of ecosystem values from a specific ecosystem to an entire stock of similar ecosystems or the provision of ecosystem services over a large geographical area (TEEB 2010a Ch. 5).

Finally, it is worth noting that many of the environmental valuation methods mentioned above were first tested and applied in developed countries. Their **application in developing country contexts** may involve methodological and practical challenges (e.g. low levels of literacy and education creating barriers to the use traditional survey techniques, prevalence of informal and subsistence economies making it difficult for people to allocate a meaningful value to complex environmental goods, environmental and security issues making it difficult for researchers to access some areas, lack of local research capacity) and raise questions on their possible use for supporting decision and policy making. These challenges are not insurmountable but **careful adjustment of research and valuation methods** is required when operating in developing countries. Possible solutions include:

- The use of deliberative and participatory approaches to data collection.
- The assessment of willingness to pay in terms of other measures of wealth than money (e.g. bags of a staple good).
- The building of local research capacities, notably with regard to environmental valuation.
- The incorporation of action research approaches into valuation studies, with a view to influencing policy (TEEB 2010a Ch. 5).

Annex 2: Benefits of biodiversity and ecosystem conservation and sustainable use – Short case studies

Case study 1: Cotton production and the destruction of the Aral Sea

(Sources: TEEB 2010c, Box 2.2, Ch. 2 and Annex 2.1 "Case studies", based notably on Cai, McKinney and Rosegrant 2001, FAO 1998, Glazovsky 1991 and 1995, Kijne 2005, Micklin 1992, Micklin and Aladin 2008, Nalwak and Krilsin 2000, Severskiy et al. 2005, World Bank 2003)

In the Aral Sea region in **Central Asia**, excessive expansion of irrigated area and consumption of water resources, from the 1960s onwards, for growing cotton, had severe impacts on ecosystems and people. By 2007, water abstraction from the Amu Darya and Syr Darya rivers had caused the Aral Sea to shrink to 10% of its original size. The problem was compounded by pollution of surface and groundwater resulting from the intensive use of fertilizer and pesticides. Key observed impacts include:

- The disappearance of 90-95% of wetlands and the drying up of most lakes in the Amu Darya delta in Uzbekistan and the Syr Darya delta in Kazakhstan – and their replacement with sandy deserts.
- The salinization of the region's remaining lakes and wetlands.
- The loss of 70 000 hectares of forests.
- Declining soil fertility and soil erosion, and an increase in dust storms.
- A significant decrease in mammal and bird species in the river deltas, and of fish species in the lakes.
- The destruction of commercial fisheries, resulting in the loss of 60 000 jobs.
- A change in the local climate, now characterized by shorter, hotter, drier summers and longer, colder, snowless winters – resulting in a shortening of the growing season.
- Significant impacts on the health of local populations, with large increases in chronic bronchitis, in kidney and liver diseases including cancer, in arthritic diseases, as well as a very high infant mortality rate and a decrease in life expectancy.

The industry at the origin of this catastrophe is also affected: water pollution, water-logging and increasing soil salinity caused by poor irrigation practices have resulted in a decline in cotton yields, with lost crop production valued in 2005 at US$ 1.4 billion per year, i.e. about one-third of the value of potential crop production.

In 1990, a study estimated the environmental damage due to unsustainable agricultural and irrigation practices at minimum US$ 1.4 billion, based on the cost of measures to address some of the impacts. A follow-up study undertaken in 1995 revised these estimates to over US$ 3.5 billion, after taking into account the costs of improving sanitary hygienic and medical services, creating alternative jobs and shifting the economy onto a more sustainable path. More recently, a TEEB study team estimated (on a conservative basis) the loss of ecosystem services resulting from the disappearance of 522,500 ha of wetlands over the period 1960-1990 at around US$ 100 million annually.

In conclusion, the agriculture industry boosted short-term production by over-exploiting water resources, and reduced its costs by ignoring ("externalising") the value of the associated environmental damage. If this had been accounted for in the costs of cotton production, "both overall output and the scale of irrigation would probably have been much lower. The lesson to be learned from the destruction of the Aral Sea is that water resources can and do disappear when used unsustainably, and that changes in ecosystems can have far-reaching impacts on those that depend on the services they provide. The loss of ecosystem services and the costs of protecting and rehabilitating ecosystems need to be valued and considered explicitly in decisions on how to use water resources more efficiently." (TEEB 2010c, Annex 2.1:10)

Case study 2: Deforestation and ecosystem restoration in China

(Sources: TEEB 2010c, Box 2.3, Ch. 2 and Annex 2.1 "Case studies", based notably on Earth Policy Institute 2002, Lang 2002, McVittie 2010, Song and Zhang 2009, Sun et al. 2002, Wang 1997, Yin 1998 Xu et al. 2002)

