# THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY

TEEB for National and International Policy Makers

## Chapter 9: Investing in ecological infrastructure

**Coordinating Lead Author:** Carsten Neßhöver (Helmholtz Centre for Environmental Research – UFZ)

**Lead authors:** James Aronson, James Blignaut

**Contributing authors:** Florian Eppink, Alexandra Vakrou, Heidi Wittmer

**Editing and language check:** Clare Shine

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## TEEB for Policy Makers Team

**TEEB for Policy Makers Coordinator:** Patrick ten Brink (IEEP)

**TEEB for Policy Makers Core Team:** Bernd Hansjuergens (UFZ), Sylvia Kaplan (BMU, Germany), Katia Karousakis (OECD), Marianne Kettunen (IEEP), Markus Lehmann (SCBD), Meriem Bouamrane (UNESCO), Helen Mountford (OECD), Alice Ruhweza (Katoomba Group, Uganda), Mark Schauer (UNEP), Christoph Schröter-Schlaack (UFZ), Benjamin Simmons (UNEP), Alexandra Vakrou (European Commission), Stefan van der Esch (VROM, The Netherlands), James Vause (Defra, United Kingdom), Madhu Verma (IIFM, India), Jean-Louis Weber (EEA), Stephen White (European Commission) and Heidi Wittmer (UFZ).

**TEEB Study Leader:** Pavan Sukhdev (UNEP)

**TEEB communications:** Georgina Langdale (UNEP)

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY
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# Chapter 9

## Investing in ecological infrastructure

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# Key Messages of Chapter 9

**Investing in 'ecological infrastructure' makes economic sense** in terms of cost effectiveness and rates of return, once the whole range of benefits provided by maintained, restored or increased ecological services are taken into account. Well-documented examples include investing in mangroves or other wetland ecosystems as well as watersheds, instead of man-made infrastructure like dykes or waste water treatment plants, in order to sustain or enhance the provision of ecosystem services.

**It is usually much cheaper to avoid degradation than to pay for ecological restoration.** This is particularly true for biodiversity: species that go extinct can not be brought back. Nonetheless, there are many cases where the expected benefits from restoration far exceed the costs. If transformation of ecosystems is severe, true restoration of pre-existing species assemblages, ecological processes and the delivery rates of services may well be impossible. However, some ecosystem services may often be recovered by restoring simplified but well-functioning ecosystems modelled on the pre-existing local system.

## Recommendations:

Investments in **ecosystem restoration can benefit multiple policy sectors** and help them to achieve their policy goals. This applies – but is not limited to – urban development, water purification and waste water treatment, regional development, transport and tourism as well as protection from natural hazards and policies for public health.

In the light of expected needs for significant investment in **adaptation to climate change**, investing in restoring degraded ecosystems also has important potential for many policy sectors. Obvious examples include enhancing the productive capacity of agricultural systems under conditions of increased climate fluctuations and unpredictability, and also providing buffering services against extreme weather events.

Investment in natural capital and conservation of ecosystems can **help to avoid crises and catastrophes** or to soften and mitigate their consequences. However, if catastrophes do strike, they should be regarded as opportunities to rethink policy and to incorporate greater investments in natural capital into new programmes and rebuilding efforts – e.g. mangrove or other coastal ecosystem restoration and protection following a tsunami or hurricane, wetland restoration and protection after flooding in coastal areas, forest restoration after a catastrophic mudslide.

**Direct government investment is often needed**, since many returns lie in the realm of public goods and interests and will be realised only over the long term. This applies especially to degraded sites and ecosystems such as post-mining areas, brownfield sites, converted forests, dredged wetlands and areas prone to erosion or desertification.

**Proactive strategies for investment** in natural capital need to be further developed and implemented and link natural capital explicitly with natural hazard risks. Systematic assessments of natural capital, creating natural capital accounting systems and maps pave the way for combining environmental risk reduction with economically efficient investment.

# 9 Investing in ecological infrastructure

"More and more, the complementary factor in short supply (limiting factor) is remaining natural capital, not manmade capital as it used to be. For example, populations of fish, not fishing boats, limit fish catch worldwide. Economic logic says to invest in the limiting factor. That logic has not changed, but the identity of the limiting factor has."

Herman Daly, 2005, former chief economist with World Bank

"If we were running a business with the biosphere as our major asset, we would not allow it to depreciate. We would ensure that all necessary repairs and maintenance were carried out on a regular basis."

Prof. Alan Malcolm, Chief Scientific Advisor, Institute of Biology, IUPAC

This chapter focuses on ways to augment renewable natural capital – upon which our economies ultimately depend –by investing in the maintenance, restoration and rehabilitation of damaged or degraded ecosystems. Such investments can promote many different policy goals including secure delivery of clean drinking water, natural disaster prevention or mitigation, and climate change adaptation.

**9.1** shows how investments in renewable natural capital are a worthwhile investment. Building on Chapter 8 (protected areas), it discusses the **costs and benefits of restoration** and focuses on specific situations in which policy makers should consider directly investing public money in natural capital. **9.2** highlights the **benefits of ecosystem restoration beyond the environmental sector**, particularly with regard to water management, natural hazard prevention and mitigation and protection of human health. **9.3** explores the potential of ecosystem investments to deliver concrete **benefits for climate change mitigation and adaptation** policies. **9.4** concludes the chapter by identi-fying opportunities for **developing proactive investment strategies** based on precaution to provide benefits across a range of sectors.

# 9.1 IS NATURAL CAPITAL A WORTHWHILE INVESTMENT?

Does investing in natural capital make economic sense? To answer this we have to determine:

- if it is ecologically feasible to restore degraded natural capital or to invest in ecological infrastructure;
- whether restoring the natural capital in question is expected to generate significant benefits; and
- if investment is both possible and a high priority, what might it cost?

Only a few studies have addressed these questions comprehensively to date. However, there are encouraging examples that illustrate the potential for a positive economic outcome. The following section highlights and synthesises these results.

## 9.1.1. THE ECOLOGICAL FEASIBILITY OF NATURAL CAPITAL ENHANCEMENT

There is a lively debate between ecologists, planners and economists about the extent to which building 'designer' or engineered ecosystems – such as artificial wastewater treatment plants, fish farms at sea or roof gardens to help cooling cities– can adequately respond to the huge problems facing humanity today. Increasingly, ecological restoration – and more broadly, the restoration of renewable natural capital – are seen as important targets for public and private spending to complement manmade engineering solutions.

**True restoration to prior states is rarely possible**, especially at large scales, given the array of global changes affecting biota everywhere and that 'novel' ecosystems with unprecedented assemblages of organisms are increasingly prevalent (see Hobbs et al. 2006; Seastedt et al. 2008). Nevertheless, the growing body of available experience on the restoration and rehabilitation of degraded ecosystems suggests that this is a viable and important direction in which to work, provided that the goals set are pragmatic and realistic (Jackson and Hobbs 2009).

**Success stories exist**, such as providing nurseries for fish in mangroves, reconstructing natural wetlands for water storage, restoring entire forest ecosystems after centuries of overuse and reintroducing valuable species e.g. sturgeon in the Baltic Sea for replenishing fisheries. As catastrophic destruction of the world's coral reefs accelerates, effective restoration techniques are at last being developed (Normile 2009). Over the last thirty years, considerable progress has been made in our know-how both in fundamental (Falk et al. 2006) and practical realms (Clewell and Aronson 2007). Ways and means to integrate restoration into society's search for global sustainability are moving forward quickly (Aronson et al. 2007; Goldstein et al. 2008; Jackson and Hobbs 2009).

Box 9.1 shows how the concept and focus of restoration has been gradually broadened in recent years to encompass natural capital in order to better integrate ecological, environmental, social and economic goals and priorities.

Depending on an ecosystem's level of degradation, **different strategies can be applied** to improve its state and to enhance or increase its capacity to provide services in the future. Box 9.2 illustrates a conceptual framework for decision-making on restoration within the broader context of integrated ecosystem management at the landscape scale.

**Box 9.1: Key definitions and the expanding focus of restoration**

**Ecological restoration** is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" and is "intended to repair ecosystems with respect to their health, integrity, and self-sustainability" (International Primer on Ecological Restoration, published by the Society for Ecological Restoration (SER) International Science and Policy Working Group 2004). In a broader context, the ultimate goal of ecological restoration, according to the SER Primer, is to recover resilient ecosystems that are not only self-sustaining with respect to structure, species composition and functionality but also integrated into larger landscapes and congenial to 'low impact' human activities.

The concept of **restoring natural capital** is broader still.

**'Natural capital'** refers to the components of nature that can be linked directly or indirectly with human welfare. In addition to traditional natural resources such as timber, water, and energy and mineral reserves, it also includes biodiversity, endangered species and the ecosystems which perform ecological services. According to the Millennium Ecosystem Assessment (MA 2003), natural capital is one of four types of capital that also include manufactured capital (machines, tools, buildings, and infrastructure), human capital (mental and physical health, education, motivation and work skills) and social capital (stocks of social trust, norms and networks that people can draw upon to solve common problems and create social cohesion). For further details, see TEEB D0 forthcoming, Chapter 1 and glossary.

Restoring renewable and cultivated natural capital (Restoring Natural Capital – RNC) includes ***"any activity that integrates investment in and replenishment of natural capital stocks to improve the flows of ecosystem goods and services, while enhancing all aspects of human wellbeing"*** (Aronson et al. 2007). Like ecological restoration, RNC aims to improve the health, integrity and self-sustainability of ecosystems for all living organisms. However, it also focuses on defining and maximising the value and effort of ecological restoration for the benefit of people, thereby helping to mainstream it into daily social and economic activities.

RNC activities may include, but are not limited to:

- restoration and rehabilitation of terrestrial and aquatic ecosystems;
- ecologically sound improvements to arable lands and other lands or wetlands that are managed for useful purposes i.e. cultivated ecosystems;
- improvements in the ecologically sustainable utilisation of biological resources on land and at sea; and
- establishment or enhancement of socio-economic activities and behaviour that incorporate knowledge, awareness, conservation and sustainable management of natural capital into daily activities.

In sum, RNC focuses on achieving both the replenishment of natural capital stocks and the improvement in human welfare, all at the landscape or regional scale.

