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Demonstrating the Role of Ecosystems-based Management for Disaster Risk Reduction

Partnership for Environment
and Disaster Risk Reduction (PEDRR)

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and the Council of Europe

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Prepared by the Partnership for Environment and Disaster Risk Reduction (PEDRR)

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Table of Contents

9. Integrating DRR and NRM priorities from a local livelihoods perspective in the Indian Ocean Tsunami Early Warning System

10. Landslides and Vegetation Cover in the 2005 North Pakistan Earthquake: a GIS and statistical quantitative approach

11. Integrating ecosystems and climate change factors in risk and vulnerability assessments: The case of RiVAMP in Jamaica

12. Impacts from the 2004 Indian Ocean Tsunami: Analysing the potential protecting role of environmental features

13. Vulnerability assessment and protective effects of coastal vegetation during the 2004 Tsunami in Sri Lanka

Glossary of Terms[1]

Climate change: The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as change that can be attributed "directly or indirectly to human activity and that alters the composition of the global atmosphere, which is in addition to natural climate variability observed over comparable time periods". However, scientists often use the term for any change in the climate, whether arising naturally or from human causes. Each of these perspectives is relevant. There is now strong evidence of increases in average global air and ocean temperatures, melting of snow and ice and rising average global sea levels. Climate change is expected to impact on vital sectors, namely water, food production and health, as well as contribute to extreme weather events.

Disaster risk: The potential significant losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period. Risk is often described as a result of the combination of: the exposure to a hazard, the conditions of vulnerability that are present, and insufficient capacity or measures to reduce or cope with the potential negative consequences.

Ecosystem: An ecosystem is a dynamic complex of micro-organism, plant, animal and human communities and their non-living environment interacting as a functional unit.[2]

Ecosystem services: Ecosystem services refer to the goods and benefits derived from ecosystem functions; these include "provisioning services" such as food, water, timber and fibre; "regulating services" that affect climate, floods, disease, wastes and water quality; "cultural services" that provide recreational, aesthetic, and spiritual benefits; and "supporting services" such as soil formation, photosynthesis and nutrient cycling.[3]

Environment: Environment refers to the physical and external conditions, including both natural and human-built elements, which surround and affect the life, development and survival of organisms or communities.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Measures of exposure can include the number of people or types of assets found in hazard zones.

Hazard: A hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. There are different types of hazards: natural hazards, technological and biological hazards. Natural hazards are natural processes or phenomena, such as earthquakes, droughts and tropical cyclones, that may constitute a damaging event, but their occurrence and scale of impact are often influenced by human-induced activities as a result of inappropriate land use, poor building codes and environmental degradation.

Natural resources: Natural resources are actual or potential sources of wealth that occur in a natural state, such as timber, water, fertile land, wildlife and minerals. A natural resource qualifies as a renewable resource if it is replenished by natural processes at a rate comparable to its rate of consumption by humans or other users. A natural resource is considered non-renewable when it exists in a fixed amount, or when it can not be regenerated on a scale comparative to its consumption.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner that minimizes hazard impacts and contributes to reducing risk and vulnerability.

Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Vulnerability is the result of the whole range of economic, social, cultural, institutional, political and even psychological factors that shape people's lives and create the environment that they live in. In other words, defining vulnerability also means understanding the underlying factors or root causes of vulnerability. However, multiple definitions of vulnerability exist. Some sources regard vulnerability as a composite of exposure, sensitivities or susceptibilities, and coping capacities and resilience.[4]

Section 1. Introduction

1.1. Overview

The number of disasters linked to natural hazards continues to rise, exacting a significant toll on human lives, livelihoods, assets and economies. Over the past three decades (1975-2008), over 2.2 million people globally have lost their lives in natural hazard-induced disasters (excluding epidemics), with associated economic losses amounting to USD 1,527.6 billion.[5] Disaster impacts undermine livelihoods and progress towards poverty reduction and the Millennium Development Goals. Climate change and the expected increase in the frequency and intensity of extreme weather events will further magnify disaster risk associated with storms, floods, landslides and droughts.[6] From 1988-2007, 76 percent of all disaster events were hydrological, meteorological or climatological in nature, accounting for 45 percent of the total deaths and 79 percent of total economic losses caused by natural hazards.[7]

Greater investment in disaster risk reduction is clearly warranted. This calls for a whole spectrum of priority actions that compete for scarce resources and support from policymakers and decision makers. Why then should disaster risk reduction take into account ecosystems and ecosystem services? Is there value-added in applying ecosystems management for reducing disaster risk, including climate-related risk?

The 2004 Indian Ocean tsunami triggered global interest in promoting ecosystem management approaches for reducing disaster risk, placing increased international attention on the role of coastal ecosystems as natural shields against coastal hazards and resulting in major initiatives such as the Mangroves for the Future (MFF) Programme. In 2005, the Hyogo Framework for Action (HFA)[8], the first global agreement on disaster reduction, recognized the importance of sustainable ecosystems and environmental management in reducing disaster risk. The 2009 *Global Assessment Report on Disaster Reduction* identified ecosystems decline as one of four major drivers of risk[9] and called for greater protection and enhancement of ecosystem services, a message that was further reinforced at the Global Platform for Disaster Risk Reduction in June 2009.

Moreover, during the course of UNFCCC negotiations for a global climate agreement and in particular since the Conference of Parties (COP) in Copenhagen in 2009, ecosystem-based approaches have been recognized as a key climate change adaptation strategy. Sustainable ecosystems management is therefore increasingly viewed as an effective approach for achieving both disaster risk reduction and climate change adaptation priorities. For example, the World Bank recommends that adaptation programmes integrate an ecosystem-based approach into vulnerability and disaster risk reduction strategies.[10]

The sheer scale of risks posed by climate change and variability, in conjunction with globally widespread ecosystems decline, requires solutions that are cost-effective but also locally accessible and applicable. Ecosystems-based approaches that local communities already practice as part of their livelihood strategies and that clearly provide risk reduction services thus offer a good alternative. While ecosystems management is not a new concept, further evidence is still needed to build the case and demonstrate how ecosystems management can be maximized for disaster risk reduction and thus facilitate uptake by communities, disaster management practitioners, policymakers and decision makers.

1.1 Purpose and rationale for the study

This study aims towards developing a more robust understanding of ecosystems-based approaches to disaster risk reduction and contribute to the growing literature on this subject. Equally important is understanding *how* ecosystems-based DRR can be successfully applied. The study targets primarily policymakers who are responsible for setting development priorities and the disaster risk reduction community that is continually searching for effective and viable solutions to achieve substantial reduction in disaster losses. It also serves as a challenge to the environmental community to fine-tune existing tools and instruments so they can add value by reducing vulnerability to hazard impacts.

This study has been commissioned to serve as a supporting document for the 2011 *Global Assessment Report on Disaster Risk Reduction* (forthcoming), in which ecosystem services are recognized as an enabling mechanism for risk reduction.[11] Moreover, the first draft of this paper served as a background document for a workshop on "Ecosystems, Livelihoods and Disaster Risk Reduction", organized by the Partnership for Environment and Disaster Risk Reduction (PEDRR) in Bonn, Germany, on 21-23 September 2010. This final version of this study now reflects specific outcomes and recommendations from the PEDRR workshop in Bonn.

1.2 Focus and scope of the study

This study is largely a review of literature, supported by a compilation of selected case studies from around the world. It focuses mainly on ecosystem services and ecosystems-based approaches for disaster risk reduction, with emphasis on long-term planning and prevention. It synthesises the current state of knowledge and practice in ecosystems-based DRR and examines the following key questions:

- What is our conceptual understanding of ecosystems-based disaster risk reduction? What are the key elements?
- What are the available tools and entry points (opportunities) for promoting ecosystems-based DRR? How have they been applied, in which contexts?
- What are the limits and challenges in applying such integrated approaches?
- What are the enabling conditions and factors that facilitate effective implementation?

Although the literature review draws from experiences and case examples from around the world, it should not be considered an exhaustive study. The review is restricted to English language literature; without doubt more experiences in other languages are available from the various regions but are not captured here. It relies for the most part on published documents, although some "gray" or unpublished material is also used. It also utilizes articles from scientific or academic journals, although a comprehensive scientific review was beyond the scope of the study. The study provides an overview of this evolving field of work, but should be regarded as a work-in-progress, as concepts, ideas and applications continue to be developed and tested.

Section 2. Ecosystem Services and Disaster Risk Reduction

While the terms ecosystems and environment are related and often used inter-changeably in the literature, a distinction is made here between these two concepts. An *ecosystem* is a dynamic complex of living communities, including micro-organisms, plants, animals and humans, and their nonliving environment interacting as a functional unit in a given area.[12] Ecosystems are thus viewed as integrated human-ecological systems that work together to provide the range of goods and other benefits necessary to support life, livelihoods and human well-being. On the other hand, the term *environment* is often applied in a more generic sense, which can include ecosystems but also refer to the physical and external conditions, including both natural and human-built elements, which surround and affect the life, development and survival of organisms or communities.[13] In this paper, both terms are used but with a greater focus placed on ecosystems, as this perspective enables a more encompassing approach to the sustainable management of natural resources and ecosystem services for risk reduction.

2.1. Ecosystem services for disaster risk reduction

People derive indispensable benefits from nature, also referred to as ecosystem services. These include *provisioning* services, such as food, fuel and water; *regulating* services such as natural hazard mitigation, erosion control and water purification; *supporting* services such as soil formation and nutrient cycling; and *cultural* services such as recreational and other nonmaterial benefits.[14] "Sustainable ecosystems" or "healthy ecosystems" imply that ecosystems are largely intact and functioning, and that human demand for ecosystem services does not impinge upon the capacity of ecosystems to maintain future generations.[15] Unfortunately, approximately 60 percent of all ecosystem services and up to 70 percent of regulating services are being degraded or used unsustainably.[16]

It is suggested that the regulating services of ecosystems may form the largest portion of the total economic value of ecosystem services, although they are also, along with cultural services, the most difficult to measure in economic terms.[17] Some examples of the value of natural hazard mitigation are presented in Table 2.1, although it is important to note that ecosystem service values are often very context specific. For example, the role of a coastal vegetation to protect against extreme weather events can be vital or marginal, depending on the location of the community. In consequence, the value of a service measured in one location can only be extrapolated to similar sites and contexts if suitable adjustments are made.[18] In addition, it is often difficult to assess the full economic value of a given ecosystem, especially non-use values, but even approximate estimates can be useful to guide resource management decisions. The Economics of Ecosystems and Biodiversity (TEEB) report is an important attempt to address economic valuation of ecosystem services.