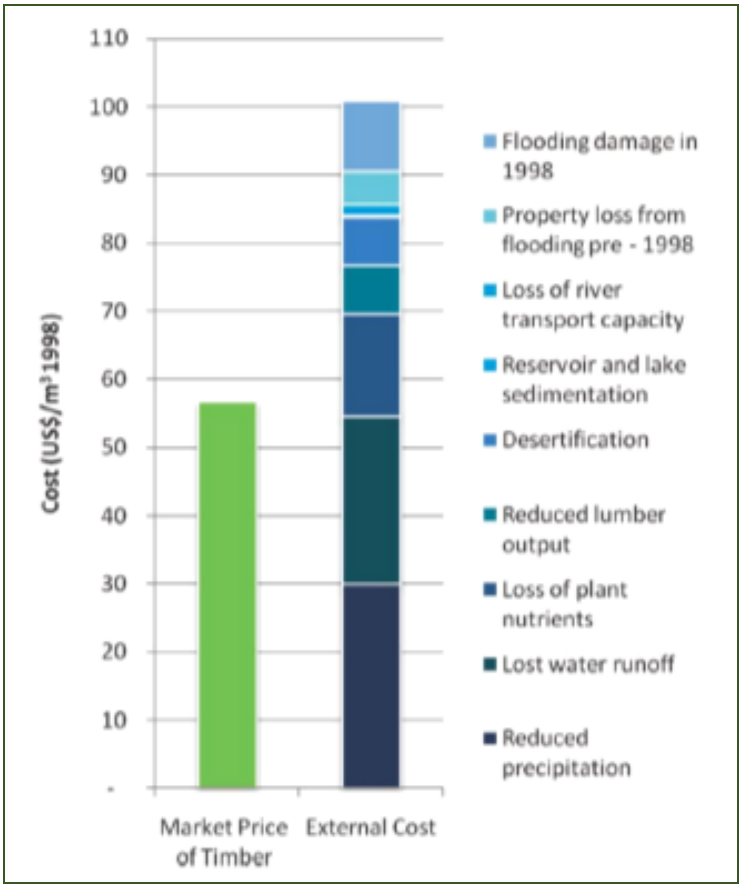
Between 1949 and the 1990s, **China** allowed intensive timber extraction to meet the demands of the construction industry. A cumulative area of 75 million hectares was harvested, of which 92% were natural forests. Rapid deforestation led to adverse structural changes in forest ecosystems, a significant decrease in ecosystem services (particularly watershed protection and soil conservation), and biodiversity loss due to the disturbance, destruction and fragmentation of habitats. The amount of damage done became apparent in the mid- to late 1990s, which saw the occurrence of severe droughts (in the Yellow River basin), major flash floods (in all water basins and notably the Yangtze basin) – and the resulting displacement of millions of people alongside significant damage to property and infrastructure. With 85% of the upper river basin's original tree cover gone, hydropower generation and navigation waterways were also threatened by siltation resulting from severe erosion of hills and mountain slopes.

It became clear that environmental degradation in the upper reaches of the Yangtze and Yellow River basins were affecting the economic welfare and the security of millions of people in downstream areas. In response, the Chinese government had to ban logging in 17 provinces, and started a Natural Forest Conservation Program aimed at repairing some of the damage done and restoring vital ecosystem services. Costs were incurred in the billions of dollars for forest protection and restoration – and also to relocate the large number of loggers and other forest sector employees who had lost their jobs. The debts incurred by state-owned forest enterprises also had to be written off.

The value of forest ecosystem services lost before this major restoration effort was estimated at US$ 12.2 billion annually over the 1950-1998 period. A comparison of the market price of timber with the external costs imposed by deforestation (in the form reduced precipitation, lost water runoff, loss of plant nutrients due to erosion, reduced timber output, desertification, reservoir and lake sedimentation, loss of river transport capacity, property loss from flooding) shows that the costs of environmental degradation (over 100 US$/m^3) far exceed the market value of timber (approx. 57 US$/m^3) – see **Figure 4**.

Unsustainable harvesting of timber over several decades thus led to an ecological disaster with significant human and economic consequences, and also ended up creating shortages in timber supply that caused the cost of timber to increase, disrupting the construction industry that had been at the origin of the problem. At a large cost, China has been able to recover some of the damage done. However, the logging ban had impacts far beyond China's borders: "As a result of the decline in domestic forest resources and the 1998 logging ban, China's own production has not been able to keep pace with demand for timber. Imports have made up the difference, putting increased pressure on forests in other countries. In effect, the external costs of deforestation have been shifted abroad, leading to growing concerns about deforestation in timber-exporting countries, such as Burma, Indonesia and Russia" (TEEB 2010c, Annex 2.1:9).

Figure 4: External impacts of the construction and materials sector in China vs. price of timber



Source: TEEB (2010c) Annex 2.1 "Case studies", Figure 4, p. 9

Case study 3: Wetland valuation in Burkina Faso

(Source: Somda, J. and A. J. Nianogo (2010) TEEBcase: Wetland valuation changes policy perspectives, Burkina Faso, mainly based on Somda et al. 2010)

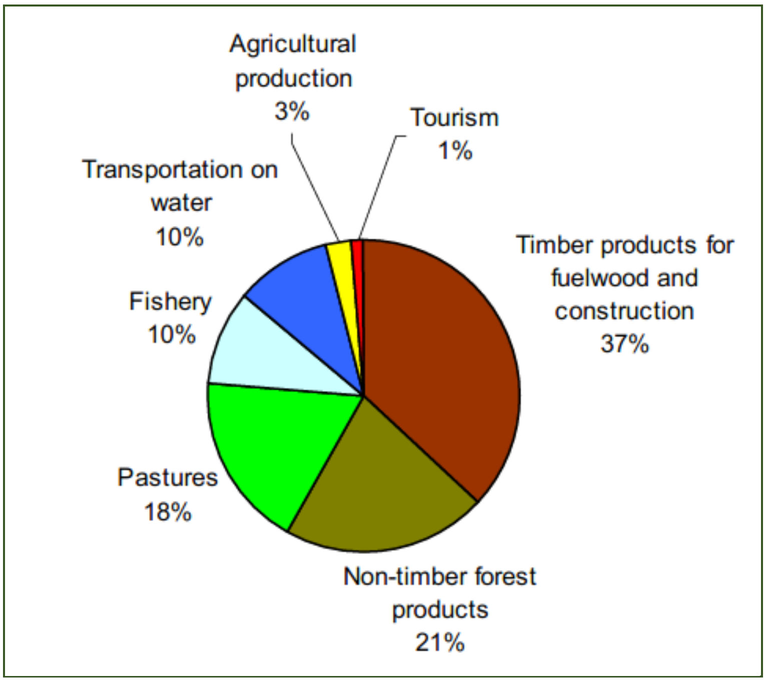
The Sourou valley wetlands are among the most important wetlands in **Burkina Faso**, and are considered a priority area for agricultural production. Athough local communities depend on ecosystem services for income and livelihoods, insufficient attention has been paid to sustainability and agricultural practices are causing many negative environmental impacts, including the degradation of river banks and siltation, the destruction of hippopotamus and bird habitat, and reduced river flow.