*Source: Aronson et al. 2007*

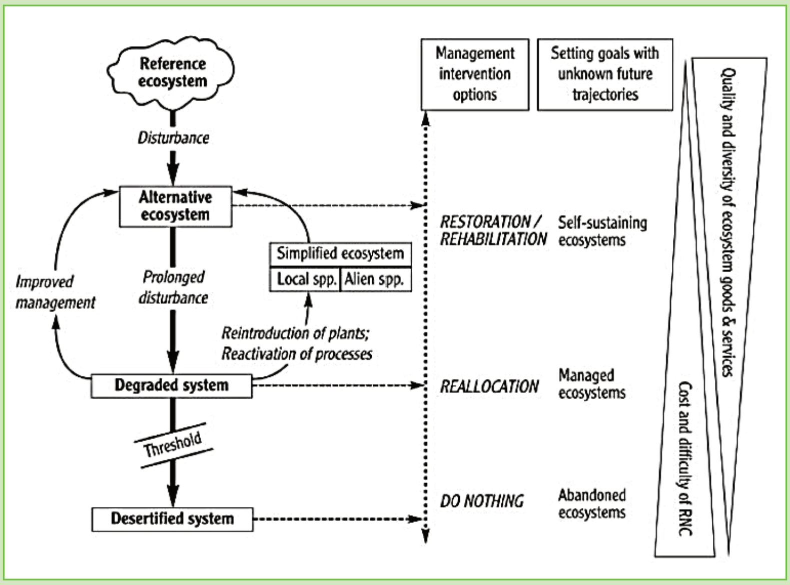
**Box 9.2: An ecosystem-based framework for determining restoration strategies**

Where the spatial scale of **damage is small** and the surrounding environment is healthy in terms of species composition and function, it may be sufficient to implement **measures for 'passive restoration'** so that the ecosystem can regenerate itself to a condition resembling its pre-degradation state in terms of their "health, integrity, and self-sustainability", as per the SER (2004) definition of restoration. This of course requires a series of decisions and trade-offs and thus is ultimately not a passive process at all. If self-regeneration is not possible in a reasonable time period, **active interventions** may be necessary to 'jump-start' and accelerate the restoration process (e.g. by bringing in seeds, planting trees, removing polluted soil or reintroducing keystone species).

In both the above cases, reduction, modification and/or rationalisation of human uses and pressures can lead to full or at least partial recovery of resilient, species-rich ecosystems that provide a reliable flow of ecosystem services valued by people. In both cases it is important to clarify objectives and priorities ahead of time (Society for Ecological Restoration International Science and Policy Working Group 2004; Clewell and Aronson 2006 and 2007).

**If transformation is severe** and ecosystems have crossed one or more thresholds of irreversibility (Aronson et al. 1993), **ecological rehabilitation** may be a more realistic and adequate alternative. This aims to repair some ecosystem processes at a site and help recover the flow of certain ecological services, but not to fully reproduce pre-disturbance conditions or species composition. It is typically done on post-mining sites as well as grazing lands (Milton et al. 2003) and in wetlands used by people for production (see example in Box 9.4).

Where **profound and extensive transformations** of ecosystem structure and composition have taken place, it may be advisable to implement measures for **reallocation of the most degraded areas**. This means assigning them a new – usually economic – main function which is generally unrelated to the functioning of the original ecosystem e.g. farmland reallocated to housing and road construction.




*Source: Aronson et al. 2007*

**Conceptual framework for restoration**

As part of a holistic planning approach, all three interventions can – and generally should be – undertaken simultaneously within appropriate landscape units. This type of landscape or regional scale programme, if conceived and carried out effectively in close collaboration with all stakeholders, can provide the much-needed bridge between biodiversity conservation objectives and local, regional or national economic development needs (Aronson et al. 2006 and 2007).

**The timescale required for ecosystem restoration varies considerably** (see Table 9.1). As noted, full restoration is not feasible for many ecosystems destroyed or degraded beyond a certain point. Even the more realistic goal of rehabilitation (recovery to an acceptable state of ecosystem resilience and performance) tends to be a slow process though recovery may be quick in some instances (Jones and Schmitz 2009). This means that the full benefits from restoration or rehabilitation may only become obvious at some time in the future, which reinforces the need to protect functioning ecosystems to maintain current levels of biodiversity and flows of ecosystem goods and services.

However, the flow of some goods and services may increase from the early stages of a restoration programme (Rey-Benayas et al. 2009), even if the optimum is only reached much later. Detailed information remains

**Table 9.1: Feasibility and time-scales of restoring: examples from Europe**

| Ecosystem type | Time-scale | Notes |
|---|---|---|
| Temporary pools | 1-5 years | Even when rehabilitated, may never support all pre-existing organisms. |
| Eutrophic ponds | 1-5 years | Rehabilitation possible provided adequate water supply. Readily colonised by water beetles and dragonflies but fauna restricted to those with limited specialisations. |
| Mudflats | 1-10 years | Restoration dependent upon position in tidal frame and sediment supply. Ecosystem services: flood regulation, sedimentation. |
| Eutrophic grasslands | 1-20 years | Dependent upon availability of propagules. Ecosystem services: carbon sequestration, erosion regulation and grazing for domestic livestock and other animals. |
| Reedbeds | 10-100 years | Will readily develop under appropriate hydrological conditions. Ecosystem services: stabilisation of sedimentation, hydrological processes. |
| Saltmarshes | 10-100 years | Dependent upon availability of propagules, position in tidal frame and sediment supply. Ecosystem services: coastal protection, flood control. |
| Oligotrophic grasslands | 20-100 years + | Dependent upon availability of propagules and limitation of nutrient input. Ecosystem services: carbon sequestration, erosion regulation. |
| Chalk grasslands | 50-100 years + | Dependent upon availability of propagules and limitation of nutrient input. Ecosystem services: carbon sequestration, erosion regulation. |
| Yellow dunes | 50-100 years + | Dependent upon sediment supply and availability of propagules. More likely to be restored than re-created. Main ecosystem service: coastal protection. |
| Heathlands | 50-100 years + | Dependent upon nutrient loading, soil structure and availability of propagules. No certainty that vertebrate and invertebrate assemblages will arrive without assistance. More likely to be restored than re-created. Main ecosystem services: carbon sequestration, recreation. |
| Grey dunes and dune slacks | 100-500 years | Potentially restorable, but in long time frames and depending on intensity of disturbance Main ecosystem service: coastal protection, water purification. |
| Ancient woodlands | 500 – 2000 years | No certainty of success if ecosystem function is sought – dependent upon soil chemistry and mycology plus availability of propagules. Restoration is possibility for plant assemblages and ecosystem services (water regulation, carbon sequestration, erosion control) but questionable for rarer invertebrates. |
| Blanket/Raised bogs | 1,000 – 5,000 years | Probably impossible to restore quickly but will gradually reform themselves over millennia if given the chance. Main ecosystem service: carbon sequestration. |
| Limestone pavements | 10,000 years | Impossible to restore quickly but will reform over many millennia if a glaciation occurs. |

*Source: based on Morris and Barham 2007* scarce but recent reviews show clearly that when done well, restoration across a wide range of ecosystem types can achieve enhancement of services even if full recovery is rarely possible (Rey-Beneyas et al. 2009; Palmer and Filoso 2009). The modern approach for ecological restoration and RNC is therefore pragmatic. Jackson and Hobbs (2009) state, for example, that "restoration efforts might aim for mosaics of historic and engineered ecosystems, ensuring that if some ecosystems collapse, other functioning ecosystems will remain to build on. In the meantime, we can continue to develop an understanding of how novel and engineered ecosystems function, what goods and services they provide, how they respond to various perturbations, and the range of environmental circumstances in which they are sustainable".

In summary, many restoration processes take considerable time but can often have rapid effects with respect to at least partial recovery of some key functions. From an ecological perspective, a strategy to avoid damage and maintain ecosystem functions and services should be preferred. However, given the scale of current damage, **ecological restoration is increasingly required** and understood to play an important role in bridging conservation and socio-economic goals, linked to better appreciation of the values of natural capital (see Aronson et al. 2007; Goldstein et al. 2008; Rey-Benayas et al. 2009). Its crucial role is further illustrated by the fact that billions of dollars are currently being spent on restoration around the world (Enserink 1999; Zhang et al. 2000; Doyle and Drew 2007; Stone 2009).

## 9.1.2. POTENTIAL COSTS OF ECOSYSTEM RESTORATION

Thousands of projects are carried out each year to improve the ecological status of damaged ecosystems. Unfortunately and surprisingly, cost-benefit analyses of those projects are scarce. Even simple records of restoration costs are rare in the peer-reviewed literature, let alone a full discussion of the benefits to society (Aronson et al. in press). Over 20,000 case studies and peer-reviewed papers were reviewed for this chapter (and for Chapter 7 in TEEB D0 forthcoming) yet only 96 studies were found to provide meaningful cost data on restoration.

The breadth and quality of information available, however, varies from study to study: Some only provide aggregate costs, others only capital or only labour costs. Some restoration activities are conducted on a small scale for research An analysis of the studies gives an overview of restoration project costs and outcomes. They cover a wide range of different efforts in different ecosystem types as well as very different costs, ranging between several hundreds to thousands of dollars per hectare (grasslands, rangelands and forests) to several tens of thousands (inland waters) to millions of dollars per hectare (coral reefs) (see Figure 9.2). Costs also vary as a function of the degree of degradation, the goals and specific circumstances in which restoration is carried out and the methods used.

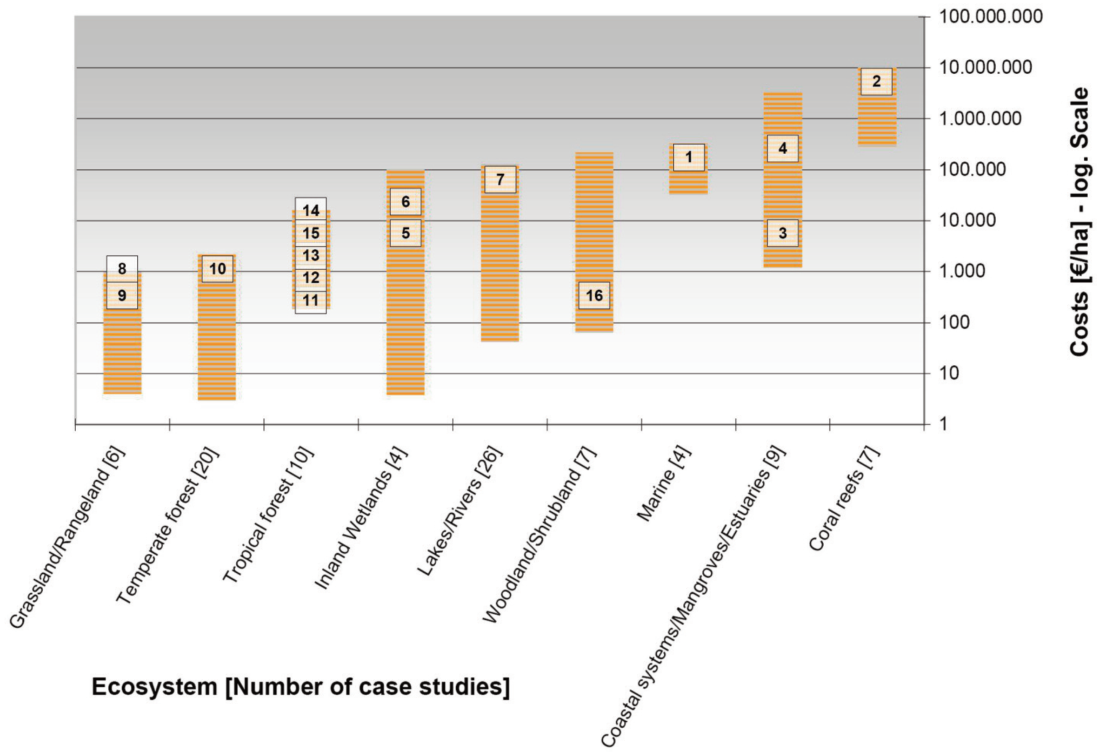
One way to decide whether investments are worthwhile from an economic perspective is to **compare the costs of services provided by ecosystems with those of technically-supplied services**. The most famous example of this type of cost-effectiveness estimation is New York City's decision to protect and restore the Catskill-Delaware Watershed (see Box 9.3).