Table 2.1. Estimated economic value of ecosystem services for natural hazard mitigation[19]

Ecosystem	**Hazard**	**Hazard mitigation value (US$)**
Coral reefs (global)	coastal	189,000 per hectare/year[20]
Coral reefs (Caribbean)	coastal	700,000– 2.2 billion per year (total value)[21]
Coastal wetlands (United States)	hurricane	8,240 per hectare/year[22]
Coastal wetlands (United States)	storms	23.2 billion per year (total value).[23]
Lužnice floodplain (Czech Republic)	floods	11,788 per hectare/year[24]
Muthurajawela marsh (Sri Lanka)	flood	5 million per year (total value); 1,750 per hectare/year[25]
Coastal ecosystems (Catalonia,	disturbance	77,420 per hectare/year[26]

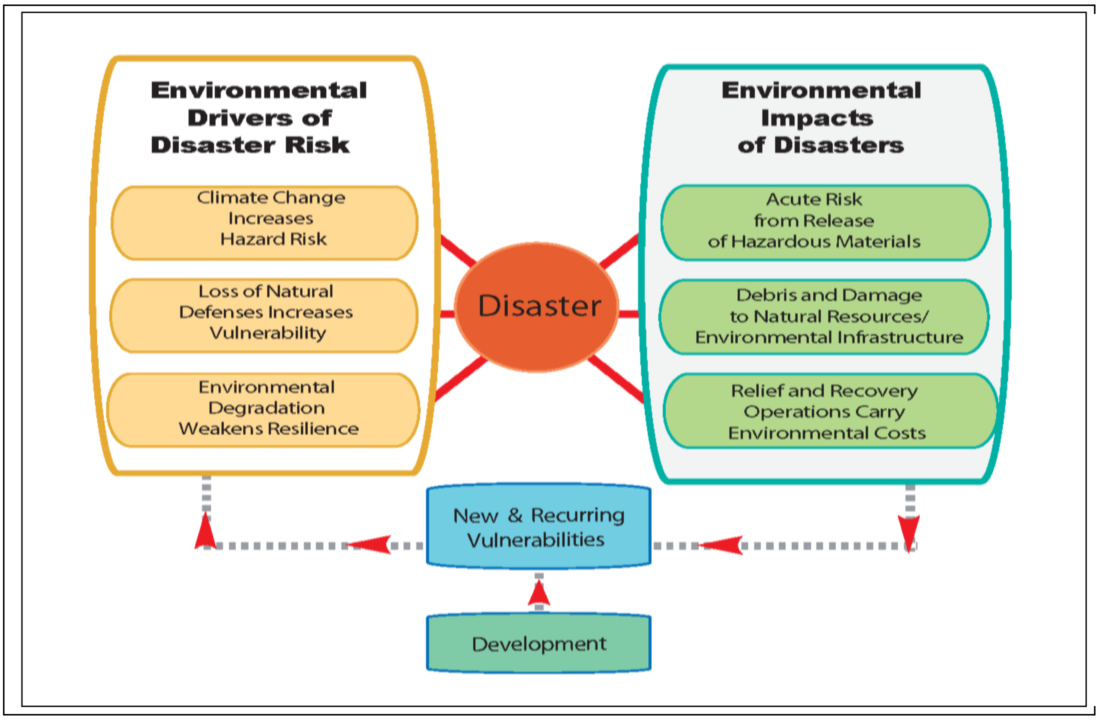
Spain)	protection, including storms	
Mountain forests (Switzerland)	avalanche	up to 170,000 per hectare/year in high-value built up areas[27]

2.2 Ecosystems, Livelihoods and Disasters

2.2.1 Understanding linkages between environment, disasters and development

That the environment, development and disasters are linked is now widely accepted. What is less understood is the multi-dimensional role of the environment in the context of disasters, and how environment-disaster linkages in turn are affected by and can also shape development processes and outcomes.[28]

Figure 2.1. Environmental causes and consequences of disasters[29]



Disasters can have adverse consequences on the environment and on ecosystems in particular, which could have immediate to long-term effects on the populations whose life, health, livelihoods and well-being depend on a given environment or ecosystem. Environmental impacts may include: (i) direct damage to natural resources and infrastructure, affecting ecosystem functions, (ii) acute emergencies from the uncontrolled, unplanned or accidental release of hazardous substances especially from industries, and (iii) indirect damage as a result of post-disaster relief and recovery operations that fail to take ecosystems and ecosystems services into account. As a result, pre-existing vulnerabilities may be exacerbated, or worse, new vulnerabilities and risk patterns may emerge especially in circumstances where there are cumulative impacts due to recurring natural hazards.[30]

On the other hand, environmental conditions themselves can be a major driver of disaster risk, as highlighted by the 2009 Global Assessment Report.[31] Degraded ecosystems can aggravate the impact of natural hazards, for instance by altering physical processes that affect the magnitude, frequency and timing of these hazards. This has been evidenced in areas like Haiti, where very high rates of deforestation have led to increased susceptibility to floods and landslides during hurricanes and heavy rainfall events.[32] In the US, the devastation caused by Hurricane Katrina in 2005 was exacerbated due to canalisation and drainage of the Mississippi floodplains, decrease in delta sedimentation due to dams and levees, and degradation of barrier islands.[33]

Environmental degradation also contributes to risk by increasing socio-economic vulnerability to hazard impacts, as the capacity of damaged ecosystems to meet people's needs for food and other products is reduced.[34] This was the case in Myanmar where pre-existing degradation of coastal vegetation limited livelihood recovery efforts following the devastating impacts of cyclone Nargis in 2005.[35] Poor communities are particularly affected, as their livelihoods depend heavily on natural resources and ecosystem services.[36] Appropriate management of ecosystems can therefore play a critical role in reducing vulnerability and enhancing resilience of local communities, as healthy socio-ecological systems are better able to prevent, absorb and recover from disasters.[37]

However, environment-disaster linkages can only be fully understood when situated in the broader context of development. Linkages between poverty and environmental degradation are already well-documented.[38] The poor often occupy fragile and marginal spaces, possess limited rights and entitlements over natural resources and are less capable of applying more sustainable resource use strategies. Similarly, the connections between poverty, development and increasing disaster risk are also now better understood; the poor suffer the highest casualties and generally have the least capacity to recover from disasters.[39]

Less well-recognized is how development processes in general create underlying vulnerable and unsafe conditions that are linked to ecosystems decline. For instance, urbanization and agricultural intensification have resulted in significant land cover and land-use changes as well as resource over-exploitation, increasing human exposure to hazards and undermining the ability of ecosystems to support livelihoods and continue providing services. Human-induced climate change will also significantly compromise ecosystems' structures and functions, weakening natural resilience against hazards.[40] Furthermore, as discussed above, disasters and post-disaster recovery interventions can adversely impact ecosystems and thus jeopardize the resource base needed for long-term development, including achievement of the Millennium Development Goals (MDGs).

2.2.2 Why do ecosystems matter in disaster risk reduction?

Many experiences from around the world point to the potential benefits of ecosystems for disaster risk reduction. It is argued that ecosystems contribute to reducing disaster risk in two important ways. First, ecosystems, such as wetlands, forests and coastal systems, can reduce physical exposure to natural hazards by serving as natural protective barriers or buffers and thus mitigating hazard impacts. Well-managed ecosystems can provide natural protection against common natural hazards, such as landslides, flooding, avalanches, storm surges, wildfires and drought.[41] For example, in the European Alps, mountain forests have a long history of being managed for protection against avalanches and rockfall.[42] In Switzerland national guidelines for protection forest management have been developed collaboratively with local forest managers and scientists, and the state provides financial incentives to manage forests for hazard protection.[43] Several countries in Europe, such as Germany, the Netherlands[44], the UK (case study 8), Eastern European countries bordering the Danube River (see Box 2.1), and Switzerland[45] aim to mitigate floods through "making space for water" initiatives that remove built infrastructure and restore wetlands and river channels to improve their water retention capacity. In the Bolivian Altiplano region, communities successfully reversed the trend of high erosion and frequent landslides through community-based reforestation and forest management (case study 1). Agroforestry and healthy coastal ecosystems were key in protecting communities in southern Mexico, when hurricane Dean hit the area in 2007 (case study 6). In Argentina, extensive areas of natural forest are protected for flood control, which is seen as a low-cost alternative to costly infrastructure, with added biodiversity benefits.[46]

Box 2.1 Danube Wetlands, Eastern Europe[47]

Most of Danube River floodplains have been converted to agriculture and other uses, leading to increased flood peaks and pollution. Climate change is expected to further exacerbate these problems. The Lower Danube Green Corridor seeks to restore 2,236 km^2 of floodplains in Bulgaria, Romania, Moldova and Ukraine in order to reduce vulnerability to flooding, improve water quality, and increase local incomes. Restoration will cost an estimated €183 million[48], much less than the €396 million damages caused by the 2005 flood alone, indicating the cost-effectiveness of the approach. Some of the restoration challenges have included the long time-lag in appointing national focal officials and agencies, developing national implementation plans and allocating funds by governments, as most of the funding has come from donor organisations. Making use of post-disaster policy windows is seen as a key entry point - floodplain restoration is viewed much more favourably following the 2005 and 2006 floods. In addition, international agreements for better water and river management (such as those of the European Union) have been drivers of change.

Following the 2004 Indian Ocean tsunami, numerous coastal reforestation projects were initiated in Asia to restore affected areas and to provide protection against coastal hazards, especially the more frequent events such as storms and cyclones. For example, Indonesia announced plans to reforest 600,000 hectares of depleted mangrove forest in five years, and Governments of Sri Lanka and Thailand launched large programmes to rehabilitate mangrove areas for coastal protection.[49] Multi-partner initiatives, such as the Green Coasts[50] and Mangroves for Future[51], have supported sustainable post-tsunami coastal development and resilience building with respect to hazards in the main tsunami-affected countries. While there remains considerable scientific debate regarding the tsunami mitigation potential of coastal ecosystems, their protection value against cyclones and regular storm surges are better-acknowledged. The Intergovernmental Oceanographic Commission (IOC) recommends that the potential of a variety of coastal ecosystems - coral reefs, sand dunes and coastal vegetation - should be harnessed for coastal protection, and acknowledges the importance and cost-effectiveness of natural infrastructure in mitigating lower magnitude (i.e. non-tsunami) coastal hazards and sustaining multiple uses of the coastal zone.[52]

Table 2.2. Hazard mitigation functions of ecosystems

Ecosystem	Hazard mitigation
Mountain forests and other vegetation on hillsides	o Vegetation cover and root structures protect against erosion and increase slope stability by binding soil together, preventing landslides.[53] o Forests protect against rockfall and stabilise snow reducing the risk of avalanches.[54] o Catchment forests, especially primary forests, reduce risk of floods by increasing infiltration of rainfall, and delaying peak floodwater flows, except when soils are fully saturated.[55] o Forests on watersheds are important for water recharge and purification, drought mitigation and safeguarding drinking water supply for some of the world’s major cities.[56]
Wetlands and floodplains	o Wetlands and floodplains control floods in coastal areas, inland river basins, and mountain areas subject to glacial melt.[57]

	o Peatlands, wet grasslands and other wetlands store water and release it slowly, reducing the speed and volume of runoff after heavy rainfall or snowmelt in springtime. o Coastal wetlands, tidal flats, deltas and estuaries reduce the height and speed of storm surges and tidal waves.[58] o Marshes, lakes and floodplains release wet season flows slowly during drought periods.
Coastal ecosystems, such as mangroves, saltmarshes, coral reefs, barrier islands and sand dunes	o Coastal ecosystems function as a continuum of natural buffer systems protecting against hurricanes, storm surges, flooding and other coastal hazards – a combined protection from coral reefs, seagrass beds, and sand dunes/coastal wetlands/coastal forests is particularly effective.[59] Research has highlighted several cases where coastal areas protected by healthy ecosystems have suffered less from extreme weather events than more exposed communities.[60] o Coral reefs and coastal wetlands such as mangroves and saltmarshes absorb (low-magnitude) wave energy, reduce wave heights and reduce erosion from storms and high tides.[61] o Coastal wetlands buffer against saltwater intrusion and adapt to (slow) sea-level rise by trapping sediment and organic matter.[62] o Non-porous natural barriers such as sand dunes (with associated plant communities) and barrier islands dissipate wave energy and act as barriers against waves, currents, storm surges and tsunami.[63]
Drylands	o Natural vegetation management and restoration in drylands contributes to ameliorate the effects of drought and control desertification, as trees, grasses and shrubs conserve soil and retain moisture. o Shelterbelts, greenbelts and other types of living fences act as barriers against wind erosion and sand storms. o Maintaining vegetation cover in dryland areas, and agricultural practices such as use of shadow crops, nutrient enriching plants, and vegetation litter increases resilience to drought.[64] o Prescribed burning and creation of physical firebreaks in dry landscapes reduces fuel loads and the risk of unwanted large-scale fires.