To support more balanced development, the International Union for the Conservation of Nature (IUCN) together with two national research centres undertook an economic valuation of these wetlands. The study considered four types of ecosystem services:

- Provisioning services: crops, livestock, fish, wild foods, fuelwood, provision of water for transport.
- Cultural services: tourism.
- Regulating services: groundwater recharge and discharge.
- Habitat services and biodiversity.

The first two types of services could be valued in monetary terms. The study reveals that crop production, usually considered as the most significant asset for Sourou valley development, accounts for only 3% of the value of provisioning and cultural services derived from the wetlands (see **Figure 5**). Timber, woodfuels and non-timber forest products account for over half of this value. Uses as pastures, fisheries and for transportation on water are also worth more than crop cultivation.

Figure 5: Contribution of various services to the economic value of Sourou valley wetlands



Source: Somda et al. (2010)

Preliminary estimates value the sum of these ecosystem services at minimum EUR 15 million for a population of 62 224 people. This does not account for the provision of water regulation services (the study also showed that the diversion of the Mouhoun river water into the Sourou valley improved groundwater recharge), nor for the value of the wetlands as habitat for the hippopotamus, migratory birds and other species – ome with the potential of attracting safari tourism.

These results stimulated discussion among policy makers about ways to integrate ecosystem services into development policies at both local and national levels. The study process itself, which was based on a participatory approach involving all stakeholders from the local to the national level, helped raise awareness of the multiple services provided by the wetlands and the need to balance agricultural development with the conservation and sustainable use of natural ecosystems.

Annex 3: Integration of ecosystem service appraisal and valuation in decision support frameworks – Short case studies

Case study 4: Cost-benefit analysis applied to mangrove conversion for shrimp farming

(Source: Russi et al. 2013, based on Barbier 2007 and Hanley and Barbier 2009)

In Southern **Thailand**, the net present value of mangrove benefits calculated over 9 years at a 10% discount rate was estimated at US$ 10 821/hectare for coastal protection against storms, US$ 987/ha for fish nurseries and US$ 584/ha for collected wood and non-timber forest products – i.e. nearly US$ 12 400/ha overall. This dwarfs the private benefits of commercial shrimp farming in converted mangrove areas, which net of government subsidies worth US$ 8 412/ha, in reality amount to only US$ 1 120/ha. Furthermore, because of unsustainable practices that result in pollution and the spread of viral diseases, shrimp production declines after 5 years and shrimp farms are then quickly abandoned. When this happens, restoring mangroves to recover the lost ecosystem services requires an average investment of US$ 9 318/ha.

Therefore, while shrimp farming involving mangrove destruction is a profitable activity from a financial (private sector) perspective, from an economic (societal) perspective mangrove conservation is a much better option.

Case study 5: Participatory appraisal to determine the location of protected areas

(Source: Susi Menazza and Tasneem Balasinorwala (2011) TEEB case: Assessing ecosystem services for a protected area network, Solomon Islands, based on Lipsett-Moore et al. 2010)

In the Choiseul (also known locally as Lauru) province in **Solomon Islands**, a participatory approach to the analysis of ecosystem services was used to help select the location of a network of marine and terrestrial protected areas.

The assessment started with a participatory mapping workshop attended by stakeholders from each ward (customary territory) of the province, and from the provincial government, national ministries and non-governmental organizations. Using large base maps showing features such as vegetation, reefs, rivers and roads, participants identified and located key natural assets important to them and their villages/communities, mapped areas providing ecosystem services, and also located threats to ecosystem sustainability such as proposed logging and mining concessions, sea level rise and fisheries.

Marxan, a freely available conservation planning software programme[9], was then used to determine cost-effective options for managing and protecting important areas. Several scenarios were produced, offering various choices that prioritized areas providing important ecosystem services such as mangrove areas, coral reefs, water sources and key garden forest areas.

Further on, a participatory planning exercise combining the use of 3D software, community mapping and open discussions on land use planning scenarios was undertaken to allow the concerned communities to explore land use options and ecosystem service protection at the local level. Facilitated discussions were then organized to address issues including ecosystem services, existing and proposed protected areas, current and planned economic development activities, and information on predicted climate change impacts. This helped ensure a shared understanding of threats and opportunities and generate local ownership of proposals for extending protected areas.

The process ended in October 2009 with the organization of a workshop in which over 100 chiefs representing all the customary clans of Lauru, in partnership with the provincial authorities, made a commitment to formally establish the "Lauru reefs to ridges protected area network", and create at least one marine protected area and one terrestrial protected area in each of the existing 12 wards (customary territories) within the next two years.

[9] See http://www.uq.edu.au/marxan/.

Case study 6: Multi-criteria analysis for assessing irrigation tank management options

(Source: Förster J. (2010) TEEBcase: Water tank rehabilitation benefits rural development, Sri Lanka, mainly based on Vidanage et al. 2005)

In **Sri Lanka**, communities in the Kala Oya river basin use a traditional irrigation system based on human-made wetlands for water storage (known as water tanks). Besides supporting rice production, these tanks provide goods such as fish, lotus flowers and roots that diversify household income, as well as fodder and drinking water for livestock. Also, seepage from the tanks, by recharging aquifers, maintains water quality in wells which are the main source of drinking water. However, increasing water demand in upstream areas for modern agriculture, in particular water-intensive rice cultivation, and for hydropower has led to the decline of water flows into the tank system and increased the sediment load and siltation – with negative impacts on the livelihoods of water tank users.