Cost effectiveness analysis often focuses only on one particular ecosystem service e.g. in the example discussed in Box 9.3, watershed protection and restoration costs were more than compensated by the single service of water purification. However, investing in natural capital enhancement becomes even more economically attractive if the **multitude of services** that healthy ecosystems provide is also taken into account (e.g. climate regulation, food and fibre provision, hazard regulation). This calls for **identification and valuation of the broad range of benefits of natural capital investment in order to adequately compare costs and benefits of ecosystem restoration approaches**.

## 9.1.3. COMPARING COSTS AND BENEFITS OF ECOSYSTEM RESTORATION

As noted above, few studies analysing the costs of restoration were found and even fewer provided values or detailed analysis of the achieved or projected benefits. This section uses the findings of two studies on benefits

**Figure 9.2: Summary of cost ranges of restoration efforts**




*Bars represent the range of observed costs in a set of 96 studies. The specific studies identified and listed in the annex serve as illustrative examples of the studies in which cost data has been reported in sufficient detail to allow analysis and reflection.*

*Sources for examples given (for detailed list, see Annex to this Chapter):*

*[1] Eelgrass restoration in harbour, Leschen 2007*
*[2] Restoration of coral reefs in South East Asia, Fox et al. 2005*
*[3] Restoration of mangroves, Port Everglades, USA, Lewis Environmental Services, 2007*
*[4] Restoration of the Bolsa Chica Estuary, California, USA, Francher 2008*
*[5] Restoration of freshwater wetlands in Denmark, Hoffmann 2007*
*[6] Control for phosphorus loads in storm water treatment wetlands, Juston and DeBusk, 2006*
*[7] Restoration of the Skjern River, Denmark, Anon 2007a*
*[8] Re-establishment of eucalyptus plantation, Australia, Dorrough and Moxham 2005*
*[9] Restoring land for bumblebees, UK, Pywell et al. 2006*
*[10] Restoration in Coastal British Columbia Riparian Forest, Canada, Anon 2007b*
*[11] Masoala Corridors Restoration, Masoala National Park, Madagascar, Holloway et al. 2009*
*[12] Restoration of Rainforest Corridors, Madagascar, Holloway and Tingle 2009*
*[13] Polylepis forest restoration, tropical Andes, Peru, Jameson and Ramsey 2007*
*[14] Restoration of old-fields, NSW, Australia, Neilan et al. 2006*
*[15] Restoration of Atlantic Forest, Brazil, Instituto Terra 2007*
*[16] Working for Water, South Africa, Turpie et al. 2008*

and costs of mangrove restoration as an illustrative example followed by a synthesis of findings across a range of studies.

Following the 2004 tsunami disaster, there is now considerable interest in rehabilitating and **restoring 'post-shrimp farming' mangroves** in Southern Thailand as natural barriers to future coastal storm events (see also 9.4.1). Yields from commercial shrimp farming sharply decline after five years, after which shrimp farmers usually give up their ponds to find a new location. One study found that the abandoned mangrove ecosystems can be rehabilitated at a cost of US$ 8,240 per hectare in the first year (replanting mangroves) followed by annual costs of US$ 118 per hectare for maintenance and protecting of seedlings (Sathirathai and Barbier 2001: 119). Benefits from the restoration project comprise the estimated net income from collected forest products of US$ 101 per hectare/year, estimated benefits from habitat-fishery linkages (mainly the functioning of mangroves as fish nursery) worth US$ 171 per hectare/year and estimated benefits from storm protection worth US$ 1,879 per hectare/year (Barbier 2007: 211).

In order to compare costs and benefits of restoration, it has to be recognised that rehabilitating mangroves and the associated ecosystem services will take time and may never reach pre-degradation levels. Therefore the benefits are accounted for on a gradual basis, starting at 10% in the second year and then increasing them every year until they were eventually capped in the sixth year at 80% of pre-degradation levels. Applying these assumptions and a 10% discount rate, the rehabilitation project would pay off after thirteen years. If lower discount rates – as argued for in TEEB D0, Chapter 6 – are applied, the cost-benefit ratio of the restoration project improves. At a discount rate of 1%, the project would pay off after nine years. If one extends the calculation to 40 years, the project generates a **benefit/cost ratio of 4.3 and a social rate of return**[1] **of 16%**. It should be noted that these calculations still do not account for the wide range of other ecosystem services that may be attached to the presence of mangroves, ranging from microclimate effects and water purification to recreational values.

**Box 9.3: Cost effectiveness of protection over engineered solutions: example of a US watershed**

*"It represents a commitment among all of the parties – the city, state and federal government – to focus on the challenges of protecting the source water supply rather than pursue a costly and gargantuan construction project."*

Eric A. Goldstein, senior lawyer for the Natural Resources Defense Council

Even in industrialised countries, such as the USA, restoration of watersheds is an increasingly attractive alternative. The decision summarised below sustainably increased the supply of drinking water and saved several billion dollars that would have otherwise have been spent on engineering solutions (Elliman and Berry 2007). A similar project is underway on the Sacramento River basin in northern California (Langridge et al. 2007).

About 90% of the more than one billion gallons used daily in New York City comes from huge reservoirs in the adjacent Catskill and Delaware watersheds, located approximately 120 miles north of the city. The remaining 10% are drawn from the nearer Croton reservoirs in Westchester County (these are surrounded by development and thus have to be filtered). A US$ 2.8 billion filtration plant for the Croton water supply is under construction in the Bronx and is scheduled to be operational by 2012.

In April 2007, after a detailed review lasting several years, the US federal Environment Protection Agency concluded that New York's Catskill and Delaware water supplies were still so clean that they did not need to be filtered for another decade or longer and extended the City's current exemption from filtration requirements. This means that at least until 2017, the City will not have to spend approximately US$ 10 billion to build an additional filtration plant that would cost hundreds of millions of dollars a year to operate.

In return for this extended exemption, the City agreed to set aside US$ 300 million per year until 2017 to acquire upstate land to restrain development causing runoff and pollution. It will purchase land outright or work with non-profit land trusts to acquire easements that would keep land in private hands but prohibit their development (see Chapter 5.4). The City also committed itself to reduce the amount of turbidity (cloudiness) in certain Catskill reservoirs by erecting screens, building baffles and using other technology to allow sediment to settle before water enters the final parts of the drinking water system.

*Sources: New York Times 2007 April 13th; Elliman and Berry 2007; Langridge et al. 2007*

The example mentioned above is one of the few cases where decisions can be taken on a solid data base. For cases in other biomes where only cost data was available, the TEEB team **estimated potential benefits based on a 'benefits transfer' approach**, i.e. taking results from valuation studies in similar ecosystems as a basis for estimating potential benefits for the biomes concerned. The estimation of benefit values was based on the results of 104 studies with 507 values covering up to 22 different ecosystem services for 9 major biomes. These documented values were the basis to estimate the benefit of a restored or rehabilitated ecosystem. Recognizing that projects take time to restore flows of benefits, an appropriate accreting profile was modelled for annual benefits, growing initially and then stabilising at 80% of undisturbed ecosystem benefits (see TEEB D0, Chapter 7 forthcoming). This approach makes it possible to carry out an illustrative comparison. Clearly, careful site specific analysis of costs and benefits is required before any investment decision: therefore the example listed below should be seen as indicating the scope for potential benefits.

When calculating the potential benefits for the biome in question, we found **high potential internal rates of return for all biomes**. These calculations are rough first estimates for two reasons: they do not include opportunity costs of alternative land use (which can be expected to be rather low in many degraded systems) and the value base on which the benefit transfer is based is small for some of the services considered. A detailed analysis is therefore recommended before investing in restoration. Nevertheless, these values indicate that in many situations high returns can be expected from restoration of ecosystems and their services.

For example, a study by Dorrough and Moxham (2005) found that cost for **restoring eucalyptus woodlands and dry forests** on land used for intensive cattle farming in southeast Australia would range from € 285 per hectare for passive restoration to € 970 per hectare for active restoration. Restoration of tree cover yields numerous benefits including i) reversing the loss of biodiversity, ii) halting land degradation due to dryland salinisation and thereby iii) increasing land productivity. Using a benefit transfer approach and a discount rate of 1% over 40 years these services may constitute a NPV of more than € 13,000 per ha (D0 Chapter 7 forthcoming).

Along the Mata Atlantica in Brazil a non-profit organization named Instituto Terra undertakes active **restoration of degraded stands of Atlantic Forest** by establishing tree nurseries to replant denuded areas (Instituto Terra 2007). The costs for this approach are estimated at € 2,600 per hectare as one off investment. Benefits include biodiversity enhancement, water regulation, carbon storage and sequestration as well as preventing soil erosion. Using the benefit transfer approach a 40 years NPV of tropical forests may reach € 80,000 per hectare (1% discount rate).

In South Africa the government-funded Working for Water (WfW) (see also Box 9.6) programme clears mountain catchments and riparian zones of invasive alien plants in order to restore natural fire regimes, the productive potential of land, biodiversity, and hydrological functioning. WfW introduces a special kind Payment for Ecosystem Services (PES) scheme (for PES see Chapter 5): previously unemployed individuals tender for contracts to restore public or private lands. By using this approach costs to **rehabilitate catchments** range from € 200 to € 700 per hectare (Turpie et al. 2008) while benefits may reach a 40 year NPV of € 47,000 per hectare (using the benefit transfer approach described above and a 1% discount rate).

As the above-mentioned case studies and benefits transfer analysis show, **restoration can pay**. However, the costs are also quite high and many ecosystems cannot be effectively restored within reasonable timescales (see Table 9.1). For these reasons, it is much better to conserve these ecosystems rather than letting them degrade and then trying to undertake restoration. Moreover, systematic estimation of the potential costs and economic benefits of preservation and restoration needs to be better incorporated into the projects themselves. **Valuation of ecosystem services** can help, by enabling policy makers to decide which investments are worthwhile from an economic point of view and to make informed choices (TEEB D0 forthcoming), especially as many ecosystems currently have unrecognised economic and social benefits (Milton et al. 2003; FAO 2004; Bullock et al. 2007; de Groot et al. 2007; Blignaut et al. 2008; Blignaut and Aronson 2008).