The second way in which ecosystems can lessen disaster risk is by reducing social-economic vulnerability to hazard impacts. While it is easy to focus primarily on ecosystems' protection and hazard regulatory functions, ecosystems also sustain human livelihoods and provide essential goods such as food, fibre, medicines and construction materials, which are equally important for strengthening human security and resilience against disasters. For example, in addition to providing coastal hazard protection, mangroves, coral reefs and seagrass beds are generally important resources for local livelihoods, as they support fishing and tourism activities.[65] In China, wetlands are being restored to achieve flood prevention while providing other social and economic benefits that can reduce vulnerability to hazard impacts (Box 2.2). In Mexico, the World Bank is undertaking a large-scale coastal wetland and mangrove swamp restoration project to address coastal protection against hurricanes, saltwater intrusion due to sea-level rise as well as water supply and food production to communities.[66]

Moreover, in post-disaster contexts, affected communities especially in poor, rural areas often turn to their surrounding environment to meet immediate needs (food, water, shelter). Ecosystems and the resources they provide thus form an essential part of local coping and recovery strategies. In Negril, Jamaica, following a major storm, a local fishing community relies heavily on groundwater springs when floodwaters cut off their potable drinking water supply; maintaining water quality of unprotected springs would help reduce people's vulnerability to waterborne-diseases associated with floods (case study 11). This important role of ecosystems in supporting local recovery is generally poorly acknowledged in post-disaster interventions as well as in long-term prevention strategies.

Box 2.2 Restoring wetlands for flood mitigation and local development[67]

In Hubei Province, a wetland restoration programme by WWF and partners reconnected lakes to Yangtze River and rehabilitated 448 km^2 of wetlands with a capacity to store up to 285 million m^3 of floodwaters. The local government subsequently reconnected further eight lakes covering 350 km^2. Sluice gates at lakes have been seasonally re-opened, and illegal aquaculture facilities have been removed or modified. Local administration has designated lake and marshland areas as nature reserves. In addition to contributing to flood prevention, restored lakes and floodplains have enhanced biodiversity, increased income from fisheries by 20-30% and improved water quality to drinkable levels. While central government was principally concerned to reduce flood risk, local communities and governments were motivated by better access to clean water and increased incomes. Working in partnership with government agencies has ensured that new practices are mainstreamed in daily operations, and similar measures are adopted in other areas.

Well-managed ecosystems are considered more resilient to the impacts of extreme events and are able to recover more effectively than degraded ecosystems.[68] However, it is important to recognise that ecosystems also have limits in providing physical protection against hazards. Other factors come into play that affect ecosystem performance, such as ecosystem composition (stand size, density, species) and health, and the type and intensity of the hazard event.[69] For example, forests do not seem to protect against large-scale flooding from severe events such as tropical cyclones or tsunami.[70] A small narrow belt of coastal vegetation has limited effects against major disturbances like cyclones.[71] While the force of tsunamis may, in many cases, be too strong for coastal vegetation – just like for most seawalls – natural buffers nevertheless offer important protection against storms, extreme waves and other more frequent coastal events, as well as provide valuable livelihood benefits to local communities. [72]

Sometimes a hybrid approach, combining both natural and 'hard' defences may be most effective. For example, wetlands can be used to reduce wave action to protect levees from storm surges, increasing the effectiveness and lifespan of levees. It is important to weigh the value-added of applying or mixing various alternatives. Especially in the context of extreme events and climate change and variability, human-built infrastructure may not be feasible due to the high costs and technology requirements of adaptation. In many cases, maintaining and restoring ecosystems as natural infrastructure can offer high benefit-cost ratios compared to engineered infrastructure, when taking into account the full range of benefits provided by ecosystems.[73] For example, coastal green belts or wetlands as natural buffers are often less expensive to install and maintain than human-built infrastructure, such as dykes or concrete walls, while also providing supplementary ecosystem services that support local livelihoods. In other cases, natural buffers are not feasible due to biological limitations, space constraints, incompatibility with priority land uses or prohibitive costs; therefore, hard infrastructure may be required to provide the necessary protection. On the other hand, conventional engineering solutions may also generate adverse environmental impacts, such as altering sedimentation patterns, may provide a false sense of security, and may fail dramatically, amplifying disaster damage.[74]

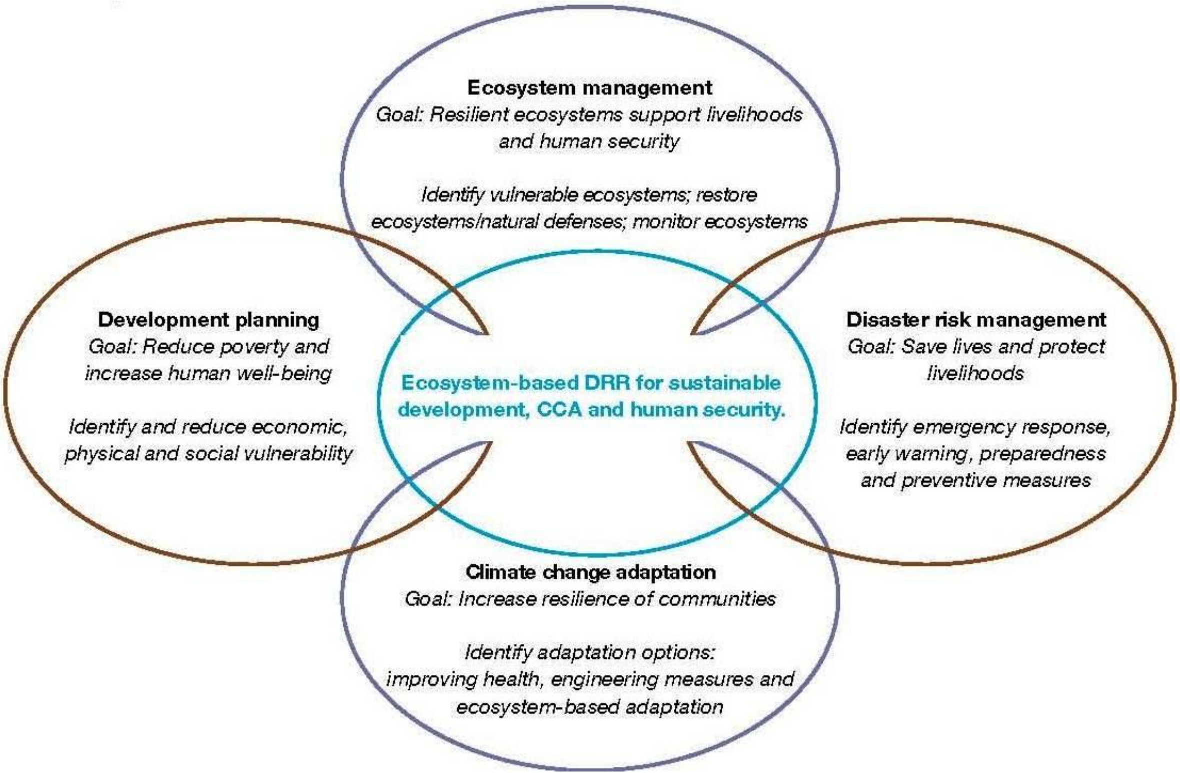
Efforts to establish causal relationships between environmental degradation and increased disaster risk have been documented in scientific literature, but this topic is also debated amongst scientists as well as practitioners. Draining of fertile floodplains for agriculture and settlement, and channelling of rivers have increased the risk of floods.[75] Other studies have demonstrated how deforested slopes are more susceptible to erosion and landslides[76], and coastal areas with degraded or no vegetation are more exposed to waves and storms. In the Caribbean, over 15,000 km of shoreline could experience a 10–20 percent reduction in wave and storm protection by 2050 as a result of reef degradation.[77] Case study 10 describes how removal of vegetation and road construction increased landslide susceptibility following the 2005 Pakistan earthquake. In addition, overgrazing and deforestation are viewed as major drivers of large-scale desertification processes in drylands, such as in the Sahel, Central Asia and the United States.[78] However, environmental degradation is often only one of many contributing factors to disaster risk, along with climate change, increase of human settlements in marginal areas and other factors.

Finally, challenges remain in measuring ecosystem thresholds or levels of resilience to various hazards, in other words how much impact or change inflicted by a certain hazard can an ecosystem absorb. This is important to assess the risk reduction potential of a given ecosystem and estimating the impact of environmental changes.[79] There are clear knowledge gaps in assessing ecosystem capacity to maintain services over time, especially in the context of changing environmental conditions and disturbances.[80] Natural buffers therefore need to be considered within the framework of overall disaster management strategies, where effective early warning systems and evacuation plans still have a primary role in disaster preparedness and mitigation.

2.3. Integrating ecosystem management and disaster risk management

Four previously separate institutional spheres need to converge to establish new working arrangements that facilitate integrated disaster risk management (Figure 2.2). Ecosystem management provides the unifying base for promoting DRR and climate change adaptation, with the overall goals of achieving sustainable development, human well-being and livelihood security. While there has been improved dialogue and coordination between these various spheres, more effort is needed to achieve greater convergence.[81] Ecosystem management initiatives could be enhanced by including disaster risk and climate change considerations, while DRR, climate change adaptation and development planning need to recognize the potential of harnessing ecosystem services and also address vulnerability linked to ecosystem degradation.

Figure 2.2. Ecosystem-based disaster risk reduction, a more sustainable approach to DRR and climate change adaptation (CCA).[82]


Ecosystem management
Goal: Resilient ecosystems support livelihoods and human security
Identify vulnerable ecosystems; restore ecosystems/natural defenses; monitor ecosystems
Development planning
Goal: Reduce poverty and increase human well-being
Identify and reduce economic, physical and social vulnerability
Ecosystem-based DRR for sustainable development, CCA and human security.
Disaster risk management
Goal: Save lives and protect livelihoods
Identify emergency response, early warning, preparedness and preventive measures
Climate change adaptation
Goal: Increase resilience of communities
Identify adaptation options: improving health, engineering measures and ecosystem-based adaptation

2.4 Overview and trends towards integration of environment and disaster risk reduction policies

Around the world, international financial institutions (IFIs), aid and development agencies, governments and civil society organizations are paying greater attention to the importance of integrated environment and disaster risk reduction policies and programmes.

At a global level, a number of IFIs and bilateral agencies have already mainstreamed disaster risk reduction in environmental policies. For example, the World Bank's Environment Strategy explicitly aims to reduce vulnerability to natural hazards, through supporting upland resource management and managing land and coastal zone resources. The EU's Water Framework Directive establishes a common strategy amongst EU countries to address water-related hazards, such as flooding and drought, through ecosystem-based approaches, such as river basin management to reduce flood risk. Since 2003, the Swedish International Cooperation Development Agency (SIDA) has been implementing SwedBio, a multi-stakeholder programme that seeks to protect and enhance biodiversity as a basis for strengthening ecosystem resilience against natural hazards, including those induced by climate change and variability.[83] SwedBio promotes the conservation of mangrove forests and coral reefs as part of coastal zone management, upland forestry initiatives and wetland management.

On the other hand, other agencies have strengthened the environmental components of their disaster reduction and climate change adaptation portfolios. Australian Aid (AusAid)'s disaster reduction policy explicitly recognizes the importance of ecosystems, such as mangroves, coral reefs and forests, in reducing the impacts of and exposure to natural hazards. The EU's strategy for disaster risk reduction in developing countries aims, among other key components, to reduce underlying risk factors linked with poor natural resource management and environmental degradation. Finally, the Inter-American Development Bank (IADB)'s disaster risk management policy recognizes how environmental degradation is linked with vulnerability to natural hazards.

At a regional level, a number of intergovernmental fora have articulated strong support for integrated disaster risk reduction approaches. For instance, at the 10th session of the African Ministerial Conference on the Environment (AMCEN) in June 2004, African environmental ministers adopted the Africa Regional Strategy for Disaster Risk Reduction. The Programme of Action for the implementation of the Africa Regional Strategy (2006-2015) adopted in April 2010 calls for increased integration of disaster risk reduction concerns in priority sectors including the environment. In the Asia and Pacific region, during the 5th Ministerial Conference on Environment and Development in March 2005, delegates endorsed the protection of natural barriers as a risk mitigation strategy, in conjunction with national and regional early warning and disaster preparedness systems.

