Chapter 17
The Role of Ecosystem Services in Increasing the Adaptive Capacity of the Poor

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17.1 The Link Between Ecosystems, Vulnerability and Adaptation

Human beings have a high adaptive capacity to adverse and variable environmental conditions. They settle in all parts of the world, ranging from tropical to polar regions. It is not just differences in skin colour and enzyme composition that allow humans to

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explore different ecosystems, but it is also their different cultures, traditions and knowledge. However, all human beings depend on nature, and many requirements for human well-being are satisfied by so called ecosystem goods and services.

17.1.1 Ecosystem Services and the Poor

Ecosystem goods and services represent the benefits that human populations derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997; Daily 1997). Most obvious are material ecosystem services such as the provisioning of food and fibres. Others are highly relevant for their regulative function, for instance the regulation of water flows (e.g., flood prevention) or of local and global climate (e.g., reduction of extreme heat in urban areas, and the storage of carbon in biomass and soils). Spiritual and recreational functions as well as habitat functions for animals and plants are also considered ecosystem services. While there are multiple classification schemes for ecosystem services, one of the most common distinguishes between provisioning, regulating, cultural, and supporting services.

This classification goes back to the Millennium Ecosystem Assessment (MA) which was initiated by the UN as the first global assessment of the state of ecosystem service provision in 2001 (Reid et al. 2005). In contrast to earlier environmental impact assessments, the conceptual framework used in the MA places ecosystems and the environment in the centre, to highlight the importance for human well-being. In the MA, 24 ecosystem services were assessed in a range of local to global case studies over the past 50 years. Four of the investigated ecosystem services showed enhancement, 15 showed serious decline (including fishery, water purification, and natural hazard regulation) and five were found to be in precarious condition (Reid et al. 2005). Further reductions in the provision of ecosystem services are expected in the future as the ecosystems degrade (Reid et al. 2005). One important ecosystem service with regard to climate change is the buffering capacity of ecosystems.

The MA scheme is applied widely (e.g., Metzger et al. 2008), although the definition of basic, supporting functions as ecosystem services has been criticised since it causes inconsistencies for the actual accounting of direct benefits to people (e.g. Wallace 2007).

A reduction of ecosystem services will especially impact the poor. More than 70% of the 1.1 billion poor people, surviving on less than $1 per day, live in rural areas and depend heavily on ecosystem services (Sachs and Reid 2006). Poverty and extreme vulnerability to droughts, crop failure and lack of safe drinking water causes millions of deaths each year.

17.1.2 Adaptation to Climate Change

Direct human intervention, such as exploitation of fishing grounds, deforestation, intensification of agriculture and other changes in land use and management, is currently the primary cause of ecosystem degradation. Climate change however, increasingly adds to the stress on ecosystems and is beginning to adversely affect the availability of ecosystem goods and services. Scenario assessments indicate that this effect is likely to become more important over time. To mitigate social impacts, it is therefore imperative to stop further degradation and at the same time to adapt to climate change.

In a biological context, ecological adaptation occurs when plants and animals adjust their physiology, behaviour, or distribution to changing environmental conditions. Given the current rate of degradation and the expected risks, these processes are generally insufficient to ensure continued ecosystem service provision (The Royal Society 2007). We focus here on the role ecosystems and their services have to support the *adaptation of human societies*, and especially those of poor people. The adaptive capacity of the poor is particularly limited due to their high dependence on ecosystem services and their limited access to financial and technological resources.

17.1.3 Increase Adaptive Capacity

One major way to increase adaptive capacity, especially of poor people, would be to improve general living conditions. Primarily this means systematically enhancing food, water and energy security, education, and health, in order to enable people to choose alternative livelihoods and possibly the reduce their own degrading impact on ecosystems. With regard to climate change, regulating services, for example buffering extremes, become more important. The promotion of development and poverty reduction, a key element of the U.N. Millennium Development Goals (MDGs), relies on the steady provision of ecosystem services. Free access to safe water, game, fish, berries and nuts can substantially support the life of the poor and buffer the direct risk of starvation, particularly in rural areas (Bharucha and Pretty 2010). Because of this strong relationship between the state of ecosystems and the development potential of rural areas, biodiversity conservation approaches are increasingly combined with rural development initiatives (Lele et al. 2010; Gockel and Gray 2010). The sustainable use of natural resources, especially in promoting long-term development for rural regions of the South, has become widely accepted (Sachs and Reid 2006) and the urgency of eliminating poverty as part of conservation policy has also been acknowledged (Adams et al. 2004).