To address the double challenge of managing competing water demands and improving the management of water tanks, an economic valuation of the provisioning services provided by the traditional tank system was undertaken. It revealed that the use of water and aquatic resources from the tanks is worth, on average, US$ 2 972 per hectare per year and US$ 425 per year per household – a significant contribution to livelihoods in a region where half of the population lives in poverty.

The value of provisioning services is dependent on the water holding capacity of the tanks, which in turn depends on how they are managed. Four different management scenarios were assessed: **S1** doing nothing and letting the tanks degrade further, **S2** raising the spillways to increase the water table, **S3** raising the spillways and decreasing the sedimentation load, and **S4** increasing the tanks' water holding capacity by removing the silt. These strategies have different impacts on the value of regulating services ("indirect uses"), in particular groundwater recharge, nutrient and sediment retention, and biodiversity – which were assessed based on qualitative criteria. A qualitative assessment was also made of "accumulated natural capital", reflecting the ability of the tanks to continue providing ecosystem services beyond the considered 30-year period.

Table 5 shows the results of this multi-criteria analysis. Scenario 4, while being the most expensive, also turns out to be the one that provides the most benefits against all criteria.[10] This had led some of the concerned communities to choose this option and invest labour in tank rehabilitation works.

Table 5: Cost-benefit assessment of alternative water tank management scenarios

Scenario	Net present value (NPV) over 30 years at 6% discount, 2004 US$ '000)			Indirect use trends	Natural capital in 30 years
	Cost	Incremental tank benefit	Quantifiable net benefit		
S1 Do nothing	0	0	0	- 7	↓↓
S2 Raise spill	0.4	24.2	23.8	- 4	↓
S3 Raise spill, decrease sedimentation load	35.8	64.6	28.8	+ 6	↑
S4 Rehabilitate by removing silt	62.8	120.7	57.9	+ 7	↑↑

Source: Russi et al. 2013, Box 3.9, based on Emerton (2004) and Vidanage et al. (2005)

[10] This is unusual – generally some options score better against some criteria, other options against other criteria.

Annex 4: Practical options for better stewardship of natural capital – Short case studies

Case study 7: Integrating ecosystem services into spatial planning in Sumatra

(Source: T. Barano, E. McKenzie, N. Bhagabati, M. Conte, D. Ennaanay, O. Hadian, N. Olwero, H. Tallis, S. Wolny, G. Ng (2010) TEEBcase: Integrating ecosystem services into spatial planning in Sumatra, Indonesia

In Sumatra, **Indonesia**, deforestation and forest conversion (including the conversion of lowland peat forests), mostly for palm oil, pulp and paper plantations and illegal logging, are causing losses of biodiversity, degrading many ecosystem services, and threatening the livelihoods, security and wellbeing of local communities.

Spatial plans guide decisions about whether and where concessions are granted for economic activities such as plantations, and which areas are reserved for conservation and ecosystem restoration. In the context of the preparation of provincial and district spatial plans in 2010, an ecosystem service mapping and modelling tool called InVEST[11] was used to map high quality habitat and biodiversity information and assess the provision of various ecosystem services (carbon storage and sequestration, annual water yield, erosion control and water purification) under two development scenarios: one based on a "business-as-usual" scenario corresponding to the government's existing spatial plan, and one based on an "ecosystem vision" aimed at avoiding additional ecosystem degradation and balancing environmental, social and economic considerations.

Overlaying biodiversity information and projections of changes in ecosystem services associated with various land use scenarios supports more sustainable land use planning. In June 2010, the results were disseminated to government representatives from 19 districts in the pilot RIMBA ecosystem in central Sumatra. Recommendations were made on how to prioritize areas for forest restoration based on habitat quality and the potential for reducing erosion. Modelling results were also used to identify the most suitable sites for forest carbon projects. In addition, they can inform the selection of sites for ecotourism; and the design of payment for PES schemes, by identifying which areas support water flow regulation and erosion prevention services and where beneficiaries of such services are located.

Case study 8: Water transfer project influenced by strategic environmental assessment

(Source: R. Slootweg (2010) TEEBcase: Water transfer project influenced by ecosystem services valuation, Egypt)

In the West Delta area in **Egypt**, the rate of groundwater exploitation for expanding irrigated agriculture in desert plains far exceeds the rate of resource renewal. This causes the rapid depletion and in some places the salinization of groundwater reserves. To address this problem, in 2006, the government proposed to divert fresh Nile water from the Rosetta Nile branch into the project area, and distribute it over 40 000 hectares of farmland in the West Delta area as part of a West Delta Water Conservation and Irrigation Rehabilitation Programme.

Based on a preliminary technical design, SEA was undertaken at an early stage to support the assessment of economic, social and environmental aspects prior to the detailed design of the programme. A first round of qualitative analysis helped identify the most significant impacts associated with the withdrawal of water from the Rosetta Nile branch (which supplies water to tens of thousands of smallholder farms, to the city of Alexandria and to coastal lagoons and fisheries in the area), as well as the supply of surface water to the West Delta region (which can lead to reduced exploitation of groundwater but also intensified agricultural exploitation, and additional social and economic development). A second round of analysis quantified and valued the changes in ecosystem services for various alternative designs, based on assessments of the net economic benefits of an average farm in the planning area, the number of permanent and seasonal jobs in the planning area, as well as impacts on agricultural production, fishery benefits and drinking water availability downstream of the intake site.

