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1. Overview and Summary

In 2009, the International Strategy for Disaster Reduction (ISDR) system will launch a landmark assessment, “Reducing Risk to Reduce Poverty: 2009 ISDR Global Assessment Report on Disaster Risk Reduction”. The report aims to establish a credible and widely accepted reference point for information on global disaster risk patterns and trends; increase understanding and awareness of the mutually supportive relationship between development and disaster risk reduction and strengthen the ISDR system’s capacity for planning and joint programming at all levels by providing a global level review of national, regional and thematic HFA reporting.

The report summarizes some of the key trends in disaster risk and in poverty at the global level, underlined in particular by the new data generated by the global risk update carried out in support of the report. The review also highlights progress being made by various actors and challenges encountered in addressing disaster risk and poverty reduction outcomes from quite different starting points.

This paper introduces the ecosystems approach and records how it can be applied to address poverty trends and disaster risk in complementary ways. The concepts of ecosystems, ecosystems services and ecosystem resilience are introduced and their relevance to disaster risk reduction is outlined and illustrated through two indicative cases. A framework for valuing ecosystem services that reduce disaster risk is presented as both a means of weighing the costs of benefits of including ecosystem management in disaster risk reduction portfolio and perhaps even as an element of risk transfer measures. Finally, a case are made for looking beyond the material aspects of poverty to consider the impacts of disasters on human-wellbeing and the need to invest in long-term ecological governance and institutions in order to reduce disaster risk and achieve broader human-well being.

1.1 Key Questions

This chapter sets out to answer several questions, questions that illustrate the scope – conceptual and practical – of the ecosystems approach to promoting human well-being.

- Are we exacerbating the extent of disaster-related damages especially among the marginalized communities through the continued destruction of ecosystems and the corresponding decline in ecosystem services?
- Can we increase resilience and human well-being through better ecosystem management?
- Can ecosystem management be a cost effective complement to standard disaster risk management interventions?
- Can ecosystem management produce co-benefits which enhance not only personal security from natural hazards but also contribute towards the ability of individuals to achieve material wealth, health and better social relations?
- And finally, if ecosystem management is a socially and economically viable disaster risk management option, then how do we map ecosystem services and adaptive management into existing vulnerability assessments methodologies?
**1.2 Disaster, Poverty and Ecosystems**

Nearly 1.2 million people have lost their lives in natural hazard related disasters over the past two decades. Associated economic losses are estimated to total approximately 70 billion USD per year. In 2004 alone, disasters killed nearly 245,000 people; while economic damages worth 215 billion USD were recorded over the year 2005. ¹ Disasters occur when vulnerable communities are impacted by a hazard or shock. The burden of impact is being borne by socially marginalized and vulnerable communities. This is not to say that the affluent are excluded from the ravages of natural hazards but the impact of these disasters is significantly higher among the poor. The report “Reducing Risk to Reduce Poverty: 2009 ISDR Global Assessment Report on Disaster Risk Reduction” summarizes some of the key trends in disaster risk and in poverty at the global level. This section asks how role ecosystems affect disaster risk and poverty.

**1.3 What are ecosystems and ecosystems services?**

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. As elements of the ecosystem are degraded, those functions can be lost.

Humans are an integral part of ecosystems. Ecosystems are closely linked with social systems – to such an extent that some refer to coupled socio-ecological systems. People receive substantial benefits from ecosystems; these benefits have been termed ecosystem services. These may be categorized as *provisioning services* (such as food and fiber), *cultural services* (such as a sense of place or tourism), and *regulating services* (such as climate moderation or flood reduction). Few ecosystems have not been affected by human action, intentionally and unintentionally. People often modify ecosystems to increase the supply of ecosystem services that they desire, and develop institutions to govern access and use of these services. However, because ecosystems jointly produce many ecosystem services simultaneously human action to increase the supply of one service, such as food, can frequently lead to declines in other services, such as flood protection.

![Figure 1: Ecosystem services are the benefits that people receive from nature.](image)

¹ OFDA/CRED have a mandate from UN to monitor disaster impacts, this paragraph has therefore been revised based on latest data from CRED’s EM-DAT database over the two past decades 1988-2007, excluding “accidents.”
The supply of approximately 60% (15 of 24) of the ecosystem services assessed by the MA was found to be in decline (Table 1). At the same time, consumption of over 80% of the services was found to be increasing. In other words, the flow of most ecosystem services is increasing at the same time as the total stock is decreasing. Services that followed this pattern include the supply of freshwater, erosion control, aesthetic values, and water quality regulation. Four of the services measured showed an increase in both consumption and stock, including the production of crops, livestock, fish from aquaculture, and global climate regulation. Only a few services showed declines in the amount consumed, and these were generally associated with declines in the stock (and thus the supply) of these services. The services in this category include the production of fisheries and wild foods. In particular, the MA identified that while people have modified ecosystems to increase the supply of food and fiber, these modifications have unintentionally lead to the decline of regulating ecosystem services. Regulating services are critical for ensuring the reliable supply of other ecosystem services, as well as helping reduce people’s exposure to natural hazards, such as fires and floods.

<table>
<thead>
<tr>
<th>Provisioning ES</th>
<th>Regulating ES</th>
<th>Cultural ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td>Air quality control</td>
<td>Spiritual and religious values</td>
</tr>
<tr>
<td>Livestock</td>
<td>Global climate regulation</td>
<td>Aesthetic Values</td>
</tr>
<tr>
<td>Capture fisheries</td>
<td>Local climate regulation</td>
<td>Recreation and ecotourism</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Water flow regulation</td>
<td>+</td>
</tr>
<tr>
<td>Wild foods</td>
<td>Erosion control</td>
<td>+</td>
</tr>
<tr>
<td>Timber</td>
<td>Water quality regulation</td>
<td>+</td>
</tr>
<tr>
<td>Cotton</td>
<td>Disease control</td>
<td>+</td>
</tr>
<tr>
<td>Wood fuel</td>
<td>Pest control</td>
<td>+</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Pollination</td>
<td>+</td>
</tr>
<tr>
<td>Biochemicals</td>
<td>Natural hazard regulation</td>
<td>+</td>
</tr>
<tr>
<td>Freshwater</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Numeric sign shows change in use. Color shows change in supply. Green = increasing supply, red = decreasing supply, and yellow = supply more or less stable.

Table 1: Use and supply of assessed ecosystem services. (MA 2005).

Poor people are more affected by the loss of ecosystem services than rich people, because they have less capability to replace lost ecosystem services through technology or other measures. The MA stated that loss of ecosystem services is increasing the difficulty of meeting the Millennium Development Goals.

Global changes in the supply of ecosystem services have disproportionately benefitted the rich world. For example, while the supply of clean water has increased in most of...
the world, half of the urban population in Africa, Asia, Latin America, and the Caribbean does not have access to clean water and suffers reduced health and higher costs of obtaining water. Similarly, land clearing for forest plantations in Indonesia degraded air quality for 20 million people and increased health care costs an additional US$9.3 billion (WRI 2005). The poor have also lost access to ecosystem services due to the expropriation of common pool resources. For example, in many tropical countries coastal fisheries that formerly provided inexpensive source of protein and supplemental income, have been destroyed due to shrimp farming and other forms of aquaculture. The benefits of aquaculture go to a small group, while the costs are imposed on the local poor (WRI 2005).