17.1.4 The Value of Ecosystem Services

Despite their essential function for humanity, goods and services provided by ecosystems are in many cases taken for granted and insufficiently covered in national economic accounts. Their value is, however, unquestionable. In India, for instance, ecosystem services are estimated to contribute just 7% to national GDP. However, contribution to the "GDP of the poor" (i.e. the effective GDP or total sources of livelihoods of rural and forest-dwelling poor households) may be as high as 57% (Sukhdev 2009). Similar figures have been published for Brazil and Indonesia (TEEB 2010), and they also highlight the economic importance of ecosystem services for the poor.

Incorporating ecosystem services into economic accounting helps to demonstrate the value of ecosystems to society (Daily 1997; Costanza et al. 1997). It enables decision-makers to recognise trade-offs between managing different ecosystem services (Seppelt and Lautenbach 2010; Nelson et al. 2009). Modelling of different land use options can also help optimise the management of ecosystems as a resource for economic activities while enabling different priority settings over time and space (Seppelt and Voinov 2002). The study on The Economics of Ecosystems and Biodiversity (TEEB) launched by the United Nations Environmental Programme is a major international initiative to investigate the globally increasing costs of ecosystem degradation and biodiversity loss (www.teebweb.org). The references to TEEB in popular finance journals (such as QFinance) or mainstream news media (such as the Guardian newspaper) indicate that there is increasing awareness and acknowledgement of the role of ecosystems in sustaining human society in the non-scientific community. It became obvious that the economic value of an ecosystem function can be quickly produced when the ability of forests to store large amounts of carbon (e.g., Gibbs et al. 2007) was recognised as a method of climate change mitigation by the UN Framework Convention on Climate Change (UNFCCC).

Assigning monetary values to ecosystem services can be helpful for assessing alternative development scenarios and for decision-making on a regional scale. Non-market values can be included based on opportunity costs, replacement costs, or contingent valuation. However, the allocation of monetary values also has limitations, in areas such as the handling of supporting services, irreversible change, ethical aspects, or future values of goods and services. Moreover, conventional GDP-based income measures are inadequate for assessing the importance of non-market ecosystem services with respect to the livelihood of the poor. An alternative approach in capturing the essential function of ecosystems to reduce poverty and famine is to directly assess livelihoods. TEEB, for instance, suggests a six-step-approach for local to regional planning, including an ecosystem service assessment and an additional sustainable-livelihood-approach and poverty assessment.

17.1.5 Ecosystem-Based Adaption

Ecosystems already have a function in mitigating climate change, for example through carbon sequestration. However, the role of ecosystem services in climate change adaptation is also being increasingly recognised (e.g., Pisupati 2004; Sudmeier-Rieux et al. 2006). Policies for ecosystem-based adaptation aim to reduce the social vulnerability to climate change in a multi-sectoral and multi-scale approach (Vignola et al. 2009). The idea of ecosystem-based adaptation was a major topic at the Conference of the Parties (COP) of the Convention on Biological Diversity (CBD), held in October 2010 at Nagoya, Japan. Integrating ecosystem services and biodiversity into adaptation strategies is increasingly perceived as cost-effective and utilises economic co-benefits that contribute to long-term sustainable development. However, concrete implementation is often hampered by conflicting (economic) interests and is slow to enter the adaptation manuals and National Adaptation Programmes of Action (NAPA). Moreover, many conventional adaptation measures conflict with the conservation of biodiversity and ecosystem services (Turner et al. 2010).