## 9.1.4. AN INDISPENSABLE ROLE FOR GOVERNMENTS

In spite of the potentially high internal rates of return, investment in natural capital seems to be a story of unrealised potential. One important reason is that the benefits of such investments often lie far in the future or accrue over long periods of time. This means that, with some exceptions, **private investment is unlikely to occur unless this is supported or required by governments**. Governments can provide incentives for this purpose by paying for or subsidising private activities such as reforestation (see Chapters 5 and 6) and/or prescribe mandatory offsets to mitigate ecosystem disturbance caused by human interventions (see Chapter 7).

There are several key reasons why governments should consider also **directly investing public funds in natural capital** and its restoration. The first relates to large-scale and complex interrelated ecosystems, where the costs of restoration can be very high due to the size of the restoration site, the level of degradation and/or uncertainties about the technical efforts needed e.g. potentially contaminated brownfields, mining areas or other heavily degraded areas. An interesting example in this regard is the Aral Sea (Box 9.4) which has suffered from catastrophic environmental damage.

Typically, large scale and complex restoration projects involve **costs that exceed the benefits identified by private parties - even though the public benefits of restoration are likely to be higher**. It may therefore be worthwhile only for governments to invest in such efforts, although opportunities to develop public-private restoration partnerships need to be considered. To ensure the success and replicability of such projects, investments in restoration should include a multidisciplinary research component.

The second justification for direct government investment relates to situations where **early action is likely to be the most cost-effective approach**. Here policy makers need to understand the close relationship between prevention and response. Upfront precautionary measures to avoid damage are the best way to minimise long-term socio-economic and environmental costs (see example of invasive species in Box 9.5).

Government investment may also be called for in situations where potential beneficiaries are unable to afford restoration costs. Box 9.6 illustrates how livelihoods can be improved alongside with degraded ecosystems.

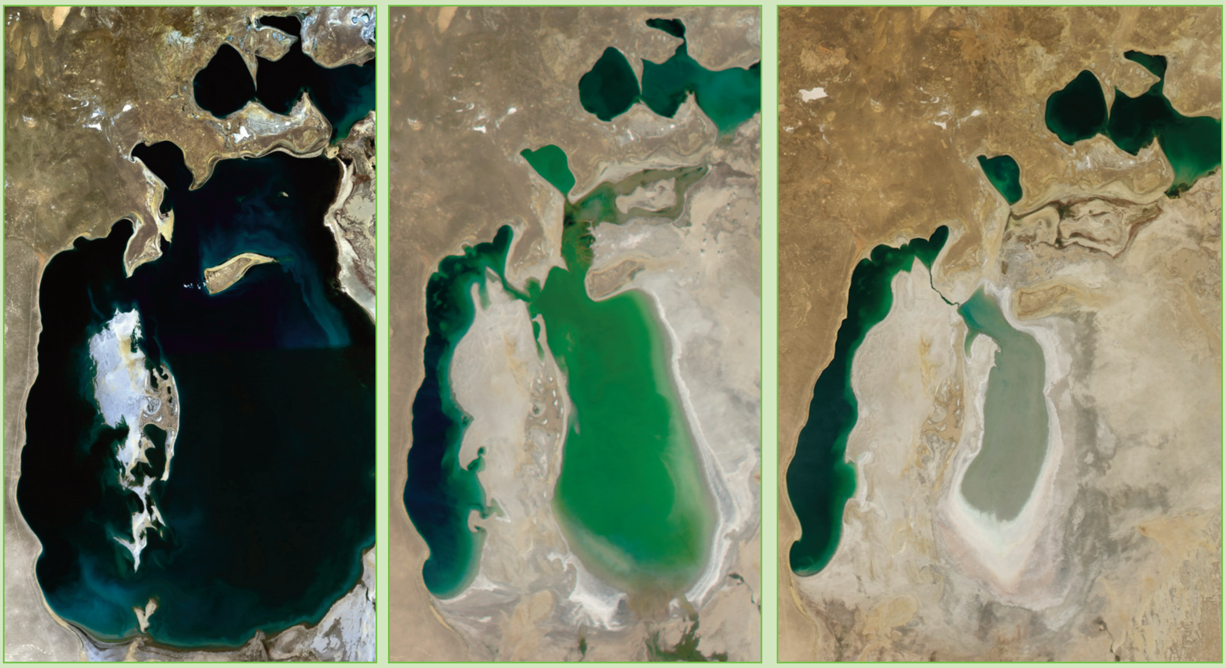
Innovative and integrated regional or landscape scale programmes to restore or rehabilitate degraded natural systems can make use of instruments such as payments for ecosystems services (PES) (Blignaut et al. 2008; see further Chapter 5 on the Clean Development Mechanism (CDM) and the proposed REDD mechanism for Reducing Emissions from Deforestation and Forest Degradation). In Ecuador, two PES-funded restoration programmes include the six-year old Pimampiro municipal watershed protection scheme and the 13-year old PROFAFOR carbon-sequestration programme (Wunder and Albán 2008). 'Pimampiro' is mostly about forest conservation, but it has also achieved some abandonment of marginal lands that have grown back into old fallows, enrolled in the scheme. PROFAFOR is a voluntary programme on afforestation and reforestation mainly on degraded lands that sought and got carbon credit certification. Many more are under way elsewhere in Latin America, Asia and, with some lag time, Africa and Madagascar. Countries making significant strides in this area include Costa Rica (Janzen 2002; Morse 2009), Indonesia (Pattanayak 2004; Pattanayak and Wendland 2007) and South Africa (Holmes et al. 2007; Mills et al. 2007; Blignaut and Loxton 2007; Turpie et al. 2008; Koenig 2009).

In summary, there is growing evidence of a positive correlation between investment and benefits from ecological restoration, both in terms of biodiversity and ecosystem services (Rey-Benayas et al. 2009). However, the funds available are far less than what is needed. It is critical to plan and budget investments at the landscape and regional scales so as to maximise returns on investments in ecological, social and economic terms.

**Box 9.4: A natural capital 'mega-project': example of the Aral Sea restoration**

Fifty years ago, the Aral Sea was the world's fourth largest freshwater lake and supported a large and vibrant economy based on fisheries, agriculture and trade in goods and services. In the 1960s, however, the two main rivers flowing into the Aral Sea were massively diverted for cotton cultivation and the Sea began to shrink and to split into smaller pieces – the 'Northern Aral' and 'Southern Aral' seas. Although large amounts of cotton were grown and exported in subsequent decades, thousands of jobs were lost in other sectors, the surrounding environment was severely degraded and the health of local people deteriorated. By 1996, the Aral Sea's surface area was half its original size and its volume had been reduced by 75%. The southern part had further split into eastern and western lobes, reducing much of the former sea to a salt pan.

*Images of the Aral Sea: 1989 (left) and 2003 (middle) and 2009 (right)*
*Source: NASA Earth Observatory. URL: http://earthobservatory.nasa.gov/IOTD/view.php?id=9036*



Against this background, neighbouring countries made several approaches to restore the Aral Sea. In 2005, Kazakhstan built the Kok-Aral Dam between the lake's northern and southern portions to preserve water levels in the north. The Northern Aral actually exceeded expectations with the speed of its recovery, but the dam ended prospects for a recovery of the Southern Aral. According to Badescu and Schuiling (2009), there are now three main restoration options: (1) halting cotton production and letting the waters of the two feed rivers (Amu Darya and Syr Darya) flow naturally into the Aral Sea; (2) diverting waters from the Ob and other major Siberian rivers to the Aral Sea; and (3) building a new inter-basin water supply canal, including a long tunnel from Lake Zaisan to the Balkhash Lake. All three options involve very high costs and there are considerable uncertainties about the ultimate restoration benefits.

To further illustrate the scale and complexity of the problem and its possible solutions, the implications for climate regulation also need to be considered. The discharge of major Siberian rivers into the Arctic Ocean appears to be increasing which could affect the global oceanic 'conveyor belt', with potentially severe consequences for the climate in Western and Northern Europe. By diverting part of this river water towards the Aral Sea, a restoration project may have potential beneficial effects on climate, human health, fishery and ecology in general (Badescu and Schuiling 2009).

*Sources: Micklin and Aladin 2008; Badescu and Schuiling 2009; World Bank 2009a*

## Box 9.5: The economic case for government-led rapid response to invasive species

Invasive species are widely recognised to be one of the major threats to biodiversity and ecosystem functioning (Vitousek et al. 1997; Mack et al. 2000; van der Wal et al. 2008). Several economic studies estimate the scale of damage and management costs they impose on society (e.g. van Wilgen 2001; Turpie 2004; Turpie et al. 2008). A well-known assessment of environmental and economic costs in the US, UK, Australia, South Africa, India and Brazil carried out in 2001 and updated in 2005 (Pimentel et al. 2001, Pimentel et al. 2005) estimated costs of invasive species across these six countries at over US$ 314 billion/year (equivalent to US$ 240 per capita). Assuming similar costs worldwide, Pimentel estimated that invasive species damage would cost more than US$ 1.4 trillion per year, representing nearly 5% of world GDP. A recent review by Kettunen et al. (2009) suggests that damage and control costs of invasive alien species in Europe are at least € 12 billion per year. The following table 9.2 shows some examples of the costs of single invasive species in European countries (Vilà et al. 2009).

### Table 9.2: Alien species in Europe generating high costs

| *Species* | *Biome/taxa* | *Country* | *Extent* | *Cost item* | *Period* | *Cost (million €year$^{-1}$)* | *Reference* |
|---|---|---|---|---|---|---|---|
| *Carpobrotus* spp | Terrestrial plant | Spain | Localities | Control/eradication | 2002–2007 | 0.58 | Andreu *et al.* (in press) |
| *Anoplophora chinensis* | Terrestrial invertebrate | Italy | Country | Control | 2004–2008 | 0.53 | Van der Gaag (2007) |
| *Cervus nippon* | Terrestrial vertebrate | Scotland | Localities | Control | | 0.82 | White and Harris (2002) |
| *Myocastor coypus* | Terrestrial vertebrate | Italy | Localities | Control/damages | 1995–2000 | 2.85 | Panzacchi *et al.* 2007 |
| *Sciurus carolinensis* | Terrestrial vertebrate | UK | Country | Control | 1994–1995 | 0.46 | White and Harris (2002) |
| *Azolla filiculoides* | Freshwater plant | Spain | Protected area | Control/eradication | 2003 | 1.00 | Andreu *et al.* (in press) |
| *Eichhornia crassipes* | Freshwater plant | Spain | River basin | Control/eradication | 2005–2007 | 3.35 | Andreu *et al.* (in press) |
| *Oxyura jamaicensis* | Freshwater vertebrate | UK | Country | Eradication | 2007–2010 | 0.75 | Scalera and Zaghi (2004) |
| *Chrysochromulina polylepis* | Marine algae | Norway | Country | Toxic bloom | | 8.18 | Hopkins 2002 |
| *Rhopilema nomadica* | Marine invertebrate | Israel | Coast | Infrastructure damage | 2001 | 0.04 | Galil and Zenetos (2002) |

*Source: Vila et al. 2009*

A biological invasion is a dynamic, non-linear process and, once initiated, is largely self-perpetuating (Richardson et al. 2000; Kühn et al. 2004; Norton 2009). In the majority of cases, invasions are only reversible at high cost (Andersen et al. 2004). Introduced species may appear harmless for a long time, and only be identified as harmful after it has become difficult or impossible – and costly – to eradicate, control or contain them and to restore or rehabilitate formerly infested sites (Ricciardi and Simberloff 2008). For these reasons, prevention should always be the preferred management option where feasible, consistent with CBD provisions and guiding principles (CBD 1993; Bertram 1999; CBD 2002; Finnoff et al. 2006).