Poverty is a useful lens for looking at the impacts of losing ecosystem services, but it only addresses the issue of material wealth, the Millennium Assessment adopts human wellbeing as the primary target, among other advantages, the human well-being approach encourages attention to issues of capabilities and entitlements.

2. Ecosystems and Disaster Risk Reduction

<table>
<thead>
<tr>
<th>Key Questions</th>
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<tbody>
<tr>
<td>• Are we exacerbating the extent of disaster-related damages, especially among the marginalized communities through the continued destruction of ecosystems and the corresponding decline in ecosystem services?</td>
</tr>
<tr>
<td>• Can we increase the resilience of the poor through better ecosystem management?</td>
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<tr>
<td>• And finally, if ecosystem management is a socially and economically viable disaster risk management option, then how do we map ecosystem services and adaptive management into existing vulnerability assessments methodologies?</td>
</tr>
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2.1 Risk Reduction and Resilience Services

Globally-regulating ecosystem services are declining. As discussed above, human modification and simplification of ecosystems to produce food, fiber and fuel, has lead to a decline in regulating ecosystem services. *This decline is expected to result in both more variable ecological dynamics and more human exposure to hazard.* Indeed exposure to natural hazards has increased globally since the 1950s and this growth is faster than global population growth or the growth of the global economy (IDD 2005; Munich Re 2006; 2007; IPCC 2007, EM-DAT 2008).

The ability of societies to cope with natural hazards has also increased due to technological advances and wealth (IPCC 2007). As a result, disaster-related mortality has decreased globally. On the other hand the number of affected people has increased and economic impacts have tripled since 1975, partially due to increasing economic investments in disaster-prone areas (Munich Re 2007). These people are disproportionately poor.

Ecosystem services shape both the exposure of people to hazards and the ability of people to cope with hazards.

In the two cases below we provide example of each of these processes. The first case considers Hurricane Katrina and the Mississippi River to illustrate how the decline in regulating ecosystem services can increase people’s exposure to hazards. The second
cases on dry spells and agriculture shows how ecosystem services help people cope with temporary failures of their main form of livelihood in Tanzania.

2.2 Case study in Exposure: Wetlands and Hurricane Katrina in New Orleans

Hurricane Katrina devastated New Orleans. It was both a predictable and predicted disaster. Poor preparedness and previous ecosystem alterations led to substantially greater social and economic costs – many of which could have been avoided. The US government has pledged USD 100 billion to rebuild the city, and it was the largest insured lost in the US. The disaster was exacerbated due to the loss of regulating ecosystem services in the region. This loss was unintended and largely due to various development projects that did not include these ecosystem services into their decision making.

Losses of the capacity for soil regeneration lead to subsidence in many regions of New Orleans. Regions that were formerly above sea level a century ago were below sea level at the time of Hurricane Katrina due to the draining of wetlands that changed soil chemistry to promote oxidization and compaction. Similarly, the removal of wetlands from within New Orleans reduced the capacity of the city of cope with flooding.

The cutting of channels for oil and gas exploration as well as the channelization of the Mississippi destroyed coastal wetlands that dissipate the energy of the storm surge. Cutting of channels destroyed wetlands and amplified disturbance on them, while channelizing the river prevented the river from depositing the sediment needed to maintain the wetlands. These recent changes have resulted in rapid wetland loss and removed an area that took several thousand years to accumulate.

Scientists have estimated that restoring the 4800 km² of wetlands lost from the Mississippi delta prior to Katrina could provide increased flood protection, but also a number of other ecosystem services, worth in total an estimated USD 6 billion a year.

The case of New Orleans points out a number of issues with ecosystem services. First, the benefit of regulating ecosystem services can be large, but this benefit is shared by many people over the long-term. Consequently ensuring that private interests do not degrade the social good requires effective and long-term institutions. Secondly, ecosystem services have often been replaced by technical infrastructure; however these can be designed to work together. For example, a New Orleans with restored wetlands would still have levees, but those levees could be quite different, and hopefully more resilient. Thirdly, there are many opportunities to engineer ecosystems to provide multiple ecosystem services, but managing ecosystem engineering to ensure that an ecosystem is designed to produce an optimal amount of services that are produced and consumed by different people at different scales is a difficult governance challenge.

2.3 Case Study in Resilience: Dealing with drought in Tanzania

The farmers of the Makanya catchment in Tanzania are poor. In 2000 their average cash income was estimated at 149,000 Tsh per capita, which then corresponded to 150 USD (Same District Council 2006). The persistent nature of poverty here, as well as elsewhere in dryland Sub Saharan Africa, is the result of a general marginalization, manifested by a lack of infrastructure, public services and market access, and by human capability deprivations, in combination with challenging hydro-climatic conditions.
Ecosystems and Disaster Risk Reduction

(Mortimore, 2005). Water for crop production is a central issue (Falkenmark and Rockström, 2004).

The Makanya catchment is semi-arid, with one longer and one shorter rainy season (Masika/Vuli). Average precipitation ranges from 200-300 mm per season, but it is highly variable both between and within seasons (Enfors and Gordon, 2007). The variability seems to have increased over time, with on average 4 out of 5 Masika seasons being hit by a major dry spell over the past 20 years. Masika 2005 was such a season. Cumulative rainfall was about 170 mm, but a four-weeks long dry-spell resulted in severe yield losses. The subsequent Vuli season (2005/2006) was classified as a meteorological drought. Only 93 mm of cumulative rainfall was recorded and most crops failed.

A study by Enfors and Gordon (in press) of strategies to cope with drought showed that food security was a major concern in Makanya already early during Vuli 2005/2006, as a consequence of the reduced harvest from the preceding Masika season. After the Vuli drought more than 75% of the interviewed households stated that they experienced food shortage. The level of shortage varied from having to change the diets, to reducing the amount of food per meal and/or the number of meals eaten per day. On average only 20% of the food needed in the households was produced within their own farming systems that season, as compared to more than 80% under normal conditions. People used a range of strategies to cover the deficit. Most common was to buy food on local markets (on average 54% of the food was bought). Consequently household food expenditures rose.

Table 2 shows the income sources used to cover the rising food costs. Cash crops normally serve as the main income source. However, this production was also affected by the drought, and generated merely 12% of the incomes, making people increasingly reliant on less rainfall dependent income sources. Interestingly, considering that diversification towards non agro-ecosystem based income sources is seen as the norm for smallholders nowadays (Barrett et al., 2001; Bryceson, 2002; Rigg, 2006), the results demonstrate the importance of the local environment’s capacity to generate goods that could provide alternative income when harvests fail. Of the interviewed households 85% earned part of their income from locally generated provisioning ecosystem services such as fibers, wood products, wild fruits, and fodder for free-ranging livestock. It was estimated that 42% of the total incomes this season came from these sources, making it roughly as important as the combined effects of short-term wage labor, remittances, non-agro-ecosystem based business, and off-farm employment, which accounted for 44% of the incomes. The remaining 14% were taken from the households’ savings. To cope with the two consecutive drought seasons, 43% of the interviewed households were forced to consume capital that they had accumulated over preceding seasons.

The study demonstrated a high reliance on provisioning ecosystem services from the surrounding landscape when harvests fail, highlighting the need for management practices that maintain the productivity of the whole agro-ecosystem. Many of the farmers were of the opinion that overcoming the uncertainties associated with water availability for crop production is not only key for improving agricultural productivity, but for improving land management as a whole. They meant that reliable agricultural outputs would reduce the need to for example engage in illegal logging, make charcoal, or expand the fields to sensitive land areas. The study also showed that the recurring droughts sustain what could be described as a climate related poverty trap (Carter et al.,
highlighting the complex interaction between droughts, poverty and agro-ecosystem productivity in the dryland farming systems of these regions.