At country level, national policies that integrate environment and disaster risk reduction are more pronounced in developed than in developing states. Many of them are featured in this paper, including the Netherlands's river floodplain policy, the UK's "making space for water" initiative (case study 8), the United States' wetland restoration programme in Louisiana and Mississippi, and Switzerland's and Japan's forest protection policies. Amongst developing states, Sri Lanka is credited for its landmark Road Map for Disaster Risk Reduction that specifies a range of activities that integrate both risk reduction and environmental management objectives. These include incorporating disaster impact assessments within environmental impact assessments and promoting "natural barriers" for coastal protection, such as the establishment of coastal vegetation or green belts.[84]

Section 3. Environmental instruments and approaches for DRR

This section provides an overview of the full range of environmental tools and instruments available that could be used to integrate environmental concerns and ecosystems-based approaches as part of disaster risk reduction. These tools include the following:

- √ Environmental assessments;
- √ Integrated risk and vulnerability assessments;
- √ Protected area management;
- √ Integrated ecosystems management (such as integrated water resource management, integrated coastal zone management, integrated fire management, sustainable land management); and
- √ Community-based sustainable natural resource management.

3.1 Integrating Disaster Risk Reduction in Environmental Assessments

3.1.1 Introduction

Environmental assessments have become important tools to support planning decisions. They are generally used to review proposed projects, plans, programmes or policies and examine their potential environmental impacts (both beneficial and adverse), enabling decision-makers to examine trade-offs, consider mitigation measures and alternatives. It is essential that environmental assessments also address disaster risk.[85] Proposed initiatives or policies may have negative environmental consequences that exacerbate risk, while pre-existing vulnerability to natural hazards can pose a threat to planned investments.

Wide scope exists for adapting and enhancing environmental assessment tools so they safeguard natural capital and improve human-ecological resilience against disasters. Applying integrated environmental assessments ensure that disaster risk reduction is considered from the outset during the appraisal stages, which better informs the formulation of projects, programmes or policies.

3.1.2 Environmental assessment tools

Environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) are the best-known tools for undertaking environmental assessments to inform policy, programme or project development. They allow information on social, economic and environmental impacts to be considered, resulting in a much more integrated assessment process. While practical experience remains very limited, EIAs and SEAs are being adapted to analyze disaster risk-related factors associated with the potential threats to and consequences from proposed projects, programmes, plans or policies.

The following describes a common set of actions required to ensure that disaster risk concerns are adequately addressed and managed during the environmental assessment process:[86]

1. *Data collation*: Collect data on natural and human-made (i.e. technological/industrial) hazards and associated risks, including those related to climate change and variability. Simultaneous collection of environmental baseline data, including identification of critical natural resources (e.g. water, wildlife habitats, sources of building materials) and ecosystems that provide important hazard regulating services. Multi-hazard risk maps may be developed and overlaid with environmental baseline information.

2. *Analysis of environmental vulnerabilities as an underlying component of risk*: Identify the environmental factors, e.g. degraded ecological resources and functions, geology, soil properties,

hydrology, climate regime etc. that aggravate vulnerability of people, their assets and environment to natural hazards, which in turn can pose a threat to proposed projects, programmes or plans.

3. *Analysis of the potential consequences of a project, programme or policy in terms of increasing disaster risk as a result of its impact on the environment*: Identify the potential environmental impacts that increase vulnerability, based on different hazard and risk scenarios.

4. *Evaluation/Assessment:* Identify and assess alternatives based on applying environmental sustainability criteria and different scenarios (e.g. climatic changes, natural hazard events and human-induced hazards); identify and assess the mitigation options to reduce both potential environmental impacts and underlying vulnerabilities; select preferred option; and determine feasibility (i.e. whether financial and human resources are sufficient to implement mitigation measures).

5. *Account for uncertainty*: Given the high level of uncertainty associated with assessing environmental impacts, the "precautionary principle" is applied where impacts on ecosystems cannot be predicted with confidence due to limited knowledge of ecosystem resilience thresholds, and/or where there is uncertainty about the effectiveness of mitigation measures.[87]

6. *Monitoring*: Regular monitoring and review of risk and vulnerability data along with environmental sustainability criteria following approval of projects, plans or programmes. Develop indicators and institutional capacity for carrying out monitoring and evaluation and determine how they will be used and tracked.

Environmental impact assessments (EIAs)

EIAs assess the likely environmental impacts of a proposed project, consider mitigation measures, and present the projections and options to decision-makers. Efforts to mainstream disaster risk reduction in EIAs have been spearheaded by the Caribbean Development Bank (CDB) and the Caribbean Community (CARICOM).[88] Together they have produced a sourcebook for integrating natural hazard concerns, including potential climate change impacts, into the application of EIAs at country level.[89] It sets out ten basic steps to merge disaster risk consideration into EIAs, which in effect provides a framework for defining acceptable thresholds of risk based on environmental sustainability criteria. The CDB has field-tested the new EIA guidelines in their own projects, while Grenada and Trinidad and Tobago have already incorporated proposed changes in their EIA processes.[90]

Strategic environmental assessments (SEAs)

In contrast to EIAs, SEAs generally have a broader focus.[91] It is a tool for integrating environmental considerations into policies, plans or programmes at the earliest stages of strategic decision-making.[92] It may be applied to a specific sector or geographical area and ideally prior to the identification and design of individual projects. SEAs have different variants, such as country environmental analysis (CEA), regulatory impact analysis (RIA), sustainability impact assessment (SIA) and integrated assessment (IA) for sustainable development.

SEAs can provide an important opportunity to highlight natural hazard-related issues and ensure they are considered in weighing alternative development scenarios. The OECD has developed general guidance on integrating disaster risk reduction considerations into each major stage of the SEA process, from data collection through to analysis of potential risks and impacts of different alternative options and monitoring of policies, plans or programmes.[93]

However, applied cases of SEAs that explicitly address disaster risk reduction still remain very limited, with few examples documented in the literature. The Asian Development Bank (ADB) in particular has applied CEAs in hazard-prone countries where risk considerations are taken into account in the assessment process. For example, in Cambodia the ADB found that its support of irrigation infrastructure development could not be considered in isolation from other proposed government and donor irrigation projects due to their cumulative environmental impacts, as large irrigation schemes and water withdrawal would alter water flows and flooding patterns.[94] A related ADB-supported CEA in Tajikistan identified natural hazards, including drought, landslides and earthquakes, as one of the country's key environmental problems and promoted environmental management as a way to reduce vulnerability to hazards.[95] In Sri Lanka, the Government in collaboration with UNDP and UNEP is undertaking an integrated strategic environmental assessment (ISEA) process that takes into account major hazards (storm surges, flooding, strong winds, sea level rise and tsunami) in defining a sustainable development framework for post-conflict rebuilding in the Northern Province (case study 7).

Rapid environmental assessments (REAs)

REAs are generally applied to assess the environmental situation in the aftermath of a disaster and quickly provide data to support decisions, paying close attention to water and sanitation, potable water supplies, solid and disaster debris management, safe handling of hazardous substances, site selection of temporary camps, and procurement of building materials. The REA process is usually designed to provide non-specialists with the tools to identify emerging environmental issues. While the focus is on protecting human health and security, REAs can early on obtain information on the general status and location of critical ecosystems in the affected area to avoid further potential damage as a result of post-disaster operations, which could then impede recovery.[96]

3.2 Integrated Risk and Vulnerability Assessments

3.2.1 Introduction

Reducing disaster risk encompasses a wide portfolio of measures that aim to reduce exposure and vulnerabilities of people and assets to natural hazards. These measures include among others early warning systems, emergency preparedness, public education, land-use planning as well as environmental protection. Each of these efforts often requires detailed risk information that anticipates the potential hazard impacts.

Although many risk and vulnerability assessment methodologies are now available, most do not adequately identify the changes to risk and vulnerability that are attributable to ecosystem conditions and environmental change, including climate change.[97] As a result, assessment methodologies often fail to identify critical aspects of risk and vulnerability affected by ecosystem conditions and thus do not sufficiently address environmental risk drivers nor consider ecosystem-based risk reduction options.

This section focuses on integrated risk and vulnerability assessments that explicitly assess in various ways the environmental dimensions of risk and vulnerability. Emphasis is placed on understanding the role of ecosystems and ecosystem degradation in influencing vulnerability and how different methodologies attempt to evaluate the "ecosystem factor" in disaster risk.

3.2.2 Overview of risk and vulnerability assessment frameworks

A risk assessment or risk analysis generally consists of undertaking both hazard analysis and vulnerability analysis, which may also include analysis of coping capacities. However, conceptual frameworks and practical guidelines on integrating ecosystem or environmental components as part of risk and vulnerability assessments have only recently emerged, and many require additional field-testing and refinement.

Nonetheless, a tangible paradigm shift has taken place towards developing more holistic concepts of vulnerability that recognizes its multi-dimensional and dynamic character.[98] Emphasis is placed on moving away from a predominantly hazard-oriented analysis and towards understanding the complex interaction between hazard events and the range of conditions that influence susceptibility to hazard impacts and capacity to cope and recover. This set of conditions may include the physical, social, economic, environmental, institutional and/or political features in a given community or society.

The push for more integrated vulnerability assessments is being driven by broader efforts in poverty reduction and sustainable livelihoods, disaster risk reduction (especially in the context of the Hyogo Framework for Action) as well as climate change adaptation. Unfortunately, there are multiple definitions, concepts and methods to systematize vulnerability.[99] Several conceptual frameworks explicitly assess environmental vulnerability but in varying degrees and approaches. These include the sustainable livelihoods framework[100], double structure of vulnerability framework[101], the Pressure and Release (PAR) model[102], Turner et al.'s vulnerability framework[103], and the "BBC" framework.[104]

The practical value of such integrated assessment frameworks lies in their application as a "meta-framework" that conceptually defines the main elements from which specific indicators could be identified to measure vulnerability. While describing each of these frameworks in detail is beyond the scope of this paper, some are elaborated further below.

3.2.3 Assessing environmental dimensions of risk and vulnerability

A wide variety of tools, guidelines and approaches are now available to assess the environmental dimensions of risk and vulnerability. They may be applied at a micro-scale or community-level, or at a more macro-scale covering a larger geographic area. However, based on the literature reviewed, applications are generally intended for local-level analysis, given the detailed information required and the often context-specific character of vulnerability.

Moreover, as with risk assessments in general, there is wide and increasing use of computer assisted techniques and quantitative methodologies, such as those based on Geographic Information Systems (GIS), remote sensing (i.e. satellite imagery analysis, use of aerial photographs), modelling and statistical analysis. Qualitative approaches, for instance based on social surveys, focus group discussions and participatory techniques (e.g. community mapping), nonetheless, remain prevalent. Combined qualitative and quantitative approaches are also being applied to strengthen and validate results and improve stakeholder engagement or ownership of the process (case study 11).

It is important to note, however, there are yet no uniform standards, guidelines or indicators for measuring the environmental dimensions of vulnerability. The following examples below survey experiences in applying integrated risk or vulnerability assessment approaches.

Measuring the protective functions of ecosystems

Integrated vulnerability assessments can focus on estimating the protective effects of ecosystems with respect to hazard mitigation or prevention. In this regard, the type and status of ecosystem services for hazard regulation or protection are regarded as one measure of vulnerability. For example, in western

Jamaica, UNEP pilot tested a methodology that quantified through spatial and statistical modelling the role of coral reefs and seagrass in minimizing beach erosion (case study 11). The assessment found that coral reefs and seagrass beds are the main factors mitigating against beach erosion and storm surge impacts, while at the same time pointing to increasing risk of beach erosion (and associated flooding) that is aggravated by coastal ecosystem degradation.

In another study, UNEP GRID-Europe concluded that the mitigating role of mangroves and coral reefs against tsunami waves could not be demonstrated, citing other environmental parameters such as seafloor topography, geomorphology of slopes and distance from the origin of the tsunami as influencing vulnerability to tsunami impacts (case study 12). This study highlights that the protective effects of coastal ecosystems must be evaluated against the type and scale of hazard and other site-specific conditions.