17.2 Examples of Ecosystem-Based Adaptation

Studies from the recent past (Table 17.1) show how undamaged ecosystems and the services they provide for people are important for climate change adaptation, especially for the poor. Table 17.1 illustrates examples of climate change effects, their social impacts, and how undamaged ecosystems can enable society to adapt and to mitigate these impacts.

17.2.1 Coastal Protection Through Mangroves

Ecosystems have always played a substantial role in protecting coastal areas from inundation and loss of land. In a changing climate an increased storm frequency and further sea-level rise are likely. Undamaged coastal ecosystems could mitigate the impact of these changes on coastal population. Many empirical studies show that mangroves provide such protection (Alongi 2008): observations from the tsunami in south-east Asia in 2004 provide a good example (Kathiresan and Rajendran 2005). Nonetheless, the pressure on mangrove forests remains and deforestation is continuing. The main drivers are coastal development including aquaculture, and logging for timber and fuel production, leading to a high extinction risk for mangrove forests especially along the Pacific and Atlantic coasts of Central America (Polidoro et al. 2010). A costly option for coastal protection would be the construction of dams and drainage systems. Another measure could be relocation of the coastal population to higher ground inland. This would, however, increase the pressure on the hinterland and its adaptation potential (Turner et al. 2010). An increasing risk arising from the unprotected coast will be migration into cities at higher elevations. These cities would need to be prepared and international treaties negotiated to deal with the flow of migrants. In most cases, the conservation and restoration of the mangrove forests would be more cost-effective

Table 17.1 Selected climate impacts on ecosystems and human societies, and ecosystem services supporting adaptation

Climate change impacts on the bio-physical environment	Climate change impacts on human society	Ecosystem services to buffer climate change impacts	Examples of ecosystems providing such buffering services	Measures to support buffering ecosystem services
Sea level rise	Inundation of coastal regions including agricultural and urban areas	Mechanical protection of the coast	Mangroves	Conservation and restoration Coastal management
Rise of water temperatures and acidification of oceans	Loss of fishing grounds	Provision of fishing grounds, marine protected areas	Coral reefs	Conservation of coral reefs; reduction of sediment load and pollution; coastal management
	Loss of tourist attraction	Habitat of fish and other sea life and its beauty		
Increased variability of river discharge	Flooding of cities and agricultural land	Regulation of water flows	Natural floodplains	Conservation and restoration
	Landslides and soil loss	Erosion control and slope stability	Mountain forests	Conservation and restoration
Temperature rise and increased frequency of heat waves	Extreme heat and low air quality in cities	Regulation of micro-climate;Air quality	Urban forests and green veins	Conservation and plantation of urban forests
Increased variability of climate	Deficiency in food provision	Variability of cultivated plants	Agricultural ecosystems	Protection of species and diversity of agro-ecosystems

Source: Own compilation/analysis of studies provided in this chapter

(McLeod and Salm 2006; Polidoro et al. 2010), and the same argument applies to coral reefs, barrier islands, or coastal dunes, which provide similar services for coastal protection.

17.2.2 Provision of Fishing Grounds by Coral Reefs

Another example of ecosystems under considerable global stress are coral reefs. Covering only about 1.2% of the world's continental shelves, they provide a habitat for around 1–3 million species, including more than 25% of all marine fish species (Allsopp et al. 2009). An estimated 30 million people are reliant on reef-based resources as their primary means of food production, income and livelihood (Gomez et al. 1994; Wilkinson 2004), and hundreds of millions of people benefit from the protein supplied by fish and edible invertebrates from coral reefs (Moberg and Folke 1999). Coral reefs are a good example of a single ecosystem providing a multitude of services.

As a result of the beauty and the species richness of the coral reefs, tourism has become the second largest source of income after fishing (TEEB 2010). Both ecosystem services have direct economic implications for the local population: tourist arrivals from all over the world are drawn by the exceptional species richness which can be considered a supporting service as well as an asset in itself.