Table 2: Income sources used to cover the food expenditures

<table>
<thead>
<tr>
<th>Source</th>
<th>Household use income source* (%)</th>
<th>Average income contribution from source (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income based on local</td>
<td></td>
<td></td>
</tr>
<tr>
<td>provisioning ecosystem services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash crops (own or locally produced)</td>
<td>85</td>
<td>42</td>
</tr>
<tr>
<td>Livestock</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td>Charcoal</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Bricks</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Timber</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Handicrafts</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Other agro-ecosystem based business</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Other income sources</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Short term wage labor</td>
<td>55</td>
<td>22</td>
</tr>
<tr>
<td>Remittances</td>
<td>38</td>
<td>12</td>
</tr>
<tr>
<td>Business</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Off-farm employment</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Savings</td>
<td>43</td>
<td>14</td>
</tr>
</tbody>
</table>

Most households use a range of different income sources, explaining why the total exceeds 100%

2.4 Lessons learned

These two examples illustrate a number of issues with ecosystem services. The New Orleans case shows that the benefit of regulating ecosystem services can be large, but this benefit is shared by many people over the long-term. Similarly, the Tanzania case shows that people rely upon a diverse set of wild ecosystem services during crises, ensuring that the ecosystems that produce such services are maintained during good times requires long-term governance. Ensuring that private interests do not degrade the social good requires effective and long term institutions. New Orleans often shows that ecosystem services have often been replaced by technical infrastructure; however these can be designed to work together. For example, a New Orleans with restored wetlands would still have levees, but those levees could be quite different, and hopefully more resilient. Similarly in Tanzania, small scale water harvesting could be combined with increasing soil organic matter to increase the resilience of farming to dry spells.

Both cases illustrate that there are many opportunities to engineer ecosystems to provide multiple ecosystem services. For example, restoring wetlands in the Mississippi delta would increase storm surge protection, and also improve fisheries, improve water quality regulation, and wildlife tourism. In Tanzania, there are many opportunities for small scale rainwater harvesting that could improve agricultural productivity and increase
soil water holding capacity, reducing vulnerability to dry spells. These actions to increase agricultural productivity would also increase the supply of non-agricultural ecosystem services. However, despite these win-win opportunities, managing ecosystem engineering to ensure that an ecosystem is designed to produce an optimal amount of services that are produced and consumed by different people at different scales is a difficult governance challenge.

People, both rich and poor, receive substantial benefits from ecosystems. However, much current development fails to adequately account for the indirect consequences of ecological change. While these changes present many difficult challenges, and have created difficult to solve problems, it also means that there are substantial opportunities for better managing multiple ecosystem services for human benefits through better design of ecological institutions, more ecologically appropriate infrastructure, and ecosystem management.

2.5 Ecosystem Resilience and Adaptive Management

Ecosystems themselves are resilient when processes and components are kept in balance, and it is important to understand the limits of ecosystem resilience to optimize their benefits to humans. Understanding the resilience of ecosystems also sheds light on why they are so effective for natural hazard mitigation. The roots of ecological resilience have been investigated in a number of regional case studies (Gunderson and Holling 2002), and while each case is unique some general principles of resilience have emerged.

2.5.1 Biodiversity and resilience

Ecosystems are resilient when ecological interactions reinforce one another, and dampen disruptions (Peterson et al. 1998). Sustaining desirable states of an ecosystem in the face of multiple or repeated perturbations requires species that maintain the functions present in an ecosystem remain available (Lundberg and Moberg 2003). In biodiverse ecosystems, species within the same functional groups will respond differently to environmental change, and this “response diversity” may be critical to ecosystem resilience (Elmqvist et al. 2003). The replication of function at multiple scales can provide cross-scale resilience that protects against disturbance at different scales (Peterson et al. 1998). High levels of biodiversity in an ecosystem can be viewed as an insurance against major disturbance. The insurance metaphor can help us understand how to sustain ecosystem capacity to cope with and adapt to change in the context of multiple-equilibrium systems and human-dominated environments (Folke et al. 1996). Insuring that an ecosystem continues to supply ecosystem services can both protect against hazards and facilitate recovery from them.

Many hazards arising from human interaction with the natural environment are sensitive to environmental change, including flash floods due to extreme rainfall events on heavily managed ecosystems that cannot retain rainwater; landslides and avalanches on deforested slopes; storm surges due to sea-level rise and the increasing use of hard coastal margins; air pollution due to intensive use of fossil fuels combined with extreme summer temperatures; fires caused by prolonged drought, with or without human intervention. Ecosystem integrity is important in protection from these hazards, but less so to geological hazards, localised to a few vulnerable areas, such as volcanic eruptions and earthquakes. However, in alpine regions, vegetation diversity is related to ability to reduce the risk of avalanches. Soil biodiversity may play a role in flood and erosion...
control through affecting the surface roughness and porosity, and increasing tree diversity is believed to enhance the protection value against rockfall. The recovery of systems following disaster is strongly shaped by what ecological functions of presence. The maintenance of ecological functions following disaster, or their rapid recovery, can enhance the ability to recover its functions following disturbance. For example, on islands in Western Polynesia, a large proportion of the tree species produce fleshy fruits that are dispersed by vertebrate frugivores. In Samoa, cyclones and a fire in the early 1990s caused extensive changes to lowland forests, but due to different vulnerability to fire while some important species declined drastically, other species in the same functional group survived and maintained the seed dispersal functions (Elmqvist et al. 2003). If this response diversity had been low or absent, ecosystem development may have been redirected into a different pathway, dominated by wind-dispersed and passively dispersed plants, with a great risk of invasion by wind-dispersed exotic opportunistic species and a changed resource base for humans. Both protection from hazards and recovery are strongly shaped by regulating ecosystem services. In particular regulating ecosystem services related to disaster prevention and recovery are climate regulation, disease regulation, and water purification.

2.5.2 Climate regulation
Climate regulation refers to the role of ecosystems in managing levels of climate forcing gases in the atmosphere. Current climate change is largely driven by increases in the concentrations of trace gases in the atmosphere, principally as a result of changes in land use and rapidly rising combustion of fossil fuels. The major greenhouse gas (CO$_2$) is absorbed directly by water and indirectly by vegetation, leading to storage in biomass and in soils, ensuring the regulation of climate. Other greenhouse gases, notably methane (CH$_4$) and nitrous oxide (N$_2$O) are also regulated by soil microbes. The interplay between biodiversity and climate regulation is poorly understood. The global C cycle is strongly buffered, in that much of the CO$_2$ discharged by human activities into the atmosphere is absorbed by oceans and terrestrial ecosystems ((Janzen 2004)).

Globally, Climate regulation is one of the most important ecosystem services. The problem we face is that the rate of emissions exceeds the capacity in oceans and terrestrial ecosystems for buffering, and the loss or damage to ecosystem function though the indirect effects of human activities, is reducing this capacity still further. Strategies will have to be adjusted to manage areas with high carbon sequestering potential. The most promising measures include: higher organic matter inputs on arable land, the introduction of perennials (grasses, trees) on arable set-aside land for conservation or biofuel purposes, the expansion of organic or low input farming systems, raising of water tables in farmed peatland, and the introduction of zero or conservation tillage. Given the importance of carbon storage, it is essential that the key ecosystems, in particular the peat soils, continue to function well. Knowledge about their performance and the mechanisms that underlie carbon sequestration and storage is therefore crucial. However, research is needed on the contribution of biodiversity to climate regulation, a significant problem given that soil biodiversity is under threat from many soil management practices.