In southern Honduras, a landslide hazard assessment demonstrated through GIS analyses that the likelihood of landslides was significantly influenced by slope and type of land cover.[105] On steeper slopes, the percentage of land affected by landslides increased sharply on land used for crop production, indicating that in these sites associated removal of deep-rooted permanent vegetation increased landslide risk. On the other hand, areas covered by shrub fallow and forests had relatively low incidence of landslides regardless of the topographic features. In a similar study, Peduzzi (2010) carried out an assessment of landslides induced by earthquakes following the 2005 earthquake in Northern Pakistan. While steepness of the slopes and proximity to the active fault are the two main factors in this area influencing susceptibility to landslides triggered by earthquakes, the study showed that areas covered by denser vegetation suffered less and smaller landslides than areas with thinner (or devoid of) vegetation cover (case study 10).

Assessing environmental conditions as one component of vulnerability

In other assessment approaches, environmental conditions are regarded as only one of several inter-linked components of vulnerability. For example, Kaplan, Renaud and Lüchters (2009) apply the Turner et al. vulnerability framework in their analysis of post-tsunami impact and recovery in southern Sri Lanka (case study 13). In the Turner et al. framework, vulnerability is viewed in the context of a linked human-ecological system. In the case of southern Sri Lanka, the extent and condition of coastal vegetation was regarded as one major factor contributing susceptibility to tsunami impacts, concluding that different vegetation classes reduced tsunami impacts while others did not. However, other components were considered, including exposure (i.e. distance to the sea, coastal topography), occupation and income.

Assessing environmental conditions is particularly relevant for local communities that are heavily reliant or dependent on specific ecosystem services, such as water supply, especially during or after a disaster, thus representing a major component of local vulnerability (also discussed in Section 2.2.2, see case study 11).

Assessing environmental vulnerability or the potential environmental impacts of hazards

Other assessment approaches focus on the vulnerability of the environment or ecosystem itself to natural hazards. These approaches measure or evaluate the potential adverse impacts on the environment, natural resources or ecosystems, and how these impacts in turn contribute to vulnerability.

For example, CRiSTAL is a community-based tool that enables users to better understand the linkages between climate-related risks and people's livelihoods and enhance project activities to increase local adaptive capacity to climate change.[106] In analyzing the local livelihood context, users are asked to identify the main resources that people's livelihoods depend on and assess the potential impacts of climate-related hazards on these resources. CRiSTAL applies some elements of the sustainable livelihoods framework which divides livelihood resources into five categories: natural, physical, financial, human and social. In CRiSTAL, natural assets are defined as the natural resource stock upon which people rely both directly (i.e. for income or food products) or indirectly (i.e. flood control, storm surge protection), which could include ecosystems (i.e. coral reefs, mangrove forests) or simply natural assets (i.e. clean air, land, fuelwood). The identified potential impacts of climate-related hazards on livelihood resources are then taken into account when planning project activities to enhance coping and adaptive strategies.

Other tools include CARE's *Climate Vulnerability and Capacity Analysis Handbook* (2009) that also assesses hazard impacts on each of the five categories of livelihood resources, the *Vulnerability and Impact Assessments for Adaptation to Climate Change* (VIA Module) that assesses climate change impacts on ecosystems and human well-being[107]. In addition, FLOOD*site*'s integrated flood risk analysis and management methodology determines flood risk based on a hazard analysis as well as a vulnerability analysis that assesses potential flood damage according to pre-identified economic, social and ecological criteria.[108]

3.3 Protected area management

Protected areas encompass a wide range of ecological spaces and include national parks, nature reserves, wilderness areas, wildlife areas, protected landscapes as well as community conserved areas, with differing governance systems.[109] Over 120,000 designated protected areas now cover approximately 13.9 percent of the Earth's land area. [110] Marine protected areas cover 5.9 percent of territorial seas and 0.5 percent of the high seas and are gradually increasing in number and size.[111]

Although protected areas are expanding globally, under-protection and significant encroachment of protected areas are leaving many sites extremely exposed and vulnerable to hazards. Protected area professionals therefore need to consider the added value of protected areas for disaster prevention and mitigation when planning, managing and advocating for protection.[112]

3.3.1 Measuring the benefits of protected areas for risk reduction

Risk reduction services from protected areas

Although protected area management is commonly associated with nature conservation and tourism, history shows that human societies have long-practiced principles of protected area management for its multiple benefits, such as for hunting, cultivation and grazing as well as for their buffering effects against natural hazards. For instance, Japan introduced forest protection in the 15th and 16th centuries as a countermeasure against landslides, and today it has 17 designated uses of protection forests, 13 of which is related to mitigating or preventing hazard events.[113] Protected areas not only safeguard biodiversity but also economic and social well-being.[114]

Protected areas play an important role in hazard regulation, which can apply to both slow onset (e.g. desertification, soil erosion), sudden onset (e.g. floods, landslides) and recurring hazards. For instance, in an effort to combat desertification, the Dana nature reserve in Jordan restricted animal grazing to naturally regenerate vegetation and stabilize soils.[115] The Whangamarino Ramsar site in New Zealand contains protected wetlands and swamps that serve as natural reservoirs against floods by containing excess rain and run-off and thus reducing flood peaks.[116] In Switzerland, protected forests have been recognized over the last century for their role in mitigating impacts from avalanches, rock falls and landslides.[117] In eastern Madagascar, the Mantadia National Park protects upland forests and watersheds which reduces flooding damage to lowland agrarian communities.[118]

Table 3.1 Risk reduction benefits provided by protected areas[119]

Hazard	**Services provided by protected areas**
Flooding	• Provide space for floodwaters • Absorb impacts of floods with natural vegetation • Block sudden storm surges and sudden incursions of sea water (for coastal and marine ecosystems)
Landslides and avalanches	*In certain circumstances:* • Retain natural vegetation (e.g. forests) that helps to stabilize soil • Tree crowns reduce the uniform build-up of snow that triggers slippage • Slow the movement and extent of damage once slippage is underway
Drought and desertification	• Reduce pressure (especially grazing pressures) on land and thus reduce or slow down desert formation • Maintain populations of drought resistant plants to serve as emergency food during drought
Fire	• Limit human encroachment into the most fire-prone areas • Maintain traditional cultural management systems that apply ecologically sound and safe fire use and wildfire control • Protect intact natural systems with associated natural fire regimes that ensure short- to long-term ecosystem stability
Hurricanes / typhoons	• Mitigate floods and landslides • Buffer communities and assets against the impacts of storms (e.g. coastal and marine ecosystems can reduce the impact of storm surges and sudden incursions of sea water)
Earthquakes	• Prevent or mitigate against associated hazards especially landslides and rock falls • Provide zoning control to prevent settlement in the most earthquake prone areas
Climate change and unpredictable events	• Mitigate climate change-induced hazards and other extreme events, such as more frequent or intense flooding, droughts, wildfires, and worsening storm surges dues to sea level rise

Protected areas also mitigate against coastal hazards, such as tropical storms and cyclones and their associated hazards (e.g. storm surges, flooding). For example, coral reefs in Hawaii’s Hanauma Bay Marine Life Conservation District protect the beach from erosion by absorbing wave energy.[120] In the Seychelles, the Aldabra marine protected area contains reefs, mangroves and seagrass that mitigate coastal erosion and storm surge and maintain and replenish the beach.[121] In China’s Zhanjiang Mangrove National Nature Reserve, mangroves are estimated to absorb up to 80 percent of the wave energy during storms and typhoons, in addition to other benefits such as coastal protection and water filtration.[122]

However, it is also important to recognize how protected areas contribute towards social and economic well-being.[123] Protected areas support local livelihoods: Nearly 1.1 billion people globally or one-sixth of the world’s population currently depend on protected areas for their livelihoods.[124] Many rural communities directly subsist on products obtained from protected areas, while urban areas also clearly benefit, for instance deriving their water supply from protected watersheds.

As with well-managed ecosystems in general, protected areas enable nearby communities to better cope with hazard events through the provision of critical products (food, water, fuel and building materials) especially during emergency and post-disaster phases. Moreover, protected areas mitigate climate change-related risks through carbon sequestration and protect against river fragmentation, wetland loss, forest degradation and deforestation.[125] For instance, according to Parks Canada, the amount of carbon stored in Canada’s 39 National Parks is estimated to amount to 4,432 million tons with a value of over CAD 70 billion.[126]

Valuation of risk reduction services from protected areas

The challenge is to demonstrate the total value of a protected area and specifically its added value for disaster risk reduction. In practice, it is difficult to measure the full benefits of a protected area, as they are disbursed over many beneficiaries and over a longer time horizon. Many benefits from protected areas such as hazard mitigation, carbon storage and maintenance of genetic diversity have no market value, and are therefore poorly appreciated.[127] In contrast, the costs of protection are generally incurred over the short-term and remain concentrated, and these include management costs, loss of access to natural resources, human displacement and foregoing alternative uses.[128] Costs are therefore perceived to be greater than benefits.

Protected area managers today often use economic valuations to quantify the values of the goods and services provided by protected areas.[129] However, measuring the indirect benefits such as flood control and climate regulation is less straightforward than assessing direct benefits derived from protected areas such as income generated from protection, for instance through tourism or crop productivity.[130] Nonetheless, efforts to valuate in monetary terms protection benefits are continuously being applied and improved.[131]

3.4 Integrated ecosystem management tools

Integrated management of ecosystems, such as forests, drylands, wetlands, floodplains, coral reefs, sand dunes and coastal forest offers several entry points for including risk management considerations. In this section, several already well-established integrated ecosystem management approaches are discussed. These instruments provide an opportunity to address issues such as ecosystem degradation, natural hazards (landslides, floods, drought, wildfire), livelihoods, and resource use and access in a holistic and collaborative manner, involving a wide group of stakeholders (e.g. government, local community, and civil society).

3.4.1 Integrated water resource management (IWRM)

Integrated water resource management (IWRM) is a process, which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.[132] IWRM provides a framework for negotiating between different, often competing water users and ensures the balance between economic efficiency (allocating scarce water resources to different sectors), social equity (access and benefiting from water use), and environmental sustainability (protecting aquatic ecosystems and the water resource base).[133]

In terms of disaster risk reduction, IWRM is relevant for managing both excess water (i.e. flood and landslide mitigation) and water scarcity (i.e. drought management). *Integrated watershed management* (IWM) and *integrated river basin management* (IRBM) may also be addressed through a broader IWRM approach, seeking to integrate conservation, development and optimal utilisation of available water resources at the watershed or river basin level. IWRM approaches can help to build a strong flood mitigation strategy by combining sustainable management of ecosystems (restoration of wetlands, forest and river basin management) with overall land-use planning for the area. It can also be particularly useful in managing transboundary river basins and watersheds, such as in the case of the Alpenrhein River that runs through Switzerland, Austria and Lichtenstein[134], and the watershed border area of Mexico and Guatemala (see Box 3.1).

Box 3.1. International transboundary watershed management for DRR in Mexico and

Guatemala[135]

In 2005, Hurricane Stan caused severe flooding and mudslides in Guatemala and Mexico, with over 2,000 deaths and material damages of up to USD 40 million. Roads, bridges, water supply systems, crops and other livelihood assets were destroyed. The devastation served as a catalyst to reduce the impact from future hurricanes.

IUCN and partners initiated an integrated watershed management programme on the border area between the department of San Marcos, Guatemala, and the state of Chiapas, Mexico, encompassing the watersheds of the Suchiate, Coatán and Cahoacán Rivers. Through ecosystem restoration, such as soil conservation and sustainable agricultural practices, the project aims to reverse watershed degradation, secure water supply to settlements, agriculture and livestock downstream, and reduce the risk of devastating floods caused by tropical storms and hurricanes. The project also seeks to ensure that local authorities and natural resource-dependent people have tools and information to develop and implement water resource management plans. The project promotes multi-stakeholder participation, and local communities are now organized into micro-watershed councils that have developed micro-watershed management plans for villages. A river basin committee for the Cahoacán River has also been established.