Delayed intervention increases the cost of intervention and thus the period required before the benefits potentially outweigh the costs. For example, Japanese knotweed (Fallopia japonica) is invasive in several EU Member States. It is estimated that in Wales, a three-year eradication programme would have cost about € 59 million (£ 53.3 million) if started in 2001 but around € 84 million (£ 76 million) if started in 2007 (Defra 2007).

**Box 9.6: Valuation of livelihood benefits arising from ecosystem rehabilitation in South Africa**

The Manalana wetland (near Bushbuckridge, Mpumalanga) was severely degraded by erosion that threatened to consume the entire system if left unchecked. The wetland supports about 100 small-scale farmers, 98 of whom are women. About 70% of local people make use of the wetland in some way, with about 25% depending on it as their sole source of food and income. The wetland was thus considered to offer an important safety net, particularly for the poor, contributing about 40% of locally grown food. As a result, the 'Working for Wetlands' public works programme intervened in 2006 to stabilise the erosion and improve the wetland's ability to continue providing its beneficial services.

An economic valuation study completed in 2008 revealed that:

- the value of livelihood benefits derived from the degraded wetland was just 34% of what could be achieved after investment in ecosystem rehabilitation;
- the rehabilitated wetland now contributes provisioning services conservatively estimated at € 315 per year to some 70% of local households, in an area where 50% of households survive on an income of less than € 520 per year;
- the total economic value of the livelihood benefits (€ 182,000) provided by the rehabilitated wetland is more than twice what it cost to undertake the rehabilitation works (€ 86,000), indicating a worthwhile return on investment by 'Working for Wetlands';
- the Manalana wetland acted as a safety-net that buffered households from slipping further into poverty during times of shock or stress.

*Sources: Pollard et al. 2008*

# 9.2 PROVIDING BENEFITS BEYOND THE ENVIRONMENTAL SECTOR

**Investing in natural capital does not only concern the environmental sector. Other policy sectors can also reap benefits from public investment to ensure or enhance the delivery of services provided by natural capital. Considering all benefits provided by ecosystems can make investments worthwhile whereas approaches focused on single sectors and services may not.**

A wide range of sectors – especially those dealing with natural hazard prevention, natural resource management, planning, water provision, alternative energy sources, waste management, agriculture, transport, tourism or social affairs – can gain from explicitly considering and valuing the services provided by natural capital. Investing in natural capital can thus create additional values, especially where natural capital has itself become the limiting factor to economic development (Herman Daly, quoted in Aronson et al. 2006).

## 9.2.1. BENEFITS FOR NATURAL RESOURCE MANAGEMENT

The limits of natural capital are most obvious in **natural resource management**. Fisheries, agriculture, forestry and water management directly depend on its maintenance in a healthy state. Ecological degradation (e.g. soil erosion, desertification, reduced water supply, loss of waste water filtering) impacts on productivity, livelihoods and economic opportunities (see Box 9.7).

Increased investments in natural infrastructure to harness and optimise fresh water resources can complement or replace technical infrastructure systems (Londong et al. 2003). Optimising microbial activity in rivers through re-naturalisation of river beds has been shown to improve water quality at lower costs than by clean-up through water treatment plants. Big cities like Rio de Janeiro, Johannesburg, Tokyo, Melbourne, New York and Jakarta all rely on protected areas to provide residents with drinking water, which offer a local alternative to piping water from further afield and cost less than building filtration plants (see also Box 9.3). Further examples include:

**Box 9.7: Socio-economic benefits from grassland restoration projects, South Africa**

In the Drakensberg mountains, local communities depend heavily on various ecosystem services for their livelihoods. By restoring degraded grasslands and riparian zones and changing the regimes for fire management and grazing, early results suggest that it may be possible to increase base water flows during low-flow periods (i.e. winter months when communities are the most vulnerable to not having access to any other source of water) by an additional 3.9 million $m^3$. Restoration and improved land use management should also reduce sediment load by 4.9 million $m^3$/year.

While the sale value of the water is approximately € 250,000 per year, the economic value added of the additional water is equal to € 2.5 million per year. The sediment reduction saves € 1.5 million per year in costs, while the value of the additional carbon sequestration is € 2 million per year. These benefits are a result of an investment in restoration that is estimated to cost € 3.6 million over seven years and which will have annual management costs of € 800,000 per year. The necessary ongoing catchment management will create 310 permanent jobs, while about 2.5 million person-days of work will be created during the restoration phase.

*Source: MTDP 2008*

- in Venezuela, just 18 national parks cater to the fresh water needs of 19 million people (83% of the country's population that inhabit large cities). About 20% of the country's irrigated lands depend on protected areas for their irrigation water;
- Venezuela has a potential for generating hydroelectricity equivalent to the production of 2.5 million barrels of oil per day (it currently produces 3.2 million barrels of oil per day); of course careful planning is required in order to minimise negative ecological impacts;
- in Peru, around 2.7 million people use water that originates from 16 protected areas with an estimated value of US$ 81 million/year (Pabon 2009).

Like sponges, forests soak up water and release it slowly, limiting floods when it rains and storing water for dry periods. Watershed and catchment protection near cities is therefore smart – economically, ecologically and socially (Benedict and McMahon 2008) – and as noted above, may justify payments for environmental services (see Chapter 5).

These benefits are attributable not only to protected areas but also to wider ecosystems. Sound management is needed to maintain and ensure the continuous provision of these ecosystem services. Restoration

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**Box 9.8: Multiple benefits from wetland restoration in the Everglades, Florida**

Much of the unique Everglades ecosystem, of enormous natural beauty and the region's primary source of water, was drained in the early 1900s to make way for the cities of Miami and Fort Lauderdale. The remaining wetlands (outside the 600,000 $km^2$ Everglades National Park) have suffered heavily from pollution and further drainage in the last two decades (Salt et al. 2008).

To improve the quality and secure the supply of drinking water for south Florida and protect dwindling habitat for about 69 species of endangered plants and animals (including the emblematic Florida panther of which only 120 individuals survive in the wild) the US Congress enacted the **Comprehensive Everglades Restoration Plan** (CERP) in 2000. The total cost of the 226 projects to restore the ecosystem's natural hydrological functions is estimated at close to US$ 20 billion (Polasky 2008).

The return on this investment, generally lower than the costs, relates to different areas including agricultural and urban water supply, flood control, recreation, commercial and recreational fishing and habitat protection (Milon and Hodges 2000). However, many benefits – especially as regards the cultural value of the intact ecosystem – can only be measured indirectly as there are no markets for these non-use values. For the Everglades, a study covering non-use values shows that the overall benefits are in a similar range to the costs of restoration, depending on the discount rate used (Milon and Scroggins 2002).

can help to keep ecosystems functioning at levels that can in principle be calculated and managed. Boxes 9.6 (above) and 9.8, and 9.9 (below) present some examples of costed approaches from Africa.

**Box 9.9: Reducing poverty by investing in floodplain restoration in Cameroon**

The Waza floodplain (8,000 $km^2$) is a high productivity area and critical for biodiversity. Whilst extremely important for the population, it is also very fragile with fluctuating levels of rainfall, widespread poverty and precarious living conditions. 125,000 people depend for subsistence livelihoods on services provided by this floodplain ecosystem, which in turn depends to a large extent on the annual inundation of the Logone River. In 1979, construction of a large irrigated rice scheme reduced flooding by almost 1,000 $km^2$ which had devastating effects on the region's ecology, biodiversity and human populations (UNDP-UNEP 2008).

Engineering works to reinstate the flooding regime have the potential to restore up to 90% of the floodplain area at a capital cost of approximately US$ 11 million (Loth 2004). The same study found the socio-economic effects of flood loss to be significant, incurring livelihood costs of almost US$ 50 million over the 20 years since the scheme was constructed. Local households suffer direct economic losses of more than US$ 2 million/year through reduced dry season grazing, fishing, natural resource harvesting and surface water supplies (see Table below). The affected population, mainly pastoralists, fishers and dryland farmers, represent some of the poorest and most vulnerable groups in the region.

By bringing around US$ 2.3 million dollars additional income per year to the region, the economic value of floodplain restoration, and return on investment, would be significant in development and poverty alleviation terms. The benefits of restoring the pre-disturbance flood regime will cover initial investment costs in less than 5 years. Investment in flood restoration measures was predicted to have an economic net present value of US$ 7.8 million and a benefit: cost ratio of 6.5: 1 (over a period of 25 years and using a discount rate of 10%). Ecological and hydrological restoration will thus have significant benefits for local poverty alleviation, food security and economic well-being (Loth 2004).

**Effects of land conversion in the Waza floodplain and costs and benefits of its restoration** (in US$)

| **Losses of floods to local households** | | **Measures of economic profitability** | |
|---|---|---|---|
| Pasture | US$ 1.31 mio/year | Net present value | US$ 7.76 mio |
| Fisheries | US$ 0.47 mio/year | Benefit: cost ratio | 6.5 : 1 |
| Agriculture | US$ 0.32 mio/year | Payback period | 5 years |
| Grass | US$ 0.29 mio/year | | |
| Surface water supply | US$ 0.02 mio/year | **Costs and benefits of flood restoration** | |
| Total | US$ 2.40 mio/year | Capital costs | US$ 11.26 mio |
| **Physical effects of flood restoration** | | Net livelihood benefits | US$ 2.32 mio/year |
| Additional flow | 215 $m^3$/sec | | |
| Flood recovery | 90 percent | | |

*Sources: UNDP-UNEP 2008; Loth 2004*

## 9.2.2 BENEFITS FOR NATURAL HAZARD PREVENTION

The damage potential of storms for coastal areas, floods from rivers and landslides can be considerably reduced by a combination of careful land use planning and maintenance or restoration of ecosystems to enhance buffering capacity. In Vietnam, for example, mangrove re-planting by volunteers cost US$ 1.1 million but saved US$ 7.3 million annual expenditure on dyke maintenance and benefited the livelihoods of an estimated 7,500 families in terms of planting and protection (IFRC 2002). The reduction of the impact of cyclones was also one of the main reasons for Bangladesh to invest in their coastal green belt. Since 1994 a continuous effort is done to implement forestry along the belt. The program with the overall scope of US$ 23.4 million also helps local farmers to use the newly accreted areas in a sustainable way (Iftkehar and Islam 2004; ADB 2005).