2.5.3 Disease regulation
Pests and diseases are regulated in ecosystems through the actions of predators and parasites as well as by the defence mechanisms of their prey. The services of regulation are expected to be more in demand in future as climate change brings new pests and increases susceptibility of species to parasites and predators.
Disease regulation is therefore related to the control of the prevalence of pests and diseases of crops and livestock, but also of human disease vectors and disease. Major outbreaks of both human and wildlife (animal and plant) diseases are usually due to the introduction of a new pathogen. Management of diseases can involve several approaches: control of diseased hosts, replacement of susceptible by resistant hosts; ecosystem management to reduce spread of the disease organism; biological control of pathogens; and chemical control of pathogens. Some ecosystems may be better able to resist invasion by novel pathogens than others, possibly because of factors such as the structure and complexity of ecosystem.

The role of biodiversity in disease regulation may be important. There is evidence that the spread of pathogens is less rapid in more biodiverse ecosystems. There is also a general consensus that a diverse soil community will not only help prevent losses or crops due to soil-borne pests and diseases (Wall and Virginia, 2000). Higher trophic levels in soil food webs can play a role suppressing plant parasites and affecting nutrient dynamics by modifying abundance of intermediate consumers ((Sanchez-Moreno and Ferris 2007). In many managed systems, control of plant pests can be provided by generalist and specialist predators and parasitoids.

2.5.4 Water Regulation and Purification
The water regulation and purification service refers to the maintenance of water quality, including the management of impurities and organic waste and the direct supply of clean water for human and animal consumption. Soil state and vegetation both act as key regulators of the water flow and storage. Changing land use (forest cover, use of drainage) is a major factor, as is changing climate – with consequent high-intensity rainfall events and more seasonality in rainfall distribution. Although vegetation is a major determinant of water flows and quality, and micro-organisms play an important role in the quality of groundwater, the relationship of water regulation and purification to biodiversity is poorly understood. In lowland Europe, there are a number of factors that will impinge on water regulation and purification, including use of floodplains, river engineering and increasing urbanisation leading to higher levels of run-off and contamination of water. Increasing land use intensity and replacement of biodiverse natural and seminatural ecosystems by intensively managed lands and urban areas have resulted in increased runoff rates, especially in mountainous regions.

2.5.5 Resilience Dynamics
The resilience of ecosystems, wild or human dominated, varies over time. Ecosystems often cycle through four phases: development, conservation, creative destruction and reorganization which then returns leads to a new cycle of development (Holling 1986). This model proposes that as weakly connected processes interact, some processes reinforce one another build a specific organization of ecological pattern and processes that shapes future development. However, the system becomes dependent upon structure and constraint for its persistence, leaving it vulnerable to either internal fluctuations or either natural or human produced external disruptions. Eventually, the system collapses, releasing accumulated species, energy, and materials to reorganize into a new organization. During this phase, an ecosystem can easily to lose resources, and new actors can enter it. The lack of control allows novel organizations to form. Such an ecosystem has little resilience, and can be easily reorganized by small inputs. This is the time when exotic species of plants and animals can invade and dominate an ecosystem. It is the time when accidental events can freeze the direction of the future.
Out of these interactions a new ecosystem organization emerges, which may be a rebirth of a past ecosystem organization or something new. During this cycle resilience decreases from development to conservation, during the process of creative destruction a system breaks apart and resilience becomes difficult to define, until a new system begins to organize.

Ecosystems are usually embedded within other ecosystem that exist at different phases of this cycles (Gunderson and Holling 2002). The opportunities and constraints for renewal of a system following a crisis or disturbance are strongly shaped by the organization within which the reorganizing system is embedded. For example, following a forest fire, the state of the regional ecosystem determines the leakage of accumulated capital of nutrients that have been mobilized and released into the soil. The options for renewal draw upon the accumulated seed bank and physical structure that has accumulated during the growth of the forest. The reorganization of the system is shaped by its ecological memory that has accumulated in the pattern, legacies, and regional context surrounding the disturbed area. Another example of this type of cross-scale change is provided by the recovery of South Florida’s mangrove forests following Hurricane Andrew. Recovery of the mangrove forest was facilitated by the history of frequent, small-scale fires produced by lightning strikes that produced patches of young mangroves that were flexible enough to survive the hurricane. The diversity produced by small scale disturbances enhanced reorganization following a large scale disturbance (Smith et al. 1994).

2.5.6 Coping with Change

The dynamic nature of ecosystems has important consequences for the species that inhabit them. From the point of view of a plant species that lives within a fire-dominated forest ecosystem, there are a number of strategies that it can adopt that favor its survival. Specific strategies correspond to different phases in the adaptive cycle. For example, one strategy plant species use to cope with fire is having thick bark to enable a plant to survive low intensity fires. An alternative strategy is, being able to quickly grow following a fire by, for example, storing energy in its root system to invest in growth following the loss of above ground biomass. Another strategy is to focus upon reorganization phase, to ensure that the plant species is present immediately following fire. An example of this strategy is serotinous pinecones, which only open to release their seeds following the heat of a fire. Another strategy is to influence disturbance by modifying the qualitative character of disturbance. For example, longleaf pine shed flammable needles that burn readily, encouraging frequent low intensity fires. Longleaf pine can survive these fires, while oaks, an ecological competitor cannot. Each of these strategies focuses a plant’s energies on adapting to different aspects of a fire dominated ecosystem. Often plant species in a fire dominated system will exhibit a suite of such strategies, but trade-offs among strategies, such as between thick bark and rapid growth, inhibit a plant from dominating during all phases of an adaptive cycle. As plants, or other animals, adapt to the ecological dynamics they inhabit, they also modify those dynamics by inhibiting or accelerating different phases in the adaptive cycle.

The response of plants to fire is provides a useful metaphor for thinking about general alternative strategies for dealing with change within a dynamic system. There are four possible active responses to disaster: learning, insurance, disaster resistance, and disaster initiation. There is also the passive strategy of doing nothing in response to change. A learning strategy attempts to understand system dynamics so that knowledge can be used to reconfigure a future system. This corresponds to the plant strategy of
colonizing new burned areas. Insurance is a strategy of investing in alternate strategies so that when a system reorganizes, quick regrowth is possible.

Resistance attempts to control systems dynamics to prevent disturbance from happening. Disaster management is a strategy of trying to control the timing and nature of change or disturbance rather than trying to prevent it. For example, the practice of prescribed fire attempts to control ecological dynamics by burning a landscape at times that people choose rather than letting wildfires occur. A comparison between the specific responses of plants to fire and general strategies of coping with change is shown in Table 1.

**Table 3.** Strategies that plants use to respond to different phases of a fire regime, and generalized strategies for dealing with change.