[11] InVEST stands for "integrated valuation of ecosystem services and trade-offs", and was developed by the Natural Capital Project of Stanford University. Information on this tool is available on http://www.naturalcapitalproject.org/invest/.

Study results provided strong arguments for decision makers to significantly reduce the scale of the initially envisaged project. Indeed, it turned out that the diversion of water from relatively poor smallholder farmers in the Nile Delta to large investors in the West Delta posed unacceptable equity problems. Furthermore, public water supply to Alexandria cannot be subjected to any significant reduction.

Case study 9: Costs and benefits of protected areas in Namibia

Protected areas (PAs) cover 17% of **Namibia**'s national territory. In addition, as of 2004, Namibia's 400 private hunting farms and conservancies on communal land covered 14% of the territory. These natural assets attract over 500 000 visitors each year, generating tourism revenues that are far higher than the operating costs of PAs but relatively little employment in and around protected areas. **Table 6** provides an overview of the costs and benefits associated with the existence of Namibia's protected areas at local, national and global levels, with values where available.

Table 6: Cost and benefits of protected areas in Namibia

Level	Costs	Benefits
Global	Approx. US$ 8 million per year in international transfer for PA management (carried by international donors)	Option and existence value of biodiversity (benefiting the global community) International tourism (accruing to foreign visitors, tour operators, airlines, etc.)
National	- US$ 18.6 million spent on PA management - US$ 20.8 million spent on operational costs of tourism facilities (carried by the Directorate of Parks & Wildlife Management of the Ministry of Environment and Tourism)	- Habitat value - Cultural and recreational value (benefiting 16% of rural households and 20% or urban households) - Water provision (minimal) - Tourism-related jobs (about 20,000 people) - Over 2 200 tourism-related businesses - Overall tourism benefits amounting to approx. US$ 335 million (benefiting private enterprises and the government through taxes at a rate of approx. 20%)
Local	- Foregone income from agriculture (low) - Damage to crops, livestock and infrastructure from wild animals (not quantified) (carried by local communities)	- Employment in protected areas (1 100 people) (accruing to PA management and government) - Accommodation near PAs (US$ 51.4 million) (benefiting private business in rural areas) - Income of tour operators and guides (US$ 13 million) - Revenue from tourism inside PAs (US$ 12.9 million of which min. 4% redistributed to local communities)

Source: Adapted from TEEB 2010b:130, Table 7.1, based on Turpie et al. 2009

Case study 10: Ecological infrastructure zoning in a biosphere reserve in Paraguay

(Source: TEEB 2010b:136, Box 7.13, based on Naidoo and Ricketts 2006 and Gross 2006)

The Mbaracayu Biosphere Reserve in **Paraguay** supports large-scale cattle ranching and soybean production as well as small-scale farming, hunting and foraging by indigenous people. As a result, it has become highly fragmented.

Cost-benefit analysis was applied to support the choice of options for reducing the fragmentation of the reserve through the implementation of a new wildlife corridor linking two large forest patches. The study identified and assessed five key ecosystem services provided by the reserve, namely sustainable bushmeat provision, sustainable timber provision, pharmaceutical bioprospecting, the existence value of unspoiled wilderness, and carbon storage. The value of each service was estimated per forest parcel, across six forest types – always identifying service beneficiaries. Localizing costs and benefits in such a way delivered some interesting insights, including the following:

- Even though the considered area was relatively small, the costs and benefits of forest conservation varied considerably across forest parcels, revealing that "some zoning options would pursue conservation at far lower costs than others".
- When considering only bioprospecting, bushmeat and timber benefits, the costs of conservation exceeded benefits for the majority of parcels. However, when the value of carbon sequestration (estimated at a conservative carbon trading market price of US$ 2.50) was added, benefits exceeded the opportunity costs of foregone development for 98% of the parcels.

The production of a cost-benefit map was very useful for discussing options with stakeholders and authorities. Based on study results, the wildlife corridor that provided the greatest net benefit was selected over two alternative options.

Case study 11: Payment for ecosystem services (PES) in watersheds in South America

(Source: R.L. Goldman, S. Benitez, A. Calvache, S. Davidson, D. Ennaanay, E. McKenzie and H. Tallis (2010) TEEBcase: Water Funds for conservation of ecosystem services in watersheds, Colombia, notably based on Goldman et al. 2010)

Forests in the watersheds of the **Northern Andean region** are threatened by conversion to crop and ranch land, while the demand for a regular supply of water by downstream users – which include citizens, water utilities, hydropower companies, agriculture companies, and beer and water bottling companies – is increasing with population growth. Natural areas that are important for water regulation are often officially protected, but governments lack resources for effective management of protected areas and buffer zones. Furthermore, reducing access to land for upstream, relatively poor ranchers and farmers that depend on it for their livelihoods is difficult from a political and an ethical perspective.

To address these problems, a concept called "water fund" was first launched in Quito, Ecuador in the late 1990s, and has now been replicated in at least 12 other sites in the Northern Andes. In a water fund, "water users voluntarily put money into a trust fund; the users and other key stakeholders in the watershed form a public-private partnership to make decisions on how to spend interest, and in some cases a portion of the trust itself, to finance conservation activities in the watershed" (TEEBcase p. 2). Conservation activities can take various forms, including the hiring of community-based park guards, and the subsidizing of sustainable land management practices (such as re-vegetating the landscape) implemented by upstream farmers and ranchers.

In the East Cauca Valley of **Colombia**, for example, a "Water Fund for Life and Sustainability" (FAVS in Spanish) was set up with the help of an association of sugar cane producers and some other donors. It aims to secure biodiversity and water-related services, particularly a reduction in sedimentation and the maintenance of regular water flows. The fund supports the conservation and sustainable management of at least 125 000 hectares of natural ecosystems, benefiting sugar production as well as 920 000 people in downstream areas.