3.4.2 Integrated coastal zone management (ICZM)

In coastal areas, *integrated coastal zone management* (ICZM) (also, 'integrated coastal area management' - ICAM) provides a multi-sectoral framework for the sustainable management of coastal zones and resources. It considers fragility of coastal ecosystems, the entire spectrum of cross-sectoral uses, their impacts and the trade-offs needed to ensure sustainable development.[136] As with IWRM, ICZM seeks to enhance dialogue between different stakeholders, and consolidate economic, social and cultural development goals while ensuring environmental sustainability and ecosystem integrity of the coastal zone.

Globally, there are increasing applications of ICZM, providing an opportunity to link disaster risk reduction to wider sustainable natural resource management and livelihood goals in coastal areas.[137] Numerous country-level experiences, such as the case in Bangladesh, draw on ICZM for reducing vulnerability to coastal hazards and developing the coastal zone (Box 3.2). Following the 'making space for water' strategy in the UK, managed realignment of coastal wetlands is used to create more intertidal habitats to buffer wave energy, while increasing biodiversity and recreation benefits. In the Netherlands, beach nourishment, with the help of dune grasses, is enhanced to create more space seawards. Such initiatives are part of a European-wide move towards integrated coastal zone management.[138] In Asia, UNEP and the Asian Disaster Preparedness Centre conducted pilot trainings in Indonesia, Sri Lanka and India for coastal zone and disaster risk managers to build capacity towards better integration of disaster risk reduction in coastal zone management (case study 3).[139]

Restoration of coastal wetlands and barrier islands as a first line of defence against coastal hazards plays a key role in the integrated coastal zone management approach adopted in Louisiana and Mississippi, United States, following the devastating impact of Hurricane Katrina in 2005.[140] Had the original wetlands been left largely intact by urban development, and levees in better shape prior to Katrina, a substantial portion of the over US$ 100 billion damages from Katrina probably could have been avoided.[141] Current plans for the Gulf Coast area are restoring coastal wetlands to complement the protective effects of levies, which will determine future land-use and development in the area.

Box 3.2 Coastal buffers and integrated coastal zone management, Bangladesh[142]

Bangladesh, one of the most vulnerable coastal countries, has since the 1960s invested in coastal afforestation, with the aim of reducing the impact of cyclones and tidal surges through coastal green belts (such as mangroves). Additional objectives include stabilisation of newly accreted mud flats, timber production, alternative livelihoods for remote rural communities, and protection of biodiversity. Coastal afforestation is a coordinated effort between the government, NGOs and local people. People's livelihoods are improved through timber, fodder and fuelwood production, and cash income from group-based forestry activities. In addition, plantations on newly accreted coastal lands facilitate the settlement of poor and displaced people.

The ICZM adopted in Bangladesh has provided a sound basis for sustainable management of coastal resources, fostering multi-agency and multi-stakeholder participation, and contributing to the social, environmental and economic wellbeing of coastal communities.

3.4.3 Integrated fire management

Integrated fire management addresses wildfire hazards together with other social, economic and ecological sustainability concerns in a given area.[143] In South Africa, integrated fire management has become an important employment opportunity for marginal community members, while effectively reducing the risk of unwanted fires through prescribed burning and community sensitisation (case study 5). In Lebanon, land restoration and traditional and modern fire management practices are combined to build the social and ecological resilience of local communities (case study 4). Several countries in Europe are using prescribed burning both for decreasing wildfire hazards and for biodiversity and forest management objectives, and there is growing interest for better use and integration of traditional fire use and management.[144]

3.4.4 Sustainable dryland management

Sustainable dryland management is an approach that attempts to manage arid, semiarid and sub-humid lands for food production and other human needs without compromising the long-term sustainability of the fragile natural resource base (water, soil) and ecosystem functions. This approach integrates a range of practices to diversify livelihood options, increase agricultural productivity and restore and protect dryland ecosystems. Amongst others, the approach involves traditional and innovative techniques that enhance land, soil and water conservation.

Restoring and securing the provision of dryland ecosystems' goods and services is key to enhance the economic and social well-being of dryland communities and strengthen their capacity to manage rainfall scarcity and uncertainty. This is because most drought mitigation strategies traditionally practiced in drylands are ecosystem-based. Well-known examples are mobile livestock herding to avoid climatic risks and the collection and consumption of wild fruits and roots as a major coping strategy during drought periods.[145] In the Sahel, sustainable agricultural practices and the careful management of protective vegetation have reversed land degradation and conserved soil moisture, thus reducing the impact of drought and ensuring food supply for communities in marginal drylands (case study 2). Agricultural practices such as agroforestry (i.e. intercropping food crops with trees), mulching, rainwater harvesting and use of shelterbelts contribute to conserve water and soils, reduce wind erosion and restore fertility, which improves community resilience in dry conditions.[146]

3.5 Community-based sustainable natural resource management

3.5.1 Introduction

Previous sections have underlined the importance of involving local communities in ecosystem-based disaster risk reduction. Whether it is consulting people for their needs and aspirations, awareness raising on the approach used, direct participation of communities in planning, establishing and maintaining natural buffer systems, or full ownership of land and natural resources, local people are key to the success and sustainability of natural resource-based activities.

Community-based natural resource management (CBNRM) describes communities with the legal right, institutional base and economic incentives to take substantial responsibility for the sustained use of local natural resources and managing these local resources.[147] In other words, CBNRM addresses how rights and responsibilities regarding natural resources are shared between the state and local communities. In defining a 'community', it is important to note that they are rarely homogenous structures, but rather characterised by multiple and somewhat conflicting interests, different actors attempting to influence decision-making, and internal and external institutions shaping decision-making processes.[148] CBNRM generally draws from local and traditional/indigenous knowledge, the cumulative and complex bodies of knowledge, know-how, practices and representations that are maintained and developed by people with extended histories of interactions with the natural environment.[149] These rich local and traditional knowledge systems also typically apply integrated ecosystem-based management approaches, particularly with respect to management of water resources, fire hazards, and coastal zones.

3.5.2 Local and traditional/indigenous knowledge

Local people possess a wealth of traditional knowledge both on ecosystem management and disaster risk reduction. Indigenous communities, in particular, maintain specific cultural systems and traditional values related to natural resource management and disaster risk reduction, accumulated over generations. For example, many indigenous communities observe environmental indicators for early prediction of disasters. Plant growth and flowering patterns, behaviour of animals and nesting height of birds, among others, are used to predict heavy rains, floods, droughts, pest infestations and other hazards, and early warnings are issued to the community (see Box 3.3).[150] However, due to climate change and climate variability these traditional forecasting indicators and predictions become increasingly unreliable. Locals will need to adjust their observations and predictions accordingly and incorporate new knowledge and technology to ensure that correct coping mechanisms will be applied.[151]

Box 3.3 Fish as tsunami early warning[152]

Just before the Indian Ocean tsunami struck in 2004, numerous people were attracted to the shoreline by fish exposed by the withdrawal of the sea. This, however, was recognized as a sign of the approaching tsunami by Coastal Moken and Urok Lawai people in Thailand, the Ong in Andaman Islands in India and the Simeulue community in Indonesia, who headed rapidly inland. The Moken and Ong villages were completely destroyed, but inhabitants were saved. Only seven out of 80,000 Simeulue people died as people escaped in time thanks to their indigenous early warning knowledge.

In Burkina Faso and Niger, thousands of farmers have restored a degraded dry landscape through low-cost adaptations of traditional agriculture and agroforestry techniques. This large scale re-greening in the Sahel took place with limited external support, and has increased considerably the coping capacity of local communities against drought (case study 2). In a separate review of successful dryland management, results also showed that local farmer knowledge and experience were vital to accelerating best practices and innovation. However, the review also highlighted the importance of external public funding that invests in institutional development and technological innovation through training in new technical, organizational and management skills.[153]

3.5.3 Risk reduction and livelihood benefits

Especially in poor, ecosystem-dependent communities ecosystem-based DRR activities should be linked to livelihood priorities, ideally enhancing both regulating and provisioning ecosystem services. For example, mangrove ecosystems have been maintained by communities for centuries and still serve as coastal shelter for indigenous populations around the world. In Bolivia, community forestry in degraded and overgrazed rural areas stabilised slopes, reduced landslides and diversified local livelihoods (case study 1). Wildfire management is another example of community- and ecosystem-based disaster risk reduction that generates multiple benefits for people and ecosystems. Community participation is vital for the success of wildfire management, as evidenced in case studies from Lebanon (case study 4) and South Africa (case study 5). In Lebanon, traditional land management and new approaches are combined to create fire-resilient landscapes and include specific activities for sustaining local forest-based livelihoods. In northern Australia, aboriginals have revived traditional fire management practices, successfully controlling large-scale fires and generating income for disadvantaged communities (Box 3.4).

Box 3.4 Aboriginal fire management in Northern Australia[154]

Aboriginals have a long history in using fire to manage habitats and food resources. Due to changes in settlement patterns and marginalisation of aboriginal communities, traditional management in vast areas was no longer practiced and destructive fires in the fire-prone savannah landscape became a major hazard. Traditional fire management practices, such as early dry season prescribed burning, are now revived and combined with modern knowledge, such as using satellite data on fire locations, over an area of 28,000 km^2 in the Arnhem Plateau. Aboriginal fire rangers have considerably reduced large-scale fires, with subsequent reduction in greenhouse gas emissions by 448,000 tonnes of CO_2-equivalent over the first four years. Darwin Liquefied Natural Gas plant compensates aboriginal communities approximately AU$ 1 million per year as carbon offsets, generating important income in disadvantaged communities. Additional fire management benefits include protection of biodiversity and indigenous culture. Local government and indigenous land management groups are looking to extend the practice to other areas in fire-prone, primarily indigenously-owned landscapes in northern Australia.

3.5.4 Community participation

Communities are most likely to be willing to invest time and resources in ecosystem restoration and maintenance when they are aware of their benefits to hazard mitigation, and have a meaningful role in the management of relevant ecosystems.[155] In areas where ecosystems are degraded due to human activity, community-based ecosystem/environmental management programmes can be very effective in raising people’s awareness and changing attitudes and behaviour. Some guidance documents for community participation in ecosystem-based hazard mitigation already exist, such as the community-based dune management guide for local authorities in New Zealand, where community groups regularly undertake dune restoration.[156] However, several ecosystem-based initiatives have failed to pay adequate attention to community participation. The 2004 tsunami reconstruction period especially collected many lessons on community-based disaster risk reduction and ecosystem restoration.[157]

Some of the failures highlight the need to adequately understand community perspectives. For instance, case study 9 illustrates the obstacles to establishing community-based early warning systems in three countries affected by the 2004 tsunami, as top-down, prescriptive approaches failed to address livelihood concerns of local communities. Another example shows how exotic trees, mainly *Casuariana equisetifolia*[158], have been planted for coastal protection in the east coast of India. As a result, some plantations invaded native ecosystems, such as mangroves, altering the services they provide. In addition, sand dunes – which are natural coastal protection systems – were flattened to make way for plantations. Although the trees are appreciated for firewood, fishermen now have poorer access to boats. Poor participation of communities resulted in inappropriate location of forest stands, inequity in the distribution of benefits and poor management of the plantations.[159]

Section 4. Informing Policies and Decisions to Support Ecosystem-based Disaster Risk Reduction

Improving knowledge and applications of ecosystem-based DRR approaches only gain real value when they begin to inform policies and decisions that call for systemic changes to reduce vulnerability to natural hazards. It is important therefore to know the building blocks and enabling factors, which could facilitate broad support for ecosystem-based DRR. This section describes the key elements of an ecosystem-based disaster risk reduction approach, drawing on the numerous "good practice" examples and case studies featured in this paper. It also reflects on the driving forces or enabling conditions that support and facilitate implementation of ecosystem-based disaster risk reduction. Finally, it identifies additional steps needed to overcome key challenges to effective application of ecosystem-based DRR.