<table>
<thead>
<tr>
<th>Phase in Adaptive Cycle</th>
<th>Reorganization (alpha)</th>
<th>Growth</th>
<th>Conservation</th>
<th>Creative Destruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy for coping with fire</td>
<td>Colonize burned areas</td>
<td>Regenerate quickly</td>
<td>Resist fire</td>
<td>Regulate fire regime</td>
</tr>
<tr>
<td>General Strategy for coping with disaster</td>
<td>Learning</td>
<td>Insurance</td>
<td>Disaster Resistance</td>
<td>Disturbance Initiation</td>
</tr>
</tbody>
</table>

These general strategies are different approaches a component of a system can take to deal with systemic change at a larger scale. Ecosystems containing species that embody a wide diversity of alternative strategies will be more resilient than those that contain a less diverse group. In planning for disaster the ecological metaphor suggests that a broader mix of strategies reduces the susceptibility to a broader range of environmental variation or disturbance.

For example, local communities in various disturbance-prone geographical settings use a portfolio approach to coping with disasters (Berkes et al. 2003). Berkes et al describe how habitat protection, shifting cultivation, and fire management can play a role in mitigating the effects of natural disturbance and how such practices may contribute to providing a flow of resources and services on which local communities depend. These examples represent ways of responding to environmental variability and natural disturbances at the local level instead of blocking them, out as is often done in conventional resource management (Holling and Meffe 1996). For example, the disturbance is perceived in different ways by the char-dwellers of Bangladesh and policy experts view the flooding of the Jamuna River. Char-dwellers, consider annual floods as normal and have developed ecological and social strategies to live with this disturbance. By contrast, the experts who designed the Flood Action Plan perceive annual flooding as a constraint to development and have devised measures to prevent flooding. People in the local communities depend directly on functioning local ecosystems for their survival and often lack sophisticated technologies to block out natural disturbance. Hence, in order to avoid large-scale social-ecological crises, the members of these communities are strongly motivated to develop strategies that deal with environmental uncertainty and variability locally. This characteristic appears to be key to maintaining resilience in any system. By contrast, in many large-scale Western societies, social hardship resulting from resource management failures is often mitigated by investment in insurance and options provided for by the capital market. While such measures may be important in
helping people survive periods of crises, they not necessarily lead to ecological learning from environmental feedback, nor to adjustments of applied management practices.

2.5.7 Management and Governance of Surprise

Ecological researchers have increasingly recognized the truly interconnected nature of social-ecological systems. Governing these systems presents a number of challenges. Two approaches that have been advocated to govern such systems are adaptive co-management and adaptive governance (Galaz et. al. 2008).

Adaptive co-management refers to the multilevel and cross-organizational management of ecosystems and focuses on the adaptive capacity of social-ecological systems to deal with ecological changes, uncertainty and surprise. Such multilevel governance systems often emerge to deal with crisis, and can develop within a decade (e.g. Olsson et al. 2004). It combines the dynamic learning characteristic of adaptive management with the linkage characteristic of collaborative management. The combination aims to address the analytical and managerial shortcomings of both adaptive and co-management. While adaptive management addresses the humans-in-nature perspective and learning-by-doing (Holling 1978, Lee 1993), the approach has been criticized for not incorporating other knowledge systems. Co-management on the other hand, addresses institutional and epistemological aspects, multi-stakeholder processes, and the sharing of power in natural resource management, but often neglects fundamental ecosystem feedback and dynamics as well as larger governance dimensions.

Adaptive co-management uses processes of monitoring, interpreting, and responding to ecosystem feedback at multiple scales to build knowledge (Folke et al. 2005). Due to the complexity involved it is usually difficult if not impossible for one or a few people to possess the range of knowledge needed for effective ecosystem management. Instead, knowledge for dealing with social-ecological systems dynamics becomes dispersed among individuals and organizations in society and requires social networks that span multiple levels in order for actors to draw on dispersed sources of information. Adaptive governance builds on adaptive co-management to focus on building multilevel governance that creates the institutional, economic and political structures to build resilience of social-ecological systems (Folke et al. 2005). The shift from “management” to “governance” is crucial in this context. While “management” implies bringing together knowledge from diverse sources into new perspectives for practice, a focus on “governance” conveys the difficulty of control, the need to proceed in the face of substantial uncertainty, and the importance of dealing with diversity and reconciling conflict among people and groups who differ in values, interests, perspectives, power, and the kinds of information they bring to situations (Dietz et al. 2003). It focuses on the ability to steer away from undesired regimes and possibly even transform social-ecological systems into new improved trajectories that sustain and enhance ecosystem services and human wellbeing.

2.6 Ecosystems and Disaster Risk Reduction: Summary Conclusions

- Ecosystems can reduce the exposure of communities (Mississippi example)
• Ecosystems can enhance community resilience and coping capacity (Tanzania)
• The benefit of regulating ecosystem services can be large, but this benefit is shared by many people over the long-term and requires long-term governance to ensure that private interests do not degrade the social good.
• There are many opportunities to engineer ecosystems to provide multiple ecosystem services. However, despite these win-win opportunities, managing ecosystem engineering to ensure that an ecosystem is designed to produce an optimal amount of services that are produced and consumed by different people at different scales is a difficult governance challenge.
• Ecosystems themselves exhibit resilience through patterns of resistance, reorganization and transformation. Understanding these processes in ecosystems can help us to identify indicators for monitoring the state of ecosystems.

3. Valuing Ecosystem Services for Risk Reduction

Key Questions
• Can ecosystem management be a cost-effective complement to disaster risk management interventions?

The case for using an ecosystem management approach to disaster risk reduction was presented in the preceding sections. There is no doubt a growing consensus among the risk reduction community that ecosystems could be used either in conjunction with conventional disaster risk reduction measures or by themselves to mitigate the adverse impact of disasters on human and natural systems in a cost-effective manner. However, in order to estimate the full potential resulting from using an ecosystem services approach to reducing disaster risk, it is imperative to understand the costs and benefits of these strategies.

The first order costs of adopting an ecosystem approach will be primarily the cost of restoring damaged or lost ecosystems to deliver the disaster regulation that can provide protection from adverse consequences of natural hazards. This might include the restoration of mangrove ecosystems long coastal shorelines or the reintroduction of coppice woodlands to prevent soil erosion to improve soil stability. The second order costs will be the opportunity costs foregone by adopting an ecosystem approach. These opportunity costs are primarily the economic benefits foregone from alternate uses of land. These might include foregone aquaculture production from mangrove lands or the conversion of uplands to residential property. Total Costs will therefore be:

$$TC = RC + OC$$

Where RC is restoration costs and OC are the opportunity costs.

The flip side of costs incurred from adopting an ecosystem approach is the benefits. Similar to costs, there are first and second order benefits. The first order benefits are the damage costs reduced or avoided from the use of an ecosystem strategy. The second order benefits will be the co-benefits that may accrue from adopting the ecosystem approach. These can include the delivery of other bundled ecosystem services that can contribute to human well-being. The total benefits will therefore be:
Where AD is the avoided damages and COB are the co-benefits

The net benefits will be TB – TC. If positive and the greater the resulting amount, the more effective the approach. The lower the result, the less effective the approach, suggesting that other more cost effective options be pursued or if there are none available that other disaster risk reduction options may be taken into account.