The success of this type of project is closely linked to integrated planning and implementation. A huge amount of money was wasted in the Philippines when two decades of replanting of mangroves, including very intensive post-tsunami replanting, were not based on sound science (see Box 9.10).

**Box 9.10: Restoration failures: an example from coastal protection in the Philippines**

Over the past century, the islands that make up the Philippines have lost nearly three-quarters of their mangrove forests. These provide key habitats for fish and shellfish but were routinely cleared for development and fish farming ponds. To reverse the trend, conservation groups started replanting projects across the archipelago two decades ago, planting 44,000 hectares with hundreds of millions of mangrove seedlings.

In practice, one of the world's most intensive programmes to restore coastal mangrove forests has produced poor results, largely because trees were planted in the wrong places. A survey of 70 restoration sites in the archipelago (Samson and Rollon 2008) found mostly dead, dying or "dismally stunted" trees because seedlings were planted in mudflats, sandflats or sea-grass meadows that could not support the trees. Some of these areas have inadequate nutrients; in other places, strong winds and currents batter the seedlings. Ironically, the failed restoration effort may sometimes have disturbed and damaged otherwise healthy coastal ecosystems, thus entailing a double ecological and economic cost.

To get mangrove restoration back on track, Samson and Rollon (2008) suggest that planters need better guidance on where to place the seedlings and that the government needs to make it easier to convert abandoned or unproductive fish ponds back to mangrove swamps. However, the study recognises that this is a thorny legal and political issue as landowners are reluctant to consider the 'voluntary surrender' of potentially valuable shorefront back to nature.

*Sources: Malakoff 2008; Samson and Rollon 2008*

Letting ecosystems degrade can exacerbate the devastating impact of natural disasters. Many cases have shown that deforestation, destruction of mangroves and coral reefs or wetland drainage have significantly increased the vulnerability of regions to natural hazards and the level of damage caused (Harakunarak and Aksornkoae 2005; Barbier 2007).

Haiti is a tragic example of this. Following steady forest degradation for firewood over many decades, Hurricane Jeanne in 2004 caused 1800 deaths in Haiti, mainly by mudslides from deforested slopes. On the other side of the island, in the Dominican Republic, which was equally hard hit by Hurricane Jeanne, very few deaths were reported (IUCN 2006; see also Chapter 3, Box 3.5).

## 9.2.3. BENEFITS FOR HUMAN HEALTH

Healthy ecosystems are recognised as essential for maintaining human health and well-being (see the summary report of the Millennium Ecosystem Assessment: WHO 2006). Yet around the world, collapsing ecosystems pose increasing risks for human health (Rapport et al. 1998).

The spread of many infectious diseases can be accelerated by converting natural systems into intensively used ones (e.g. following deforestation or agricultural development: see Box 9.11) and the concurrent spread of invasive harmful species (Molyneux et al. 2008). The management of watersheds and water borne diseases are interlinked as shown for example in watershed-level analyses in South East Asia (Pattanayak and Wendland 2007). Deforestation creates new edges and interfaces between human populations and facilitates population growth in animal reservoir hosts of major insect vector groups, creating opportunities for several serious diseases like leishmaniosis and yellow fever to spread (Molyneux et al. 2008). The destruction of forest habitat can also result in common vector species being replaced by more effective disease vectors e.g. where one Anopheles species replaces a more benign native mosquito. This has occurred following deforestation in some parts of Southeast Asia and Amazonia (Walsh et al. 1993).

Negative impacts of ecosystem change and degradation on human health can also occur much more directly. For example, the degradation of agricultural areas can lead to decreased harvests and thus contribute to malnutrition in many areas of the world (Hillel and Rosenzweig 2008; IAASTD 2008). In addition, livestock and game form a key link in a chain of disease transmission from animal reservoirs to humans - as recently seen in the bird flu pandemic outbreak.

For these reasons, the degradation of ecosystems also directly compromises efforts to achieve several Millennium Development Goals (WHO 2006; UNDP-UNEP Poverty-Environment-Initiative 2008). There is consequently an urgent need to further explore the relationships between healthy ecosystems and human health in order to better incorporate these considerations into ecosystem and landscape management and restoration planning (WHO 2006; Crowl et al. 2008).

**Box 9.11: Dams, irrigation and the spread of schistosomiasis in Senegal**

In the 1980s, the Diama Dam on the Senegal River was constructed to prevent intrusion of salt water into the river during the dry season. While it succeeded in reducing salinity, it also dramatically altered the region's ecology. One organism that made its appearance and prospered after the dam was built was the snail *Biomphalaria pfeifferi,* an important intermediate host for *Schistosoma mansoni*, which is the parasite that causes intestinal *schistosomiasis*. *Bulinus globosus*, the main snail species that B. *pfeifferi* replaced in many areas around the river, is not a S. *mansoni* host.

Previously unknown to the region, *S. mansoni* quickly spread in the human population. By the end of 1989, almost 2000 people were tested positive for *S. mansoni*. By August 1990, 60 % of the 50,000 inhabitants of the nearby town of Richard-Toll were infected.

Since 1990, schistosomiasis has continued to spread in the Senegal River basin upstream from the Diama Dam. This provides a cautionary tale about the potential effects of dam construction and human-caused changes of ecosystems on the spread of vector-borne diseases and illustrates the complexity of human-ecosystem interactions.

*Source: adapted from Molyneux et al. 2008*

# 9.3 INVESTING IN ECOSYSTEMS FOR CLIMATE CHANGE ADAPTATION

***"We cannot solve biodiversity loss without addressing climate change and vice versa. We therefore need to look for the 'triple win' of biodiversity that can actively contribute to climate mitigation and adaptation."***

Message from Athens on the Future of Biodiversity Policies
European Commission Conference on Biodiversity
(Athens, April 2009)

**Protecting biodiversity and ecosystems - and using them sustainably in the case of culturally modified systems - is the best way to preserve and enhance their resilience and one of the most cost-effective defences against the adverse impacts of climate change. An ecosystem-based approach to adaptation is crucial to ensure ecosystem services under conditions of climate change.**

Climate adaptation is a challenge to many different sectors. Benefits from investment in natural capital may provide cost-effective solutions across multiple policy areas by focusing on the maintenance and enhancement of the joint provision of ecosystem services. All ecosystems provide a set of services and this creates opportunities to streamline policy making. Flood protection, water provision and water quality regulation (including reduction of infectious diseases) may be provided by one and the same wetland area and thus buffer the effects of changing climate regimes (see Box 9.12). By making sure that climate adaptation and water provision policies are coordinated, it will be possible to minimise implementation costs whilst maximising the appropriated flow of services or dividends from relevant natural capital (World Bank 2009b). as shown for example in watershed-level analyses in South East Asia (Pattanayak and Wendland 2007).

There is clearly a need to **address biodiversity loss and climate change in an integrated manner** and

**Box 9.12: The restoration of wetlands and lakes in the Yangtze River basin**

The extensive lakes and floodplains along the Yangtze River in China form large water retention areas which attenuate floods during periods of heavy precipitation and provide a continued flow of water during dry periods. Due to the conversion of the floodplains to polder the wetland area has been reduced by 80% and the flood retention capacity reduced by 75%. Consequently, the risk of floods increases, whereas during dry periods the reduction in water flow increases pollutants concentration in the remaining water bodies, thereby causing the decline in fish stocks. It is anticipated that under continued climate change the frequency of extreme events with heavy precipitation and droughts will increase, having negative consequences for the livelihoods of the 400 million people that are living in the basin of the Yangtze River.

In 2002 WWF initiated a programme in the Hubei Province to reconnect lakes and restore wetlands – so far 448 km3 of wetlands have been rehabilitated which can store up to 285 million m3 of floodwaters. On the one hand this is expected to significantly contribute to the prevention of floods. On the other the increased water flow and better management of aquacultures and improved agricultural practices enhanced the water quality to drinking water levels. This contributed to an increase in the diversity and population of wild fish species in recent years and in turn catches increased by more than 15 %. The restoration of the wetlands thus not only reduces the vulnerability of local communities to extreme events but also improves their living condition.

*Source: WWF 2008*

to develop strategies that achieve mutually supportive outcomes for both policy challenges. One way to achieve this is by promoting sustainable adaptation and mitigation based on ecosystem approaches (e.g. World Bank 2009b). **Ecosystem-based approaches seek to maintain ecological functions at the landscape scale in combination with multi-functional land uses.** They represent potential triple-win measures: they help to preserve and restore natural ecosystems; mitigate climate change by conserving or enhancing carbon stocks or by reducing emissions caused by ecosystem degradation and loss; and provide cost-effective protection against some of the threats resulting from climate change (for discussion, see Paterson et al. 2008).

The CBD AHTEG (2009) on biodiversity and climate change supports this way forward. This expert group concluded that "maintaining natural ecosystems (including their genetic and species diversity) is essential to meet the ultimate objective of the UNFCCC because of their role in the global carbon cycle and because of the wide range of ecosystem services they provide that are essential for human well-being" and stressed that ecosystem-based adaptation is key to successful strategies. This can ensure the long-term success of relevant strategies while the wider ecosystem challenges can be addressed appropriately in climate change negotiations under UNFCCC e.g. by **establishing a REDD-Plus mechanism** and by including ecosystem-based approaches in the Framework for Climate Change Adaptation Action (see also Chapter 5.2 and TEEB 2009).