A watershed scoring system and the already mentioned "InVEST" ecosystem service mapping and modelling tool (see **case study 7**) were used to identify priority areas for investment, establish quantitative ecosystem service goals and develop a portfolio of the most efficient activities. The most suitable conservation activity (either restoration, reforestation, fencing or silvopastoral practices) was identified for each part of the landscape. Landscape units were ranked according to their capacity to produce improvements in water yield and erosion control. These rankings were then combined with cost information to determine the most cost-effective water fund investment portfolio, considering the available budget. This approach helps ensure that service beneficiaries get the best value for money from the FAVS PES scheme.

Case study 12: Benefits and limitations of forest certification in Solomon Islands

(Source: Padma N. Lal (2012) TEEBcase: Benefits of forest certification, Solomon Islands, notably based on Kabutaulaka 2000 and 2006)

Logging has played an important role in the **Solomon Islands** economy for several decades. However, in the 1990s and the early 2000s, timber harvests increased to truly unsustainable levels, while the contribution of logging revenues to government income started falling. Not only did poor forestry practices entail the loss of biodiversity, they also caused soil erosion, the silting of rivers and the degradation of coral reefs due to sedimentation.

Various approaches were used to tackle these problems, including strengthened monitoring and enforcement of existing regulations, and the adoption of a new Forestry Act and revised Code of Logging Practice – with few visible impacts on the ground. Sustainable forest management practices and forest certification were also promoted. One of the timber companies that took notice is the Kolombangara Forest Products Ltd (KFPL), which operates a 14 500 plantation forest adjacent to protected and reserve forests in the Western Province. In 1998, it joined the Forest Stewardship Council (FSC) certification scheme, which promotes environmentally sustainable, socially beneficial, economically viable forest management. This move was motivated by the existence of a specific market demand and premium prices for "green" products, particularly on the European market.

The certification process helped to implement improvements in environmental and social practices and enhance the livelihoods of the local communities. Support was provided to local communities to move away from designated buffer strips and protected areas and gain access to other land for subsistence farming. This was made possible by the premium price (approx. 36% over the price of traditionally sourced timber) obtained for FSC-certified sawn timber. Forest certification proved to be a useful market-based mechanism for encouraging sustainable forestry practices. Nevertheless, it does not solve all the issues associated with plantation forestry. Plantation forests, even those involving a mix of native and exotic commercial species as in the case of KFPL, are less good than natural forests at providing biodiversity support and water regulation services. Monitoring and verification are also costly, and often turn out to be unaffordable for smaller logging companies and community-based forestry operations.

Glossary

Benefit transfer: “The procedure of estimating the value of an ecosystem service by transferring an existing valuation estimate from a similar ecosystem” (TEEB 2010a Ch. 5:229).

Biodiversity: “The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species and between ecosystems” (TEEB 2010a:xxxi based on MA 2005).

Cost-benefit analysis: A method that values all the benefits and costs expected to arise from a policy or project over its life cycle, discounts them as appropriate to take account of their distribution over time, and compares them to determine whether the policy or project is economically advantageous.

Discounting: An economic technique that converts costs and benefits that occur at the different times in the future to their value from the perspective of the present.

Ecological threshold: “The point at which the conditions of an ecosystem result in change to a new state” (TEEB 2010a:xxxiii)

Ecosystem: “A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit” (TEEB 2010a:xxxiii based on MA 2005).

Ecosystem services: “The direct and indirect contributions of ecosystems to human wellbeing” (TEEB 2010a:xxxiv). See **Table 1** for a typology and examples of ecosystem services.

Ecosystem resilience: “The capacity of an ecosystem to absorb shocks and stresses in constructive ways” (TEEB 2008:37); also defined as “a measure of the capacity of ecosystems to function over a range of environmental conditions” (TEEB 2010a Ch. 2:59).

Multi-criteria analysis: A decision-support tool that allows incorporating different types of criteria (e.g. financial, socioeconomic, technical, environmental) into a coherent, structured framework for assessing the relative merits of various policy or project options.

Natural capital: The physical and biological resources available on earth and supporting economic processes and livelihoods (alongside economic, human and social capital).

Net present value: The sum of benefits and costs of a policy or intervention from the perspective of the present time (i.e. applying discounting as appropriate).

Opportunity costs: The costs of foregone economic development, if ecosystem conservation is preferred to conversion.

Public good: A good or service characterized by non-rivalry (i.e. use or consumption by one individual does not reduce the opportunity of another individual to use or consume it) and non-excludability (i.e. the absence of enforceable property rights). There are no markets and therefore no prices for public goods.

Stakeholders: “Persons, organizations or groups with interest in the way a particular ecosystem service is used, enjoyed, or managed” (TEEB 2010a Ch. 5:225).

Total economic value: A framework that attempts to capture all the various elements of “utility” that contribute to the economic value of an asset. See **Annex 1** for a description of these elements.

List of acronyms

FSC ....:Forest Stewardship Council
GDP : ....Gross Domestic Product
InVEST..........integrated valuation of ecosystem services and trade-off
MPA : ....Marine Protected Area
PA: ....Protected area
PES :.............Payment for Ecosystem Services
TEEB :...........Economics of Ecosystems and Biodiversity
TEV :.............Total Economic Value

References

Primary references (TEEB publications)

All TEEB publications are available (in draft or final form) from: http://www.teebweb.org/our-publications/.

Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. and Davidson N. (2013) *The economics of ecosystems and biodiversity for water and wetlands*. IEEP, London and Brussels and Ramsar Secretariat, Gland. [Online]

TEEB (2008) *The economics of ecosystems and biodiversity: an interim report.* European Communities. [Online]

TEEB (2009) *The economics of ecosystems and biodiversity for national and international policy makers*. [Online draft version]. [Final version edited by Earthscan: TEEB (2011) *The economics of ecosystems and biodiversity in national and international policy making*. Patrick ten Brink (Ed.). Earthscan, London and Washington.]

TEEB (2010a) *The economics of ecosystems and biodiversity: ecological and economic foundations.* Pushpam Kumar (Ed.). Earthscan, London and Washington. [Online draft version also available]

TEEB (2010b) *The economics of ecosystems and biodiversity for local and regional policy makers*. [Online] [Final version edited by Earthscan: TEEB (2011) *The economics of ecosystems and biodiversity in local and regional policy and management*. Heidi Wittmer and Haripriya Gundimeda (Eds). Earthscan, London.]

TEEB (2010c) *TEEB for business*. [Online draft version]. [Final version edited by Earthscan: TEEB (2012) *The economics of ecosystems and biodiversity in business and enterprise*. Joshua Bishop (Ed.). Earthscan, London and New York.]

TEEB (2015a) *TEEB for agriculture and food: an interim report*. United Nations Environment Programme, Geneva, Switzerland.

TEEB (2015b) *Agroforestry: an attractive REDD+ policy option?* Executive summary. World Agroforestry Centre (ICRAF), UNEP World Conservation Monitoring Centre (UNEP-WCMC), and United Nations Environment Programme (UNEP).

Secondary references

Secondary references are those cited in TEEB publications and case studies.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R. Green, M. Jenkins, P. Jefferiss, V. Jessamay, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R.K. Turner (2002) Economic reasons for conserving wild nature. *Science* 297: 950–953.

Balmford, A., Gravestock, P., Hockley, N., McClean, C. J. and Roberts, C. M. (2004) The worldwide costs of marine protected areas. *Proceedings of the National Academy of Science, USA* 101 (26):9694-9697. [Available from http://www.ncbi.nlm.nih.gov/]

Barbier, E. B. (2007) Valuing ecosystem services as productive inputs. *Economic Policy* 22 (49):177–229.

Cai, Ximing & McKinney, Daene C. & Rosegrant, Mark W. (2001) *Sustainability analysis for irrigation water management: concepts, methodology, and application to the Aral Sea region*. EPTD discussion papers 86, International Food Policy Research Institute (IFPRI); and FAOSTAT.

Cooper E., Burke L. and Bood N. (2008) *Coastal capital: Belize. The economic contribution of Belize's coral reefs and mangroves*. World Resources Institute, Washington, DC.

Earth Policy Institute (2002) Illegal Logging Threatens Ecological and Economic Stability. [Online: http://www.earth-policy.org/index.php?/plan_b_updates/2002/update11]

Emerton, L. (2003) *Case study in wetland evaluation 7: Nakivubo Swamp, Uganda.* Managing natural wetlands for their ecosystem services. Integrating wetland economic values into river basin management. IUCN, Gland, Switzerland.

Emerton, L. (2004) *The Kala Oya River Basin, Sri Lanka: where small irrigation tanks are not really small*. Case studies in wetland valuation Nr. 9. Integrating Wetland Economic Values into River Basin Management. IUCN Sri Lanka.

Emerton L., Baig S. and Saleem M. (2009) *Valuing Biodiversity. The economic case for biodiversity conservation in the Maldives.* AEC Project, Ministry of Housing, Transport and Environment, Government of Maldives and UNDP Maldives.

Emerton L. and Bos E. (2004) *Value: Counting ecosystems as an economic part of water infrastructure*. IUCN, Gland, Switzerland and Cambridge.

Emerton, L., Iyango, L., Luwum, P., and Malinga, A. (1999) *The economic value of Nakivubo urban wetland, Uganda*. Uganda National Wetlands Programme, Kampala and IUCN, Eastern Africa Regional Office, Nairobi.

FAO – Food and Agriculture Organization (1998*) Time to save the Aral Sea?* Agriculture and Consumer Protection Department, Paris

FAO – Food and Agriculture Organization (2006) *Sustainable grazing systems*. Agriculture and Consumer Protection Department, Food and Agriculture Organization of the United Nations, Rome.

Glazovsky, N.F. (1991) Ideas on an escape from the 'Aral Crisis'. *Soviet Geography*, 22 (2) :73-89.

Glazovsky, N.F. (1995) *Regions at risk: comparison of threatened environments, the Aral Sea basin*. United Nations University Press.

Goldman, R.L., Benitez, S., Calvache, A. and Ramos, A. (2010) *Water funds: Protecting watersheds for nature and people*. The Nature Conservancy, Arlington, Virginia.

Gross, L. (2006) Assessing ecosystem services to identify conservation priorities. *PLoS Biol.* 4: e392.

Hanley N. and Barbier E. B. (2009) Valuing ecosystem services, in *Pricing nature: Cost-benefit analysis and environmental policy*, Edward Elgar, London.

Humes A. (2010). Owners of ship Westerhaven must pay $11.5 million for damage to barrier reef caused by negligence. Amandala, Belize, www.amandala.com.bz.

Kabutaulaka, T.T. (2000) Rumble in the jungle: land, culture and (un)sustainable logging Solomon Islands. In Hooper, A. (ed.). *Culture and sustainable development in the Pacific*. Canberra: 88-97.

Kabutaulaka, T.T. (2006) Global capital and local ownership in Solomon Islands' forestry industry. In Stewart F. (ed.). *Globalisation and governance in the Pacific Islands*. *State, society and governance in Melanesia*. Studies in State and Society in the Pacific, No. 1. Canberra: 239-257.