3.1 Restoration Costs (RC)

In many countries, the ecosystems, which in the past had mitigated some of the impacts of a hazard event, have been fully or partially destroyed. The loss of ecosystems such as wetlands and mangroves has significantly reduced natural mechanisms of protection from natural hazards. Local or regional ecosystem conditions such as increased deforestation can for example contribute to the magnitude or scope of particular flooding

Figure 2: Costs and benefits of adopting an Ecosystems Approach in Disaster Risk Reduction

| Costs and Benefits of Adopting an Ecosystem Approach in Disaster Risk Reduction |
|---------------------------------|---------------------------------|
| **Restoration Costs - RC**      | **Benefits or Avoided Costs - AC** |
| 1st order costs                 | 1st order benefits              |
| - Costs occurring from maintaining ecosystems, restoring damaged or lost ecosystems, and designing ecosystems, in order that they deliver disaster regulating ecosystem services | - Costs that would have occurred from (economic, social and environmental) damage caused by natural disasters but could be reduced or avoided through the use of an ecosystem approach |
| - Costs for developing ecosystem approaches that often diverge from conventional approaches | - Direct benefits resulting from using an ecosystem approach that reduce disaster risk such as for example avoided loss of land through erosion through the establishment of protective coastal vegetation |
| - Costs for developing basis e.g. data necessary for decision makers to pursue new strategies | |
| - Costs for awareness-, knowledge- and capacity-building among involved stakeholders and civil society to support the ecosystem approach | |
| - Costs for implementing approaches, and for maintaining/monitoring implemented approaches | |

| Opportunity Costs - OC         | Co-Benefits - COB               |
| 2nd order costs                | 2nd order benefits              |
| - Costs resulting from adopting an ecosystem approach such as primarily economic benefits foregone due to alternate land use | - Co-benefits resulting from adopting an ecosystem approach |
| - Benefits as a result of using the ecosystem that is in contrary to the management of the ecosystem for disaster risk regulation such as for example benefits from logging watershed areas that are being reforested for the purpose of regulating flood and sediment flow | - Benefits that result from using an ecosystem approach as positive side effects such as for example harvest from trees that have been planted and protected against erosion or desertification |
events and by this increasing vulnerability. Human vulnerability is influenced by the characteristics of local ecosystems, social systems, and human modifications to them. For example the forested riparian wetlands adjacent to the Mississippi River in the United States during pre-settlement times had the capacity to store about 60 days of river discharge – today after removing wetland areas through development, the remaining wetlands have a reduced storage capacity of less than 12 days discharge which corresponds to an 80% reduction of flood storage capacity. This loss of wetlands contributed substantially to the severity and damage experienced in the 1993 flood in the Mississippi Basin (MA, current state and trends, chapter 16 …)

Ecosystems will need to be protected and maintained, restored or designed in such a manner that they are functioning properly, and by this providing disaster regulating ecosystem services—reducing exposure and enhancing resilience.

Box: Examples of Restoration Costs

The use of mangroves for the protection against wave impacts in Vietnam
Planting and protecting 12,000 ha of mangroves by the Red Cross in Vietnam cost around 1 million USD and as a positive side effect resulted in reducing the costs of sea dyke maintenance by 7.3 million USD per year.

Disaster mitigation and prevention through restoration of littoral vegetation in Sri Lanka
In order to re-establish coastal protection as a response to environmental degradation as well as the damages caused by the 2004 Tsunami, an initiative was started for restoring degraded littoral vegetation by assisted regeneration in selected communities in Ampara District – through establishing nurseries and planting measures - to foster regrowth of mangroves and beach vegetation. However, it was found that the use of mangroves for disaster risk reduction is limited. For the two-year project a total budget of USD 157,000 was defined, with approximately USD 61,000 for training and community capacity building expenses, and USD 96,000 for staff salaries and revegetation expenses such as nursery construction, site preparation, and baseline reports.

Managed re-alignment and re-establishment of saltmarsh habitat at Freiston Shore, UK
An existing hard sea defence was repositioned (managed realignment) to a more landward location, offering accommodation space for creating intertidal habitat, including 66ha saltmarsh habitat and 15ha saline lagoon, and thus allowing increased flood water storage and wave attenuation. The estimate of the implementation costs amounts to £1,98 million, the monitoring scheme and maintenance costs are partly funded through a 20 year DEFRA Habitats Scheme, and small additional income will be provided by renting the external marsh for cattle grazing. The realignment site is part of the Wash Banks coastal defence project that protects more than 80,000ha of low-lying land including many villages and the town of Boston with a population of more than 35,000. In the specific case of Freiston Shore the measure was proposed to combat increased erosion rates at the base of the sea wall and thus reduce the expected higher maintenance costs. The measure proves effective to adapt to the impact of sea level rise and increased wave action on low-lying coasts, as well as in the reduction of flood risk.
Just relying on a natural ecosystem by itself, however, does not guarantee the full protection from natural hazards as the ecosystem may not be able to completely absorb the impacts of hazard events. There are even ecosystems that depend on natural disturbances, such as the coniferous forests of the Sierra Nevada.

**Box: Ecosystems need disturbance (what do humans do to cope with this?)**

The conifer forests of the Sierra Nevada - managing a fire-dependent ecosystem

Originally, the conifer forests of the Sierra Nevada were dependent on fire as the major environmental factor that initiated new successions, controlled species composition and age structure of the forest, and contributed to the mosaic of vegetation that supported the animal components of these communities. The key functions of fire in a mixed-conifer forest are the preparation of a seedbed, nutrient cycling within the system, adjustments of the successional pattern, the moderation of conditions that favor wildlife, influence on the mosaic of age classes and vegetation types, alteration of numbers of trees susceptible to attack by insects and disease, and both reduction and creation of fire hazards. Also, the survival of tree species such as giant sequoia and various pines of the Sierra depends on this environment. Giant sequoia depends on fire to open cones and clear ground cover for successful regeneration. Therefore, National Park Service management policies aim at restoring fire, as nearly as possible, to its natural role in this area, through prescribed burning and allowing the burning of lightning fires. (The Ecological Role of Fire in Sierran Conifer Forests: Its Application to National Park Management, Bruce M. Kilgore, Western Regional Office, National Park Service, San Francisco, California, Originally published in Journal Quaternary Research, Volume 3, Number 3, October 1973)

Natural hazards can also have positive effects on human systems, and so for example increase pasture area for livestock, increase water availability or replenish aquifers, and have indirect positive effects in the agriculture and the construction sector ([DFID, 2005](#)). Flooding, for example, can result in benefits such as transport of sediments and nutrients to the coastal zone and thus can positively influence other ecosystem services that benefit human systems.

For the restoration of ecosystems, the effects of hazards and disasters need to be taken into account when aiming at re-establishing the original assets of the ecosystem including the disaster regulating ecosystem services as far as possible, to increase the ecosystem’s potential to absorb natural disturbances but also to maintain the other ecosystem services. For example, in Japan, the hillsides were designed in such a manner that they would reduce the rate of run off during tropical storms to prevent floods. In similar manner, the hillsides were covered with managed woodlands and carefully terraced paddy fields to maintain soil stability and therefore prevent landslides from occurring after heavy tropical storms ([Takeuchi et. al 2003](#)). The costs of restoring such a system would be the costs of undertaking such an initiative, including the labor
costs, costs of raw materials and of planting vegetation, as well as the estimated future maintenance costs. Restoration costs mainly depend on what extent the ecosystem has been destroyed.

However, in case of insufficient protection provided by ecosystem management towards natural hazards, consideration needs to be given to possible complementary measures, such as structural or preparedness measures.

### 3.2 Opportunity Costs

The opportunity costs will include the benefits that could have been reaped if the land used for ecosystem management for disaster risk reduction would have been used for other benefits including land use that would have been contradictory to the management of the ecosystem for disaster risk reduction. In the case of watershed reforestation against floods, the opportunity costs are related to the reduced earnings from alternative uses of the watershed, such as logging or the benefits that would have been captured if the land was converted for residential development (DFID, 2005).