Given the uncertainties surrounding future rates and mpacts of climate change, as well as the gaps in knowledge and uncertainty of responses to policy initiatives, a **precautionary approach** is necessary. Strong emissions-cutting policies need to be complemented with plans to adapt to major environmental, social and economic changes during the period when we are likely to overshoot safe levels of global warming, as suggested in recent IPCC reports (IPCC 2007). This will require much more **investment in adaptation** than is currently planned (Parry et al. 2009; TEEB 2009). Furthermore, mitigation activities need to be designed to **create synergies with adaptation**, biodiversity conservation and sustainable

**Box 9.13: Climate Change adaptation in Bolivia**

In Bolivia the frequency of natural disasters such as floods and forest fires has increased over the past years and is expected to rise further as climate change continues. This has negative impacts in particular for the rural communities that are heavily dependent on agricultural production. In the Altiplano farmers always had to cope with the risks from natural climate variability but over the past decades the depletion of vegetation, soil erosion, desertification and the contamination of water bodies decreased their resilience. Climate change puts additional stress on the agricultural sector and exacerbates the living conditions for rural communities. Although farmers try to adapt their management of crops to the changing climate conditions this is often not sufficient and the migration of farmers to cities is becoming a bigger problem. As the agricultural sector is contributing 20% to the national GDP and employs 65% of the work force, climate change poses a real threat to the national economy. Therefore, the government of Bolivia has identified key adaptation strategies which are of importance for national development: (i) Sustainable forest management; (ii) Enhancing the efficiency of industrialization processes; (iii) Reducing habitat fragmentation; (iv) Improving soil and water resource management, agriculture research and technology transfer; (v) Identifying pastures resistant to climate change and improving livestock management; (vi) Coordinating water use and water conservation. Five out of the six adaptation strategies are directly related to ecosystem management which highlights the significance of ecosystem services for human well-being and development under climate change. The World Bank has initiated a study on the Economics of Adaptation to Climate Change (EACC) and is assessing the costs of adaptation within a broader national and international context. Similar efforts of identifying adaptation strategies and their costs are undertaken in Bangladesh, Ethiopia, Ghana, Mozambique, Samoa and Vietnam.

*Source: World Bank 2009c*

development (Paterson et al. 2008; Galatowitsch 2009). Where such activities have negative impacts on biodiversity, such as biofuel production, they need to be carefully planned and controlled and their impacts continuously assessed. This type of 'mal-adaptation' should be avoided and remedial measures implemented. Conversely, mitigation measures with positive outcomes represent opportunities that should be sought and promoted.

Ecosystem-based approaches can be applied to virtually all types of ecosystems, at all scales from local to continental, and have the potential to reconcile short and long-term priorities. Green structural approaches – e.g. ecosystem-based adaptation - contribute to ecosystem resilience. They not only help to halt biodiversity loss and ecosystem degradation and restore water cycles but also enable ecosystem functions and services to deliver a more cost-effective and sometimes more feasible adaptation solution than can be achieved solely through conventional engineered infrastructure. Such approaches also reduce the vulnerability of people and their livelihoods in the face of climate change. Many pilot projects in this area are under way (Box 9.13, for a summary of important initiatives, see World Bank 2009b). The experience gained needs to be mainstreamed across countries and regions.

Analysis of measures targeting emission reductions illustrate that there are 'low cost co-benefit' measures which can add significantly to biodiversity conservation and sustainable use (GTZ & SCBD 2009, CBD AHTEG 2009). These include restoring degraded forestland and wetlands, increasing organic matter in soils, reducing the conversion of pastureland and use of 'slash and burn' practices and improving grassland management. These ecosystem-based approaches and land management practices also help to maintain services important for human wellbeing and vital to reinforce nature's adaptive capacity in the face of climate change. The costs of such actions may be much lower than those of major technological actions. They require policy incentives, rather than actions such as carbon pricing or research and development, and are therefore easier to develop.

Agricultural productivity is affected by rising temperatures and increased drought. Agricultural resilience is therefore a key part of adaptation, especially in countries with large populations dependent upon subsistence farming. A recent study has illustrated its potential (see Box 9.14).

**Box 9.14: Ecosystem gains from sustainable agricultural practices**

Agricultural sustainability centres around the world respond to the need to develop best practices and deliver technologies that do not adversely affect the supply of environmental goods and services, but still improve yields and livelihoods. A study of 286 recent 'best practice' initiatives in 57 developing countries covering 37 million hectares (3% of cultivated area in developing countries) across 12.6 million farms showed how productivity increased along with improvement to the supply of ecosystem services (e.g. carbon sequestration and water quality). The average yield increase was 79%, depending on crop type, and all crops showed gains in efficiency of water use. Examples of these initiatives included:

- pest management: using ecosystem resilience and diversity to control pests, diseases and weeds;
- nutrient management: controlling erosion to help reduce nutrient losses;
- soil and other resources management: using conservation tillage, agro-forestry practices, aquaculture, nd water harvesting techniques, to improve soil and water availability for farmers.

*Source: Pretty et al. 2006*

# 9.4 PROACTIVE STRATEGIES FOR MAKING INVESTMENT HAPPEN

**TEEB findings show that a proactive strategy to maintain natural capital and ecosystem services, especially regulating services, should be a high priority for decision-makers. Reactive restoration efforts are generally the fall-back option for severe cases where ecosystem degradation has already taken place. However, both natural and man-made catastrophes and crises provide important opportunities to rethink political practice and procedures and to undertake major public-private or all-public investments. Investing in natural capital can be a very beneficial strategy in the follow-up after catastrophes.**

## 9.4.1 TURNING CATASTROPHES AND CRISES INTO OPPORTUNITIES

When natural crises strike, the necessary rebuilding can be designed to allow future economic development and protection from disasters to go hand in hand (SER-IUCN 2004). After Hurricane Katrina devastated New Orleans, a billion dollars were allocated by the federal government to the city's reconstruction. The goal was to restore and revitalise the region to make it less vulnerable to future hurricanes and other natural disasters. The US Army Corps of Engineers initiated a massive Hurricane and Storm Damage Risk Reduction System that has focussed on repairing and rebuilding the artificial levees along the Gulf of Mexico seafront. However, environmental engineers and restoration ecologists pointed out that over the past century, large wetland areas surrounding the city and providing barriers against storms have been lost to urban sprawl. Now, in the wake of Katrina the opportunity existed to restore them in conjunction with reconstructing the city's built environment by using high-performance green buildings (Costanza et al. 2006a). It was argued that New Orleans could become a model of how to move towards a sustainable and desirable future after a series of severe shocks (Costanza et al. 2006b). Unfortunately, so far wetland restoration has not actually been undertaken, and rebuilding of seafront levies has been favoured instead.

Other opportunities include coastal area restoration activities implemented after the catastrophic 2004 tsunami in the Indian Ocean, and Cyclone Nargis in 2008. The goal is to improve the buffering function of coral reefs and mangroves for future events (UNEP-WCMC 2006; IUCN 2006). In 2005, the Indonesian Minister for Forestry announced plans to reforest 600,000 hectares of depleted mangrove forest throughout the nation over the next five years. The governments of Sri Lanka and Thailand, amongst others, have launched large programmes to recover the natural barriers provided by mangrove areas, largely through reforestation (Harakunarak and Aksornkoae 2005; Barbier 2007).

*Source: U.S. Navy photo by Philip A. McDaniel. URL: http://www.news.navy.mil/view_single.asp?id=19968*

**Box 9.15: Launch of the Sloping Land Conversion Programme after flooding in China**

In 1998, the Yangtze River overflowed causing severe floods. The protection capacities of nearby dams were hindered because of the river's heavy sedimentation, leading to worse damage occurring along the river. After the flood, the river's high sediment yield was linked to the erosion from intensively farmed sloping land (Tallis et al. 2008).

As a consequence, the Chinese government implemented the Sloping Land Conversion Programme which aims to reduce soil erosion in key areas of 24 provinces by converting farmland back into forest land (Sun and Liqiao 2006). Farmers are offered cash incentives, or quantities of grain, to abandon farming and restore forests on their land on steep slopes along key rivers. By the end of the programme in 2010, the aim is to have reconverted 14.6 million hectares into forest (Tallis et al. 2008).

The cost of the overall investment in this project, undertaken mainly by the Chinese government, is Yuan 337 billion (about US$ 49 billion, see Bennett 2009). The government aims to combine soil protection activities with activities for socio-economic improvement of underdeveloped regions along the Yangtze River to improve local living standards by helping families to create new means for earning their livelihoods.

*Sources: Sun and Liqiao 2006; Tallis et. al. 2008; Bennett 2009*

Another example is provided by China's land conservation programme launched after severe flooding of the Yangtze River (see Box 9.15).

Current interest in – and increased funding opportunities for – climate change adaptation and mitigation provide new possibilities for integrating a natural capital perspective into projects and programmes. The result should be to reduce the future vulnerability of societies to new catastrophes, not only by reducing the impact of future events but also by increasing the ability of local people to cope with the effects of climate change and ensure their livelihoods in a changing world (IUCN 2006).

Lastly, financial crises, like all major upheavals, should be regarded as an opportunity for major investments in natural capital. The financial crisis of 2008/2009 led to multi-billion dollar investment in 'stimulus packages' in many countries. If this money were used for investing in natural capital, it would present a unique opportunity for the environment and for redirecting economic growth towards sustainability. Some governments realise that investments in green infrastructure can lead to multiple benefits such as new jobs in clean technology and clean energy businesses (see Box 9.16). Investment in natural capital in the broader sense could secure the sustainable flow of ecosystem services and provide additional jobs in sustainable agriculture and conservation-based enterprises.

### 9.4.2 PUTTING PRECAUTION INTO PRACTICE THROUGH GREEN INVESTMENT

Do we have to wait for crises to occur or natural disasters to strike or should we invest in securing our common future before severe damages occur? The World Bank (2004) supports taking **a precautionary approach** and estimates that **every dollar invested in disaster reduction measures saves seven dollars in losses from natural disasters**. In other words, investment in natural capital pays - not only to improve environmental conditions and livelihoods but also in economic terms.

When tackling the many challenges we face (widespread environmental degradation, climate change and major threats by catastrophes), an integrated economic perspective can and should be developed by national governments to improve capacity to identify and address the benefits of maintaining and restoring our limited and increasingly threatened stocks of renewable natural capital (see examples of South Korea and Great Britain in Box 9.16 above).

**Box 9.16: Investing in the environment during the financial crisis**

**South Korea:** The government is linking its strategy to revitalise its national economy under the current crisis with green growth (Hyun-kyung 2009). In early 2009, President Lee Myung-bak announced that US$ 10 billion would be invested in restoration of four major degraded rivers to build dams and protect water reservoirs. The aim is to prevent neighbouring areas from flooding and to create 200,000 new jobs. "Our policies of green development will benefit the environment and contribute to the fight against climate change, but it is not only an environmental plan: it's primarily a plan for economic development" (Statement of Korea's Permanent Representative to the OECD, Kim Choong-Soo).

**United Kingdom:** In June 2009, the government decided to enhance research in the environmental sector and invest £ 100 million (US$ 160 million) to prepare for climate challenges and related environmental changes (LWEC 2009) through new and innovative solutions for environmental problems. The programme supports the design of more energy-efficient buildings, better public transport systems and better water solutions for cities, as well as tackling the spread of diseases and addressing the economic impact of our changing environment. Programme expectations are that the outcomes will bring benefits for the public in different sectors.

*Sources: Hyun-kyung 2009; LWEC 2009*

A crucial step towards more proactive strategies is to develop overviews of ongoing losses of and threats to natural capital. All countries require more detailed information at regional and national scales on ecosystem services and the factors that threaten their provision, as well as better accounting systems that reflect the importance of natural capital (see Chapter 3). This information will enable policy makers to develop investment strategies that include schemes to maintain or restore ecosystems that provide key services, e.g. via targeted payment schemes (see Chapter 5) or other means, including the designation of protected areas (see Chapter 8).