4.1 Core elements of applying ecosystem-based disaster risk reduction

The ecosystem approach to disaster risk reduction advocates for sustainable ecosystems management as a strategy to reduce exposure and vulnerability, through hazard mitigation or regulation (when feasible) as well as enhancement of livelihood capacities and resilience. **Ecosystem-based disaster risk reduction builds on ecosystem management principles, strategies and tools**[160] in order to maximise ecosystem services for risk reduction. It promotes the maintenance and enhancement of ecosystems and their services, with a focus on reducing vulnerability and establishing sustainable livelihoods for increased human resilience against disasters. This perspective takes into account the integration of social and ecological systems, placing people at the centre of decision-making. It involves making decisions that take into consideration current and future human livelihood needs and the biophysical requirements of ecosystems, and recognizes the role of ecosystems in supporting communities to prevent, prepare for, cope with and recover from disaster situations.[161] Conservation and enhancement of the overall ecosystem structure and functioning – to maintain ecosystem services over time – should be a priority in ecosystem-based disaster risk reduction.

This approach may be distinguished from environmental management in general, which does not necessarily focus on ecosystems as a whole but may simply address natural resource use issues in the context of disaster management. For example, in disaster response operations, water and sanitation, fuel and energy supply, and procurement of construction materials may be factored to avoid environmental damage that has implications for human health and recovery, but these activities do not necessarily tackle issues related to ecosystem protection and maintenance.

Adopting ecosystem-based disaster risk reduction is most relevant in the context of prevention and mitigation, as the available tools require long-term investment and institutional and human capacity development. In the immediate aftermath of disasters, providing for safety and basic needs is clearly the priority in humanitarian response. A set of minimum environmental guidelines, such as conducting rapid environmental assessments or promoting green technologies, however, should be integrated into emergency and early recovery operations to reduce environmental damage. As the focus shifts more towards recovery and preparing for future hazards, opportunities exist to systemically address environmental risk factors.

The following outlines seven core elements associated with implementing ecosystem-based disaster risk reduction. They serve as a guide for promoting good practices in this field. These elements have been compiled through the literature review as well as from participants' discussions at the 2010 PEDRR workshop on "Environment, Livelihoods and Disaster Risk Reduction" held in Bonn, Germany.

Core Elements of Ecosystem-based Disaster Risk Reduction

1) Recognize the multiple functions and services provided by ecosystems, including natural hazard protection or mitigation.

2) Link ecosystems-based risk reduction with sustainable livelihoods and development.

3) Combine investments in ecosystems with other effective DRR strategies, including hard engineering options.

4) Address risks associated with climate change and extreme events and reduce their impact on ecosystem services.

5) Enhance governance capacities for ecosystem-based DRR through multi-sector, multi-disciplinary platforms.

6) Involve local stakeholders in decision-making.

7) Utilize existing instruments and tools in ecosystems management and enhance their DRR value.

#1. Recognize the multiple functions and services provided by ecosystems at multiple spatial scales.

Ecosystems provide valuable services for hazard protection and regulation, which until now have been under-utilized by disaster risk reduction programmes and strategies. Ecosystems serve as natural infrastructure that can reduce physical exposure and buffer the effects from natural hazards. However, it is equally important to recognize ecosystems' contributions towards overall vulnerability reduction by sustaining livelihoods and economies and strengthening their resilience against hazard impacts. Healthy and well-managed ecosystems provide critical goods and services that enable communities to cope with and recover from disasters.

Harnessing the potential of ecosystems for disaster risk reduction should be based on rigorous understanding of the context-specific, ecological and technical requirements to enhance natural protection and hazard mitigation (discussed also in Section 4.2). Inadequate or ineffective natural buffers can create a false sense of security and jeopardize the credibility of ecosystem-based DRR as a whole.

#2. Link ecosystems-based risk reduction with sustainable livelihoods and development.

Disaster risk reduction is essentially about promoting sustainable development in hazard-prone areas. Given that poverty is one major factor driving ecosystems decline and unsustainable natural resource use, poverty reduction through sustainable livelihoods development should be a core objective of ecosystem-based risk reduction strategies. There must be clear social and economic incentives for investing in ecosystems management options, as evidenced in the case studies from Bolivia, Lebanon, Sahel and South Africa (case studies 1, 2, 4 and 5). While ecosystem-based disaster reduction should be an integral part of a long-term development strategy, demonstrating short-term tangible outcomes and benefits especially to local communities will be critical to win and maintain stakeholder engagement.

#3. Combine investments in ecosystems with other effective DRR strategies, including hard engineering options.

Investing in ecosystems is not a single solution to disasters but should be used in combination with other risk reduction measures. Ecosystem thresholds may be surpassed depending on the type and intensity of the hazard event and/or types and health status of the ecosystem which may provide insufficient buffer against hazard impacts. For instance, mangroves may not provide as much protection against tsunamis as they would for storm surges. Promoting ecosystems management as *the* main risk reduction strategy could provide a false sense of security; establishing early warning systems and disaster preparedness measures are therefore still paramount in saving lives and major assets.[162]

In some cases, combining ecosystems-based approaches with engineered infrastructure investments (e.g. embankments, groynes) may be necessary to protect critical assets including transport routes, hospitals and schools. For example, a Pakistan field manual describes an integrated approach to slope stability, combining eco-engineering and engineering measures, with an emphasis on appropriate vegetation cover such as trees and grasses.[163] In addition, the regional coastal zone management training course developed for Asia in close collaboration with national partner institutions proposes a range of both natural and engineered infrastructure to mitigate coastal hazards (case study 3).

#4. Address risks associated with climate change and extreme events and reduce their impact on ecosystem services.

Climate change is expected to exacerbate disaster risk (Box 4.1). More frequent and intense disaster events can erode community capacity to prepare, respond and rebuild after successive hazard events. Moreover, climate change will substantially alter the structure, composition and function of terrestrial, freshwater and marine ecosystems, with predicted species extinction and distribution shifts, reducing the capacity of ecosystems to restore, protect and maintain human well-being and livelihoods.[164]

Adopting an ecosystem-based disaster risk reduction approach helps to strengthen local adaptation to climate change and climate variability, including extreme hazard events. Well-managed ecosystems enable people to have more assets needed to make livelihoods sustainable and less vulnerable to climate change.[165] Incorporating the use of biodiversity and ecosystem services in an overall strategy that help people adapt to climate change is the basis of Ecosystem-based Adaptation (EbA).[166] In contrast to degraded ecosystems, well-managed ecosystems are viewed to be more resilient to climate-related risks.

Efforts to integrate DRR and ecosystems management should maximize ongoing work on climate change adaptation. For example, integrated water resource management (IWRM) is increasingly recognized as a practical tool for both climate change adaptation and disaster risk reduction. The World Bank, in a recent ecosystem-based climate adaptation report, recommends sustainable management of forests, watersheds and wetlands to address the increasing risk of floods.[167]

Box 4.1 Linking climate change and disaster risk

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007), global temperature increase is altering the amount, intensity, frequency and type of precipitation, which become highly variable and unpredictable. This translates to more areas affected by drought, heatwaves, flooding and landslides. In addition, sea level rise will increase wave energies and make coastal cities and communities, in particular, more vulnerable to storm surges. The accelerated melting of permafrost and mountain glaciers will increase risk of flooding in glacier-fed river basins and deltas. Increased weather extremes and unpredictability are therefore largely expected to result in corresponding increases in the number or scale of disasters. An IPCC Special Report on Extreme Events (forthcoming) considers the extent to which ecosystems can buffer against extreme events and how ecosystems management could be integrated into DRR policy mechanisms and practices.[168]

#5. Enhance governance capacities for ecosystem-based DRR through multi-sector, multi-disciplinary platforms.

A shift towards ecosystem-based DRR is possible through adoption of national policies and legislation promoting natural infrastructure for risk reduction, as demonstrated by the Netherlands, UK, Switzerland and Sri Lanka (discussed in Sections 2 and 3, and case study 8). Such innovative policies are still, however, more exceptions than common practice. Integrated policies can both minimize implementation costs and improve flow of services.[169] In many cases, however, appropriate policies and legislation may be in place, but the main problem lies in their enforcement and the lack of political will.

In order to facilitate cross-sectoral collaboration and stimulate innovative policies, strong multi-sectoral mechanisms or platforms are needed. It is particularly important to develop multi-disciplinary teams and involve people with different technical expertise and knowledge, for instance city engineers and land developers working together with ecologists and disaster management experts. This should apply both at national as well as sub-national levels. In several pilot countries in Asia, collaboration between national disaster management agencies and environmental agencies was strengthened through development and implementation of national training courses on integrated coastal zone management (case study 3).

Multi-sectoral, multi-disciplinary mechanisms facilitate sharing of available data, help ensure scientific and technical rigour in designing and implementing ecosystem-based DRR initiatives and obtain the political support necessary to integrate them into national and local development plans. However, clear incentives are needed for such mechanisms to build consensus and work effectively. In the Sri Lanka case, for example, it was important to ensure that the ISEA for the Northern Province was perceived by participating national government agencies as a practical decision-making support tool that enables them to achieve dual objectives: environmental protection as well as economic development (e.g. tourism, agriculture, resettlement, infrastructure) (case study 7, discussed also in Section 3.1).

#6. Involve local stakeholders in decision-making.

Local stakeholders clearly have a role to play in promoting risk reduction through sustainable ecosystems management. This has been illustrated especially by successful experiences in protected area management and community-based natural resource management, such as in the cases of community-based forestry and slope stabilisation in Bolivia (case study 1), integrated forest management with participation from and collaboration between community- and government-level stakeholders, both in Lebanon and in South Africa (case studies 4 and 5), and community level large-scale land rehabilitation in Sahel, with catalyzing external funding and technical support (case study 2). What these successful examples– as well as clear failures such as the experience of establishing early warning systems in tsunami-affected countries (case study 9) - show is the need to take into account local livelihoods needs and priorities, utilize local or indigenous knowledge, and involve local stakeholders in decision-making.[170] Local communities are often direct resource users and their knowledge of local ecosystems can provide critical information in planning successful ecosystem-based DRR initiatives. Raising the awareness of local people by demonstrating the combined livelihoods and risk reduction benefits of ecosystem-based solutions is equally important in winning and sustaining local support.

Initiatives often fail when there is limited or lack of participation by local stakeholders, which may include local government authorities, informal leaders, community-based organizations and residents. However, it is important to recognize that communities are not homogenous and pressure groups exist with competing interests, as illustrated in post-2004 tsunami affected communities (case study 9). Identifying community actors, such as disaster management committees, forest user associations, and farmers' associations, who can become advocates for ecosystem-based DRR is essential.

#7. Utilize existing instruments and tools in ecosystems management and enhance their DRR value.

A variety of tools, instruments and approaches used in ecosystem management can be readily adopted and applied at country and community levels as part of risk reduction strategies, as discussed in Section 3. What is needed is the improved and routine use of disaster risk information (e.g. types of hazards over time and space, socio-economic vulnerability profiles of communities, elements at risk, etc.) in the design of integrated ecosystem approaches to maximize their added value for DRR. For instance, rehabilitation of upland watersheds can be further harnessed for flood mitigation by improved understanding of the local hazards, hydrology, topography as well as socio-economic demands on forest products and the types of indigenous tree species that are best suited for reforestation activities.

Box 4.2 Identifying positive drivers that facilitate implementation of ecosystem-based DRR

Based on this literature review and results from the 2010 PEDRR workshop on "Environment, Livelihoods and Disaster Risk Reduction" held in Bonn, Germany, a number of driving factors may be identified to support implementation of ecosystem-based DRR approaches. These include the following (in no particular order of priority):

(i) Disasters

While disasters can have devastating impacts in terms of lost lives, assets and property, they sometimes present opportunities for introducing new concepts and approaches. Post-disaster recovery and rehabilitation needs often can serve as an impetus for "building back safer" and promoting ecosystems' rehabilitation or restoration to reduce future hazard impacts.