**Box: Opportunity Costs**

**Comprehensive ecosystem value reduce opportunity costs**

A more comprehensive value of healthy coastal mangroves - including as nurseries, pollution filters and coastal defences – is estimated by the MA at 1,000 USD per ha which is five times their value as prawn ponds. Next to the protective function, these mangroves offer many additional social and economic benefits. (MA)

**Wetland ecosystems on floodplains for flood impact reduction and water flow regulation - Quantification of ecosystem services of a floodplain with a preserved hydrological regime in the Czech Republic**

In the Lužnice floodplain – one of the last floodplains with unaltered hydrological regime in the Czech Republic – on a study area of 470 ha four ecosystem services were quantified: flood mitigation, biodiversity maintenance, carbon sequestration, and production of hay, wood and fish. Results show that ecosystem services are of significant value - with a total value of 27,068 USD per ha - with a much higher value assigned to non-production services than to production services. The monetary value for flood mitigation (water retention) is 11,788 USD per ha and for biodiversity refugium 15,000 USD per ha, but only 144 USD per ha for carbon sequestration, 37 USD per ha for fish production, 78 USD per ha for hay production, 21 USD per ha for wood production. (The role of environmental management and eco-engineering in disaster risk reduction and climate change adaptation; ProAct Network/Ministry of Environment, Finland/Gaia/UNISDR; 2008.)

### 3.3 Avoided Damages

The avoided damage is the amount of loss which would not have occurred if an ecosystem approach for disaster risk reduction was adopted. However, it is important to introduce the notion of probabilities when computing the cost of inaction which should be done on the basis of an adequate risk assessment by taking into account hazard and vulnerability. Particularly in face of climate change impacts, weather patterns are changing and predictability for the occurrence of hazards and disasters becomes
increasingly challenging. The cost of inaction would therefore have a distribution with estimates based on different risk profiles of the disasters.

**Box: Avoided Damages**

**Avoided economic loss through disaster risk reduction measures**
Estimations indicate that with an investment of 40 billion USD in physical or engineering disaster risk reduction measures, an economic loss of 280 billion USD worldwide from disasters would have been avoided in the 1990s (World Bank, US Geological Survey). In China it is estimated that a 3.15 billion USD investment in flood control over the past four decades has led to avoided loss of about 12 billion USD (World Bank, 2004). (DFID, 2005)

**Economic value of mangroves as coastal defences**
Mangrove forests as coastal defences have been estimated to have an economic value of 300,000 USD per km in the example of Malaysia, taken into account the costs of hard engineering work to achieve the same protective effect. (The role of environmental management and eco-engineering in disaster risk reduction and climate change adaptation; ProAct Network/Ministry of Environment, Finland/Gaia/UNISDR; 2008.)

**Forest cover to stabilize steep slopes and prevent landslides and avalanches**
The economic value of forests for preventing avalanches is estimated at around 100 USD per ha per year in open expanses of land in the Swiss Alps up to more than 170,000 USD per ha per year in areas with valuable assets. (The role of environmental management and eco-engineering in disaster risk reduction and climate change adaptation; ProAct Network/Ministry of Environment, Finland/Gaia/UNISDR; 2008.)

**Soil and Water Conservation through traditional Bamboo Plantation: A Disaster Management Technique Adopted by the People of Nandeswar, Assam**
Bamboo plantation along canal bunds by the local people of Nandeswar Village in many ways has benefited their village. With plantation of bamboo, one of Assam’s most prevalent vegetation, canal bunds (embankments) are kept from being breached and soil is kept from further erosion. Although floods occur every year in Assam, this technique has maintained and protected embankments and has kept bridges and roads from damage during heavy rains. (Indigenous Knowledge for Disaster Risk Reduction: Good Practices and Lessons Learned from Experiences in the Asia-Pacific Region. UN ISDR. Bangkok. 2008.)

**3.4 Co-Benefits**
One of the main advantages of using an ecosystem services approach is the presence of synergies among ecosystem services. This means that by producing one ecosystem service such as disaster risk regulation, also a bundle of other ecosystem services will be provided. It would also mean that there may be a constraint on some ecosystem services, which may cause a decline in the disaster risk regulation service but these will already be captured in the opportunity costs section.

**Box: Co-benefits**
Planting and protecting trees against desertification in Niger
In Dan Saga, Niger, villagers decided to plant and protect young trees to halt the
desertification. Today, the trees form part of the villagers’ farming system as providing
fodder for livestock.

Permaculture against drought in Jordan Valley
In the southern Jordan Valley, integrated methodologies of permaculture were used for
the rehabilitation of 4ha of otherwise non-productive farmland under high salinity and
drought conditions. Implementation costs in most cases did not exceed present less
sustainable agriculture practices. (The role of environmental management and eco-
engineering in disaster risk reduction and climate change adaptation; ProAct
Network/Ministry of Environment, Finland/Gaia/UNISDR; 2008.)

3.5 Summary Conclusions

- The value of protecting ecosystem services for risk reduction can be estimated by
  considering RC, OC and AD and COB
- The benefits of ecosystem services accumulate in bundles; protecting regulatory
  services can also support improvements in water supply, protect biodiversity,
  sustainably provide the resources that support livelihoods
- By including disaster risk reduction services, particularly those that reduce exposure
  or enhance resilience) in emerging markets represent an important contribution to
  risk transfer mechanisms.

4. Well-being and the Distribution of Multiple Benefits

Key Question
- Can ecosystem management produce co-benefits which enhance not only
  personal security from natural hazards but also contribute towards the ability of
  individuals to achieve material wealth, health and better social relations?

In addition to the costs and benefits view presented above, the (spatial and) temporal
dynamics of ecosystems and the services they provide need to be taken into account
when considering the cost effectiveness of an ecosystem approach in disaster risk
reduction.

Box: Temporal Dynamics of Ecosystem services for risk reduction

Effects of different forest stand ages on slope stabilization, and landslide
prevention in Japan
Benefits of forest vegetation in Central Japan have been evaluated by quantitatively
assessing the effects of different forest stand ages on landslide frequency and sediment
production from landslides, with the result showing that older forest vegetation with
mature root systems are more effective in reducing landslide erosion and sediment
delivery to streams than younger forests with little root strengths.
(The role of environmental management and eco-engineering in disaster risk reduction
and climate change adaptation; ProAct Network/Ministry of Environment,
Finland/Gaia/UNISDR; 2008.)
In addition, other important factors such as vulnerability, resilience, and coping and adaptive capacity of the human as well as the natural system need to be taken into account as they influence the disaster risk reduction potential of an ecosystem approach. A study focused on natural hazards in coastal regions found that natural capital can substantially contribute to disaster risk reduction, in conjunction with Human, Built, and Social capital and an increasing awareness of the consequences of different development decisions (Perez-Maqueo et al, 2007). However, it was also recognized that interactions of natural and managed ecosystems with extreme events, as well as their modified vulnerability due to human influence still are largely unknown. Therefore, a combination of natural and modified ecosystems, adequate infrastructure, and social awareness is suggested to achieve the best results in living with hurricanes, while a country specific balance among the four capitals would help to increase living standards and reduce the risk and damage from hurricanes. (Coastal disasters from the perspective of ecological economics, Perez-Maqueo et al, Ecological Economics 63 (2007) 273-284)

4.1 Disasters and Well being

This section is being further developed to better illustrate ecosystem services’ role in well-being.