Achieving this transition will require much closer links between different actors in development and restoration projects, especially in developing countries. Too often, academic institutions, government forestry and agricultural research partners, communities and commercial operators are not adequately connected and therefore do not adequately use the potentials of working together closely. Environmental agencies and institutions have a critical role to play in promoting strong cross-sectoral policy and project coordination, facilitating the development of efficient and cost-effective actions and ensuring that the benefits of such actions are fairly shared across different stakeholder groups.

To pave the way for **combining environmental risk reduction with economically efficient investment**, TEEB recommends that each country carries out a **systematic assessment of their national stocks of natural capital by creating natural capital accounting systems and maps**. These tools will enable restoration needs to be identified in different ecosystem types, especially with regard to endangered biodiversity and the services that ecosystems provide to people, and should be developed at local up to national scales. High priorities should include:

- water provision and purification for cities;
- climate change adaptation and associated natural hazard management, risk management and natural capital;
- carbon storage and sequestration; and
- protecting biodiversity hotspots and other ecosystems considered valuable from a conservation and landscape management perspective.

A structured scientifically-based framework for natural capital accounting will open up new possibilities for decision-makers to systematically and proactively invest in ecological infrastructure. This will not only protect communities and societies against natural hazards – including those most exposed to environmental risk – but also makes economic sense by providing a positive return on investment in the mid-term (see e.g. World Bank 2004). Such investments in a resource-efficient economy are fundamental to help humanity move towards a sustainable future in the long-term, including fairer sharing of nature's social and ecological benefits.

**Chapter 9** has, complementing the chapters 5 to 8, outlined the role **of direct investment in ecological infrastructure**, stressing the economic argument for proactive strategies and the precautionary principle, but also outlining the needs and the costs and benefits for restoration efforts on different scales.

**Chapter 10** will sum up the findings from the study and give an overview for the future **steps needed to respond to the value of nature**.

## Endnotes

[1] Instead of ‚internal rate of return' we use ‚social rate of return' to highlight that besides private benefits some of the public benefits have been considered.

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## Direct costs and potential benefits of restoration: selected examples by ecosystem

| Restoration effort & context | Type of restoration and cost items | Source or link | Ecosystem | Last Year of data collection | Cost: €/ha | Benefits of restoration |
|---|---|---|---|---|---|---|
| [1] Eelgrass restoration in harbour (seabed) following the installation of an oil pipeline | Growing of shoots and the transplantation thereof using volunteer workers | Leschen 2007 | Seagrass meadows | 2007 | 170,000 | Habitat improvement to support the proliferation of juvenile marine resources and other forage species. |
| [2] Restoration of coral reefs following blast fishing in South East Asia | Construction of new reef using special cement: All inclusive | Fox et al. 2005 | Coral reef | 2002 | 11,000,000 | Dynamite fishing destroys corals and habitat, which leads to reduced fishing and income from tourism. In Indonesia, lost income from this cause ranges from €410million and €2.2 billion. Restoration attempts to restore value, both economically and biologically. |
| | Establishment of EcoReefs, i.e. branching ceramic stoneware modules: Materials only | | | | 500,000 | |
| | Placement of stones (from terrestrial sources) | | | | 50,000 | |
| | Comparison with Florida Keys restoration | | | | 5,000,000 - 80,000,000 | |
| | Comparison with restoration in Maldives | | | | 300,000 - 1,200,000 | |
| [3] Restoration of mangroves in West Lake estuary (Port Everglades, USA) | The restoration of 500 ha of mangrove forest through hydrologic improvements to blocked mangroves, and the removal of 80 ha of historical dredged material fill and various Pine species | Lewis Environmental services 2007 | Mangroves & estuaries | 1995 | 7,148 | Habitat creation to restore fish populations and to develop nature-based tourism through construction of a nature centre and outdoor classroom, multi-use boardwalks, fishing facilities, small boat launching site, public observation areas, and hiking trails. |
| [4] Restoration of the Bolsa Chica estuary, California | Restoration to form part of the offset program to mitigate large industrial scale development | Francher 2008 | Mangroves & estuaries | 2006 | 325,000 | Creation of habitat to i) food for fish, crustaceans, shellfish, birds and mammals, ii) absorb pollutants, iii) reduce erosion of the marine shore, iv) provide an opportunity to observe nature. |

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| [5] Restoration of fresh-water wetlands in Denmark | Wetland restoration through hydrological manipulation | Hoffmann 2007 | Inland wetland | 2005 | 8,375 | The reduction of nitrogen loads to down-stream recipients and to enhance the resource value. |
| [6] Control for phosphorous loads in stormwater treatment wetlands | Wetland construction and hydrological manipulation | Juston and DeBusk 2006 | Inland wetland | 2005 | 25,000 | The removal of phosphorous loads from open water bodies. |
| Restoration of the little Tennessee River, North Carolina | Riparian buffer costs, without fencing cost | Holmes et al. 2004 | Rivers & riparian zones | 2000 | 2,302 (€/km) | Restoration benefits are i) abundance of game fish, ii) water clarity, iii) wildlife habitat, iv) allowable water uses, and v) ecosystem naturalness.<br>The benefit/cost ratio for riparian restoration ranged from 4.03 (for 2 miles of restoration) to 15.65 (for 6 miles of restoration). |
| | Riparian buffer costs, with fencing cost | | | | 7,341 (€/km) | |
| | Average cost of revetments where on-site trees were available | | | | 36,348 (€/km) | |
| | Average cost of revetments where on-site trees were not available | | | | 47,670 (€/km) | |
| | Average cost of establishing a riparian buffer in a "Representative" restoration | | | | 4,825 (€/km) | |
| | Average cost of establishing a representative mix of restoration activities | | | | 17,870 (€/km) | |
| [7] Restoration of the Skjern River, Denmark | Construction and restoration of water courses | Anon 2007a | Rivers & riparian zones | 2002 | 130,000 | Benefits are to i) reinstate flow conditions of the Skjern River and remove unnatural barriers, ii) improve the aquatic environment of Ringkøbing Fjord and allow the river, fjord and sea to function as a single biological entity, iii) enhance conditions for migratory fish, iv) recreate a natural wetlands habitat of international importance, v) develop the leisure and tourist potential of the Skjern River Valley. |
| Restoration of the Cheong-gyecheon River, Seoul | Flood mitigation and channelling of the river | City of Seoul 2007 | Rivers & riparian zones | 2005 | 120,000 | Benefits are to i) improve environmental conditions in the downtown area, ii) create a focal point of both historical significance and aesthetic appeal, iii) trigger long-term economic growth by attracting tourists and investors, iv) aid in making Seoul a financial and commercial hub in the East Asian region. |

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| [8] Re-establishment of native eucalyptus trees in former grassy woodland, southeast Australia | Re-vegetation after intensive grazing and farming: Active restoration | Dorrough and Moxham 2005 | Grasslands & rangelands | 2003 | 970 | Benefits are to i) stop and reverse the loss of biodi-versity, ii) land degradation, iii) land [productivity loss and, iv) dryland salinisation. |
| | Re-vegetation after intensive grazing and farming: Passive restoration | | | | 285 | |
| [9] Restoring land to increase forage for bumblebees in in-tensively farmed landscapes in UK | Reseeding of study area with a mixture of grass seeds | Pywell et al. 2006 | Grasslands & rangelands | 2003 | 101 | Pollination services for semi-natural ecosystems and a wide range of agricultural and horticultural crops, and many garden plants. |
| [10] Restoration in Coastal British Columbia Riparian Forests | Thinning treatments, Conifer Planting. Structures were made using surplus conifer and alder trees removed at stre-amside to release existing site conifers. | Anon 2007b | Temperate forests | 2002 | 2,200 | Management aims to improve streamflow integrity (bank stability, water quality, shade) and provision of downed trees (large woody debris) for stream channels. Large woody debris is crucial for healthy salmon and trout habitat, by creating pools and cover, retains nutrients and stabilizes the stream. |
| [11] Masoala Corridors Restoration, Masoala National Park, Madagascar | Tree and plant nurseries | Holloway et al 2009 | Tropical forests | 2008 | 11-223 | Communities depend on the ecosystem services delivered by the forests and the establishment of corridors between existing clumps of forests are essential to ensure the survival of these and the ongoing delivery of ecosystem services to communities. |
| | Plantation | | | | 19-372 | |
| | Forest maintenance | | | | 15-670 | |
| [12] Restoration of rainforest corridors, Andasibe area, Toamasina Region, Madagascar [Tetik'asa Mampody Savoka TAMS] | Sourcing and planting of trees | Holloway and Tingle 2009 | Tropical forests | 2008 | 570 – 1,250 | Enhancement of native biodiversity, human and ecosystem wellbeing through restoring degraded wasteland to a mosaic of integrated/ing, diverse natural forest and productive ecosystems. |

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|---|---|---|---|---|---|---|
| [13] Polylepis forest restoration, Peru | Restoration and re-vegetation of landscape | Jameson and Ramsey 2007 | Tropical forests | 2005 | 760 | Regulation of water supplies in a seasonally dry climate - the importance of this is likely to increase as tropical glaciers retreat and dry season meltwater declines in volume. The forest floor, with a high coverage of shaded mosses, also regulates the flow of water into the rivers and the reduction of soil erosion during heavy rain on the shallow soils of the steep Andean slopes. |
| [14] Restoration of old-fields, New South Wales, Australia | Restoration and enhancement of natural succession of old-growth tropical plantations | Neilan et al. 2006 | Tropical forests | 2004 | 16,000 | Soil productivity, biodiversity, reduced vulnerability and exposure to the invasion by alien species, and the reduction of soil erosion. |
| [15] Restoration of the Atlantic Forest (Mata Atlântica), Brazil | Aroeira trees *(Lithraea molleoides)* were thinned as needed, tree seedlings of other native species were planted on degraded sites and natural regeneration in these areas is being monitored | Instituto Terra 2007 | Tropical forests | 1999 | 2,600 | Besides biodiversity, water from the Bulcão stream and other springs is beginning to return. A dam that had previously been silted up, along with two other springs, have been recovered. During the dry season, these recovered springs have outflows of around 20 liters/minute. |
| [16] Working for water, South Africa | Clearing of invasive alien plants | Turpie et al. 2008 | Woodland and shrub-land | 2008 | 200-700 | Improved water supply, carbon sequestration and fire protection, |
| [17] Mangrove restoration from former shrimp farms | Replanting mangrove trees and other rehabilitation measures | Barbier 2007 | Mangroves | 2007 | 8,800-9,300 | Improved coastal protection, Fisheries and forest products from mangroves |

*Source: Aaronson et al. in press*

[i]Instead of ‚internal rate of return' we use ‚social rate of return' to highlight that besides private benefits some of the public benefits have been considered.