Coral reefs are considerably threatened by sea level rise, sea temperature rise, and increased acidification due to the absorption of carbon dioxide from the atmosphere (Hoegh-Guldberg et al. 2007). In addition to climate change, pollutants from local sources, sediment load of rivers, and over-fishing weaken these ecosystems (Hoegh-Guldberg et al. 2007). Explicit coral reef management, including small "no-take" areas and even "no-entry" areas, protects the biodiversity of the system and increases its resilience. It also supports the social and economic values of the ecosystem (McCook et al. 2010).

17.2.3 Buffering Drought Through Termites

Semiarid and arid regions such as the savannas of sub-Saharan Africa are characterised by high climatic variability. In several regions climate change is expected to lead to a further increase in precipitation variability expressed by an increased frequency, duration and intensity of dry periods, with an increasing risk for food security. Improved rain water management can dramatically increase agricultural water use efficiency, provide higher and more reliable biomass production, and result in a reduced risk of crop failure (Rockström 2004). The water storage and regulation function of soils can be improved particularly through in-situ rain water harvesting methods. One noteworthy example is the 'Zai' method of using soil-improving termites in West Africa (Roose et al. 1999): woody litter is placed in planting holes and integrated by termites into their mound systems. This leads to increased infiltration of water and enhanced organic soil carbon content, which is beneficial for crop growth (Fatondji et al. 2001; Vohland and Barry 2009).

17.2.4 Buffering Inundations Through Flood Plains and Mountain Forests

An increasing climatic variability will lead to a higher frequency in flooding events in some parts of the world, such as regions affected by the Asian monsoon (e.g., Schewe et al. 2011). Inundation may affect large areas along rivers, which are often densely populated and intensively used for agriculture. Wetlands, however, have a great potential to buffer such extremes. Floodplains, and especially peat lands, can store large amounts of water in the soil and regulate groundwater levels. Despite the high regulative value of floodplains for local populations, settlement in floodplains is increasing in many parts of the world and wetland systems are highly disturbed and fragmented. Consequently, the number and size of floodplain areas to buffer extremes are substantially reduced worldwide (Keddy et al. 2009).

The buffering function of ecosystems should be supported by sound landscape planning (Kimmel and Mander 2010). Wetlands themselves require restoration and adaptation measures to fulfil their supporting function for humans. Communities, especially in poor countries, have to be empowered to implement adaptation measures (Fabricius et al. 2007). In mountains, floods and landslides often kill people and damage settlements, infrastructure, and agriculture. Maintaining mountain forests and implementing other soil conservation measures reduce erosion and the risk of shallow slope instability (Murdiyarso et al. 2005; Vignola et al. 2010). These forests offer additional services, such as the production of wood, honey or volatile oils, and recreational values as well as regulating the water cycle.

17.2.5 Regulation of Micro-climates and Reduction of Air Pollution Through Urban Forests

Energy demanding transpiration of water and the provision of shadow contribute to a reduction in temperature of the environment surrounding a plant. Due to their large leaf area, forests contribute significantly to a cooling of their immediate environment and the suppression of heatwaves. In addition, trees also directly reduce the amount of air pollution: they capture and trap pollutant particles on their leaf surface or direct them into the ground during rainfall, while gaseous pollutants (e.g., nitrogen dioxide) are directly absorbed into the leaf (Brack 2002). Temperature regulation through urban forests significantly reduces costs and emissions from air conditioning (Wee 1999). Extending urban green spaces and forests would be an important adaptation to climate change, especially for large tropical and subtropical cities. Given the (sometimes extremely) low air quality in these cities, filtering the air would contribute to a healthier environment and improve living conditions for all citizens, including the poor. Urban forests are good examples of ecosystems that provide a multitude of services (Jim and Chen 2009), and ideally combine climate adaptation and mitigation efforts.