Five major constituents of well-being were identified by the MA as closely influenced by ecosystem services. These are material wealth, security, health, social relations and the freedom of choice and action. Each one of these constituents can be affected by disasters.

4.1.1 Material wealth - most commonly affected by major natural hazards

The 2004 Tsunami in the Indian Ocean was the most dramatic disaster in recent years, with 300,000 people dead or missing and about 1.5 million people displaced. The high number of affected people is also due to the fact that communities have increasingly occupied areas that are exposed to natural hazard. The disaster’s macroeconomic impacts vary from one country to another, depending on how severely the country’s economy had been affected. The economic impact on the Maldives has been estimated to be quite substantial with 14 of about 200 inhabited islands having been destroyed.

Reported increases in GDP growth after the Tsunami have to be interpreted carefully, as they are most probably due to significant increases in reconstruction spending and foreign aid, not necessarily due to changes in productive assets.

Positive side effects were experienced in the case of Bangladesh where disaster risk reduction measures had significant development benefits, even in the absence of natural hazards raised flood shelters are used on a day-to-day basis as schools or clinics, and boreholes that protect against droughts provide the co-benefit of cleaner water and easier access than other sources. (DFID, 2005; MA 2005, Synthesis Report)

4.1.2 Security at stake due to inaction

In 2005 hurricane Katrina affected the Bahamas, the US, the North Atlantic, Florida, the Gulf of Mexico, Louisiana, Mississippi, Alabama, and Tennessee; caused 1’836 deaths and displaced over 75’000 people; resulted in a total economic loss of 125 billion USD of which about half was insured; and led to extensive wind-related property damage, extensive flooding along its path, flooding and pollution in New Orleans, oil rig damage in
the Gulf of Mexico, damage to oil refineries along the coastal areas, and power line damage.

In New Orleans, the rapid flooding inundated about 80% of the city leading to contamination and pollution from chemicals and waste. Extensive loss of life and devastation particularly affected the less-privileged members of society, which was not only the result of the hurricane but also of human decisions, including the initial choice of the location for the early settlement of the city, the neglect of scientifically-based hazard scenarios by public officials, the repeated federal budget cuts for disaster preparedness resulting in increased vulnerability of New Orleans’ inhabitants, the failure of the government manifesting in the delay in response measures after the disaster occurred which led to further loss of life and devastation, and looting of abandoned areas.

The inaction in New Orleans was strongly criticized worldwide, and when recently facing a similar hurricane event, it was shown that prevention and preparedness measures in the affected areas had substantially improved so that the worst could be prevented. (Swiss Re, NZZ)

4.1.3 Health at risk due to flooding

Health can be affected by disasters that cause death, injury, and disease. Rising flood waters across West Africa in August 2008 increased health risks for millions of people, constituting an additional threat besides the food price crisis. Benin, Burkina Faso, Mali, Mauritania, Niger and Togo needed urgent assistance since flooding had caused widespread damage to bridges, roads, railway lines and other infrastructure vital for delivering health services and humanitarian supplies. Seasonal rains also caused damage in Guinea-Bissau, Liberia and Sierra Leone. Due to heavy rains forecasted to last until September, there was the risk to exacerbate health threats for malaria, diarrhea, and other potentially fatal communicable diseases. Only for emergency health care in West Africa, US$ 76 million was needed. (www.who.int, 2008)

4.1.4 Social relations exacerbated by environmental degradation

In the case of Darfur, Sudan, human-made severe environmental degradation exacerbates social relations affected by continued human rights violation. More than two million internally displaced people live in camps in Darfur and are putting increased pressure on the arid environment through their constant need for fuelwood and timber supply, deforestation and desertification is taking place at an increased rate. Fuelwood collection is traditionally the task of women and girls who put themselves at risk of assault when leaving the camps, particularly since the distances they have to go are getting longer due to increased deforestation nearby. Fuelwood not only serves for personal use but also as an important source of income. As a response to this fatal situation, organizations have started to organize fire wood patrols for the protection of the vulnerable people, but also are trying to promote fuel-efficient technologies such as improved stoves or alternatives such as solar stoves. However, even if fuelwood collection could be controlled, the prevailing attitudes within the community and local and national authorities still need to be addressed. (Finding Trees in the Desert: Firewood collection and alternatives in Darfur, Women’s Commission for Refugee Women and Children, New York, March 2006; Sudan: Post-Conflict Environmental Assessment, UNEP, June 2007)
4.1.5 Freedom of choice and action at risk by climate change impacts
Where all constituents of human well-being are at risk, one of the options left is migration. In face of the potential future impacts of climate change, developing countries will be disproportionately affected by resulting disasters; for example, a drought in a developing country can affect the sole or main livelihood of agriculture. Already today, climate change impacts can be experienced; the intensification of droughts, storms and floods are believed to aggravate in future and to lead to environmental migrations and potential conflicts in the areas, migrated to. Effective measures for minimizing such impacts are seen in the investment in areas affected by environmental problems. An analysis of three case studies – the US Dust Bowl in the 1930s; Bangladesh since the 1950s; and Hurricane Katrina in 2005 – shows despite of climate change causing large population movements, public policy can alleviate the pressures of ecomigration. (ScienceDaily (Nov. 28, 2007); 1. Reuveny R (2007). Ecomigration and violent conflict: case studies and public policy implications. Human Ecology)

4.2 Summary Conclusions
• To effectively assess the benefits of ecosystem services for disaster risk reduction will require us to effectively account for the needs of future generations and explicitly recognize the distribution of benefits among within and between communities; to effectively address these public goods requires long term ecological governance and institutions.
• The distribution of benefits should look not only at poverty but at the wider picture of human well being.

5. Conclusions
• Ecosystems can reduce the exposure of communities (Mississippi example)
• Ecosystems can enhance community resilience and coping capacity (Tanzania)
• The benefit of regulating ecosystem services can be large, but this benefit is shared by many people over the long-term and requires long-term governance to ensure that private interests do not degrade the social good.
• There are many opportunities to engineer ecosystems to provide multiple ecosystem services. However, despite these win-win opportunities, managing ecosystem engineering to ensure that an ecosystem is designed to produce an optimal amount of services produced and consumed by different people at different scales is a difficult governance challenge.

• A combination of natural and modified ecosystems, adequate infrastructure, and social awareness is suggested to achieve the best results in living with hurricanes, while a country-specific balance among the four capitals would help to increase living standards and reduce the risk and damage from hurricanes.

• Ecosystems themselves exhibit resilience through patterns of resistance, reorganization, and transformation. Understanding these processes in ecosystems can help us to identify indicators for monitoring the state of ecosystems.

• The value of protecting ecosystem services for risk reduction can be estimated by considering RC, OC, and AD and COB.

• The benefits of ecosystem services accumulate in bundles; protecting regulatory services can also support improvements in water supply, protect biodiversity, sustainably provide the resources that support livelihoods.

• By including disaster risk reduction services, particularly those that reduce exposure or enhance resilience) in emerging markets represent an important contribution to risk transfer mechanisms.

• The distribution of benefits should look not only at poverty but at the wider picture of human well-being.
References:


Endnotes

i The importance of charcoal is likely underestimated, since charcoal making is illegal and informants therefore are reluctant to admit engaging in it. In contrast to these figures, the qualitative data suggest that it is a quite important income source when harvests fail.

ii E.g. selling wild-growing fruits or firewood

iii Mostly labor on neighboring farms or construction work