Kijne, J.W. (2005) *Aral sea basin initiative: Towards a strategy for sustainable irrigated agriculture with feasible investment in drainage.* Synthesis report. Food and Agriculture Organization, Rome.

Lang, G. (2002) Deforestation, floods, and state reactions in China and Thailand, Working Paper Series, 21, City University of Hong Kong, SEARC

Lipsett-Moore G., Hamilton R. , Nate Peterson, Game E., Atu W., Kereseka J., Pita J., Ramohia P. and Siota C. (2010) Ridges to Reefs Conservation Plan for Choiseul Province, Solomon Islands. TNC Pacific Islands Countries Report No. 2/10.

MA – Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: current state and trends*. Volume 1, Island Press, Washington, DC.

McVittie, A. (2010) Personal communication, Land Economy & Environment Research Group, Scottish Agricultural College.

Micklin, P.P. (1992) The Aral crisis: Introduction to the special issue. *Post-Sov. Geogr.*, 33 (5):269-82.

Micklin, P. and Aladin, N.V. (2008) *Reclaiming the Aral Sea*. Scientific American, April 2008. [Online: http://www.scientificamerican.com/article/reclaiming-the-aral-sea/]

Monela, G.C., S.A.O. Chamshama, R. Mwaipopo and D.M. Gamassa 2005. *A study on the social, economic and environmental impacts of forest landscape restoration in Shinyanga Region, Tanzania*. Dar-es-Salaam, Tanzania, Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism, United Republic of Tanzania, and IUCN – The World Conservation Union Eastern Africa Regional Office.

Naidoo, R. and Ricketts, T. H. (2006) Mapping the economic costs and benefits of conservation. *PLoS Biol.* 4: e360.

Nalwalk, Krilsin (2000) *The Aral Sea crisis: The intersection of economic loss and environmental degradation*. University of Pittsburgh, Graduate School of Public and International Affairs.

PBWO/IUCN (2009) *Scenario report: The analysis of water-allocation scenarios for the Pangani River Basin.* Unpublished technical report. Pangani River Basin Flow Assessment, Moshi.

Schuyt, K. and Brander, L. (2004) *The economic values of the world's wetlands.* WWF, Gland/Amsterdam.

Severskiy, I., Chervanyov, I., Ponamorenko, Y., Novikova, N.M., Miagkov, S.V., et al. (2005) Global International Waters Assessment (GIWA) 24, Aral Sea. University of Kalmar, Sweden and United Nations Environment Programme

Somda, J., Zonon, A., Ouadba, J.M., and Huberman, D. (2010) Valeur économique de la vallée du Sourou: Une évaluation préliminaire. Ouagadougou, Burkina Faso, Bureau regional.

Song, C. and Zhang, Y. (2009) Reforestation and afforestation efforts in China from 1949 to 2006. Chapter 15 in H. Nagendra and J. Southworth (eds.) *Reforesting landscapes: linking pattern and process*. Landscape Series 10, Springer.

Sun, J., Zhao, C. and Wang, L. (2002) *The long march of green: The chronicle of returning agricultural land to forests in China*. China Modern Economics Press, Beijing.

Turpie, J., Y. Ngaga and F. Karanja (2005) *Maximising the economic value of water resources.* Policy briefs for water management. Pangani River Basin Issue 1, Tanzania. IUCN Eastern Africa Regional Office.

Turpie, J., Barnes, J., Lange, G.M. and Martin R. (2009) *The economic value of Namibia's protected area system: a case for increased investment*. Report by ANCHOR Environmental, South Africa.

van Beukering, P.J.H., H.S.J. Cesar and M.A. Janssen (2003) Economic valuation of the Leuser National Park on Sumatra, Indonesia. *Ecological Economics* 44: 43-62.

van Beukering, P., K. Grogan, S.L. Hansfort (2008) *An Economic valuation of Aceh's forests: The road towards sustainable development*.

Vidanage S., Perera S. and Kallesoe M. (2005) *The value of traditional water schemes: small tanks in the Kala Oya Basin, Sri Lanka*. IUCN Water, Nature and Economics Technical Paper No. 6, IUCN – The International Union for Conservation of Nature, Ecosystems and Livelihoods Group Asia

Wang H. (1997) Deforestation and desiccation in China: A Preliminary Study. In Mao Y., Ning D., Xia G., Wang Ho. and Smil V. (1997) *An assessment of the economic losses resulting from various forms of environmental degradation in China.* Occasional paper of the Project on Environmental Scarcities, State Capacity, and Civil Violence. American Academy of Arts and Sciences, Cambridge, and University of Toronto.

Xu, J.T. and Cao, Y.Y. (2002) Converting steep cropland to forest and grassland: Efficiency and prospects of sustainability. *International Economic Review* (Chinese) 2:56-60

Yin, R.S. (1998) Forestry and the environment in China: The current situation and strategic choice. *World Development* 26(12): 2153-2167.

World Bank (2003) *Irrigation in Central Asia: social, economic and environmental considerations.* The World Bank: Washington, D.C.

World Bank and Food and Agriculture Organization (2008) *The sunken billions: The economic justification for fisheries reform.* Agriculture and Rural Development Department. The World Bank, Washington D.C.

Resources

www.teebweb.org: All **TEEB publications** are available on line, either in draft or final form. Other available resources include **case studies** (over 120 of them, classified by region); training materials; a glossary of terms; and some useful links.

www.evri.ca: Environmental Valuation Reference Inventory: on-line database of empirical studies on the economic value of environmental benefits and human health effects, developed as a tool to help policy analysts use the **benefits transfer approach**.

www.ipbes.net: site of the **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)**, an intergovernmental body which assesses the state of biodiversity and ecosystem services in response to requests from decision makers. Resources currently include information on the organisation's work programme, webinars, and a few "summaries for policy makers".