17.2.6 Regulating Infectious Diseases

Climate change can change the occurrence and violence of a range of health conditions, ranging from heat collapses to the increased spread of diseases. Alien invasive species provide an additional risk by introducing novel pathogens (Thomas et al. 2009). Although the approach of relating health to ecosystem services is still in its infancy, some scientists are exploring different ecosystems with regard to their disease limiting function. Forests, for example, increase physical and mental health, offer valuable sources of plant and microbial material, and support the regulation of infectious diseases (Karjalainen et al. 2010). Deforestation was followed by an increase of malaria and/or its vectors in Africa, Asia, and Latin America. However, there are also some forest-borne diseases such as Hanta or Borreliosis which are transmitted by small mammals or insects.

17.2.7 Increase Food Security with Agrobiodiversity

With increasing frequency of meteorological extremes, such as droughts, heat waves and storms, a strategy to maintain agricultural diversity also is a pre-requisite to regional climate change adaptation in agriculture (Alcázar 2005). Given limited financial resources and high vulnerability to food shortages of the rural poor, a low-risk intensification strategy based on biodiversity is therefore preferable to the rather risky high-input high-yield strategy, especially for the subsistence farming in poor, rural areas of Africa, Asia and South America. Maintaining a high genetic diversity of crops, and cropping systems can substantially reduce the risk of complete loss of harvest with significant benefits for the rural population (Hajjar et al. 2008; Kotschi 2007). Regional case studies (e.g., Hadgu et al. 2009) as well as international organisations (e.g., Convention on Biological Diversity or Bioversity International) reflect on the possible contribution of locally adapted crop species to reduce the vulnerability of the agricultural system and increase food security. Further risk reduction can be achieved through improved access to and conservation of natural and semi-natural areas which provide wild plants and undamaged hunting and fishing grounds.

17.3 Conclusions

Competition for access to ecosystem services as well as to closely linked land titles has already led to violent conflicts, such as the riots of Peruvian and Indonesian locals against the exploration of indigenous forest. Moreover, climate change may reduce the provision of ecosystem products and services (Alcamo et al. 2005). This is a topic where poor people face a double disadvantage: they rely directly on functioning ecosystems for adaptation to climate change, and they have little political or economic influence for protecting these ecosystems. The TEEB study has shown the economic importance of ecosystem services to human society.

The concept of ecosystem services helps to join two strongly interlinked perspectives within one formal approach. The protection of ecosystems and habitats were often considered to have negative impacts on local rural communities by preventing future alternative land use (Adams et al. 2004; Fischer 2008; Norton-Griffith and Southey 1995). At the same time, rigorous development schemes often put ecosystems and their functioning heavily at risk. The concept of ecosystem services considers both sides. In multi-stakeholder processes the educative power of the approach supports the development of socially acceptable solutions, especially at the local to regional scale. Ecosystem service assessments have been successfully conducted in many case studies (e.g., Nelson et al. 2009; Grêt-Regamey et al. 2008) and the development of tools for operational use in planning and monitoring is highly desirable (e.g., Tallis and Polasky 2009). However, while balancing the resulting values against each other, one needs to be aware that the selection of single isolated ecosystem services may considerably affect the overall result. The value of so-called "supporting services" (MA 2005) which build the essential basis for the existence of ecosystems and many of their services (e.g., soil formation or nutrient cycling) is probably underestimated as the value chain is not completely understood.

Financing ecosystem based adaptation remains a great challenge. The UNFCCC established the Adaptation Fund "to finance concrete adaptation projects and programmes in developing countries that are part of the Kyoto Protocol" (www.adaptation-fund.org). Although the handbook does not mention the ecosystem-based adaptation approach (Adaptation Fund 2010) the first project financed refers to it with regard to coastal management. The significance of ecosystem-based adaptation will most likely increase, not least through lobbying of the CBD. The biggest opportunity, however, is the integration of ecosystem-based adaptation in national development and adaptation planning. Mainstreaming of ecosystem-based adaptation is being facilitated by intense dialogues between policy-makers and other stakeholders. However, while UN organisations and NGOs very much rely on the ecosystem-based approach, there is a lack of research on specific aspects (Vignola et al. 2009). More research is needed to provide evidence on the relation between ecosystem services and human welfare. Potential synergies between ecosystem contributions to mitigation and adaptation have to be explored further.

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