(ii) Supportive international policy environment

Global agendas on disaster reduction, such as the Hyogo Framework for Action, can also play an influential role in supporting ecosystem-based DRR solutions at country and local levels. International donors or funding agencies can also exert influence in countries and set investment policies to help catalyse environmental recovery efforts and support ecosystem management solutions for DRR.

(iii) Government commitment

Clear government commitment at the national level can provide the sustained momentum needed to implement and mainstream ecosystem-based DRR initiatives. It is also essential to identify positive "change agents" or "champions" within key agencies to rally support and build political consensus.

(iv) Climate change agenda

The climate change agenda and increasing climate-related risks are also a strong driving force that supports the integration of DRR and ecosystem management, through "Ecosystem-based Adaptation" approaches.

(v) Available financial resources

While there may be clear government and community commitment to ecosystem-based DRR, in many (if not most) instances, securing financial resources, usually from external sources, is key to full and effective implementation.

4.2. Additional next steps for enabling effective implementation of ecosystem-based DRR

This paper has reviewed the current state of knowledge and practice on ecosystem-based DRR. We conclude that emerging scientific research, current good practices and successful implementation examples have clearly demonstrated the added value of ecosystem-based DRR approaches. Certainly, the evidence base we currently hold needs to become more robust through further testing and replication as well as more effective monitoring and reporting of impacts, outcomes and benefit-cost ratios. In addition, information and tools on ecosystem-based approaches to DRR need to reach the right stakeholders. The following discusses additional pointers on how to further improve and address gaps in these fields (in no particular order of priority):

(i) Bridge knowledge gaps

There is still much to be learned about ecosystem services for DRR. Only limited information exists on performance thresholds of different ecosystems and levels of ecosystem resilience against environmental change and different hazards (i.e. hazard type, intensity and frequency), although there is initial work by IUCN on developing ecosystem health and resilience indicators.[171] Further investment in scientific research on ecosystem services is therefore needed. One area of research flagged at the PEDRR 2010 Bonn workshop is to conduct long-term monitoring and evaluation of ecosystem functions and performance before and after disaster events. Research in this area is needed to understand both the potential and limits of ecosystem services for risk reduction and when alternative options, including hard engineering solutions, may be required.

Another critical area is the economic valuation of ecosystem services for hazard mitigation.[172] In October 2010 at the Convention on Biological Diversity meeting in Nagoya, the World Bank announced a new Global Partnership for Ecosystems and Ecosystem Services Valuation and Wealth Accounting, an initiative designed to integrate ecosystem services into national accounting and raise the visibility of ecosystem contributions to national economies.[173] The results from this initiative could very well catalyse increased national investments in improved ecosystems management in general.

Nonetheless, given the challenges of fully monetizing ecosystem services, there should also be further development and testing of non-economic valuation methodologies. This includes evidence-based assessment methodologies, such as RiVAMP and the approach used in Northern Pakistan (Section 3.2, see case studies 10, 11 and 13), which utilize scientific and stakeholder-based analyses to measure and quantify the role of ecosystems especially for hazard mitigation. Such evidence-based assessments can also be effective in demonstrating the added value of sustainable ecosystems management.

(ii) Develop better guidelines and practical tools

When establishing natural buffers, it is important to base them on correct technical and scientific information and adequate understanding of local conditions. While there is now a range of environmental tools and instruments available that integrate ecosystems and DRR – or could do so - (see Section 3), more guidance is needed on how to use and apply these tools. For example, planners in protected area management need additional guidance to identify ecosystem and disaster risk "hotspots", prioritize those areas for protection, and develop management strategies that mitigate hazard impacts.[174] Some tools still require field-testing, for instance in the case of integrated EIAs and SEAs and risk and vulnerability analysis that incorporate the role of ecosystems and environmental change (including climate change).

Existing manuals and guidelines for ecosystem restoration and rehabilitation need to be adapted to local requirements and contexts to identify suitable site- and country-specific solutions. In the case of coastal buffers, detailed technical guidelines for restoring or rehabilitating coastal ecosystems are already available.[175] Unfortunately, a number of coastal reforestation/restoration initiatives have used incorrect planting techniques, inappropriate locations, introduced problematic exotic species, and paid insufficient attention to involving local communities in decision-making and maintenance of restored areas, resulting in wasted resources and undermining the credibility of coastal bioshields.[176]

Aside from developing technical guidelines, there is also a need for more practical decision-making support tools that enable policymakers and planners to weigh different alternatives and at least consider the potential role of ecosystems in risk reduction. Feagin et al (2009), for instance, offers a decision tree that helps assess options for the establishment of natural buffers or "bioshields" in appropriate locations. Similar decision support tools are needed that take into account different hazards and ecosystems.

(iii) Develop and enhance institutional capacities for ecosystem-based DRR in vulnerable countries

While there are now a significant number of DRR trainings being delivered around the world, very few of them address environment-disaster linkages and focus on ecosystem management tools for DRR. Training materials with an environment-DRR thematic coverage have only been recently developed, for instance by ADPC (case study 3), GFMC, IUCN, WWF-US/American Red Cross as well as national training institutions such as the National Institute for Disaster Management (NIDM) based in India.[177] Moreover, trainings that focus on practical applications of specific environmental tools for DRR, such as integrated EIAs and SEAs, integrated watershed management and vulnerability assessments, are in demand at the country level. In Sri Lanka, upon government request, UNEP delivered technical training on SEA especially targeting the environmental regulatory, disaster management and urban development planning agencies, in parallel with on-going SEA activities being undertaken to support post-conflict reconstruction in the Northern Province (case study 7).

Capacity development should enhance national awareness and capacities to apply environmental tools for DRR and mainstream these into development planning. This involves increasing awareness among policymakers and decision makers in government and building capacities of practitioners and technical staff involved in programme and project implementation. Capacity development should target land-use planners, city planners, disaster managers and staff in key sectoral agencies (e.g. forestry, agriculture, tourism, etc.). Environment-DRR training should also be integrated into already existing national training programmes in order to ensure that they are mainstreamed in governance and institutional practice. PEDRR is presently working to consolidate available training material and deliver a training "package" on ecosystem-based DRR, targeting especially national and local governments.[178]

(iv) Developing effective communication strategies that target policymakers and decision makers

Often scientific research and field-based initiatives produce solid analysis and results that clearly show the value of ecosystems for risk reduction but fail to communicate these findings in a convincing way to policymakers. This is one lesson learned from the RiVAMP pilot in Jamaica, which provided robust statistical evidence of shoreline protection provided by coral reefs and seagrass beds; yet, additional follow-up is still required, including an economic analysis of these protection values in relation to the tourism industry.

A targeted communication strategy is needed to translate science-based results and extract general lessons from local experiences in a way that "fits" or responds to the political priorities, timeframes and competing pressures faced by public officials. For instance, calculating cost and benefits between alternative scenarios (i.e. damage or replacement costs avoided, revenue generated, etc) could be one way of effecting policy change and influencing investment decisions.

(v) Foster science-practitioner dialogue

One way to bridge knowledge gaps is to foster dialogue between scientists and environment-DRR practitioners, through various fora such as the 2010 international workshop sponsored by PEDRR in Bonn. Practitioners can help identify more targeted and applied scientific research that innovate environmental solutions for risk reduction. Likewise, scientists can share the latest scientific research that can inform programme and project development and improve technical rigour in their implementation. Such learning exchanges can be organized at global, regional and national levels.

Section 5. Looking ahead

This study has explored the potential of sustainable ecosystems management as a strategy to reduce vulnerability to natural hazards and climate change-related risks. At least three emerging contemporary trends point to additional opportunities in applying an ecosystems approach to disaster risk reduction.

First, urbanization is occurring worldwide at a rapid rate, especially in developing countries with growing economies. Governance systems are unable to keep up with rising populations, expanding settlements and industrial development, resulting in unplanned and unsafe urban areas. At the same time, urbanization exerts significant pressures on surrounding ecosystems through land-use conversions, increasing expansion of human activities into fragile or marginal lands. Yet ecosystems provide critical services to urban populations, for instance flood and landslide mitigation by forest watersheds or storm surge protection from coral reefs and coastal vegetation, in addition to producing goods and products that support human well-being and livelihoods. Greater attention is therefore needed to protect ecosystems and maximize their risk reduction values in urban contexts, as called for in the 2010-2011 International Strategy for Disaster Reduction (ISDR) “Resilient Cities” global campaign. Innovative programmes in the UK and the Netherlands that aim to restore natural river channels and floodplains in urban centres, as discussed in Sections 2 and 3, can provide important lessons in this regard.

Second, natural hazards and their impacts often cross national boundaries and may be disproportionately felt depending on the level of risk within the countries. As ecological infrastructure can also reach beyond national borders, applying an ecosystems approach can provide an opportunity to reduce vulnerability to natural hazards through transboundary or regional cooperation. A transboundary ecosystems-based approach would allow for efficient pooling of hazard and risk information, facilitate inter-state dialogue and learning, and deliver coordinated disaster response and prevention strategies. However, this approach remains largely untested. Experiences in cross-border protected area management for hazard mitigation provide the most promising examples to date.

Finally, over the past sixty years, at least 40 percent of all intrastate conflicts can be associated with natural resources.[179] While certainly not the only driver of conflict, environmental and ecosystems degradation is an important contributing factor, as a result of increased scarcity or competition over access and supply of critical or high value natural resource goods (e.g. wood/timber, water, land) provided by ecosystems. Peacebuilding and post-conflict reintegration initiatives therefore increasingly recognize sustainable natural resource management as a basis for fostering security. Since conflicts also often take place in hazard-prone areas that are equally vulnerable to climate change, an ecosystems-based approach to disaster risk reduction can provide a neutral platform for peacebuilding. Disaster risk reduction in conflict and post-conflict zones is in general a new field of work, with field-based experiences only recently emerging.

Given escalating disaster losses globally and the new risks posed by climate change, the search for cost-effective, locally accessible and integrated solutions for reducing disaster risk will continue. As demonstrated in this study, ecosystems-based disaster risk reduction may offer important opportunities in this regard. Further efforts are, however, still needed to assess the value-added of ecosystem approaches, to sensitize disaster management, environmental and development communities, and to provide decision makers and practitioners with the necessary tools to effectively implement, replicate and scale-up ecosystem-based DRR.

Endnotes

[1] Definitions related to disasters and disaster risk are sourced from UNISDR Terminology on Disaster Risk Reduction (2009) (http://www.unisdr.org/eng/terminology/terminology-2009-eng.html).
[2] Millennium Ecosystem Assessment (2005).
[3] Millennium Ecosystem Assessment (2005).
[4] Turner et al (2003); see also Birkmann (2006) for a review of differing concepts of vulnerability.
[5] ISDR/Global Assessment Report (2009).
[6] IPCC (2007).
[7] (Centre for Research on the Epidemiology of Disasters (CRED) cited in UN ISDR (2008), "Climate Change and Disaster Risk Reduction", *Briefing Note 1*, 11 pp.).
[8] The HFA is a non-binding agreement that has been signed by 168 countries and which provides the global framework for achieving disaster risk reduction. The HFA outlines five priority areas of action, namely: mainstreaming disaster risk reduction in development, early warning and assessment of risk, education and capacity development, addressing underlying risk factors and disaster preparedness.
[9] Other underlying risk drivers include poverty, climate change and poor urban governance.
[10] World Bank (2010).
[11] This paper will be used as input to Section 5 entitled "Enabling Environment" in the GAR 2011, which will focus on ecosystem services, among other themes.
[12] Millennium Ecosystem Assessment (2005).
[13] UNEP/UNISDR (2008).
[14] Millennium Ecosystem Assessment (2005).
[15] Sudmeier-Rieux and Ash (2009).
[16] Millennium Ecosystem Assessment (2005).
[17] TEEB (2009).
[18] TEEB (2009).
[19] These examples have used different valuation approaches, such as the avoided damages approach, or comparing natural infrastructure to alternative human-built structure such as a reservoir. See TEEB (2009) and www.teebweb.org for further discussion on approaches to economic valuation of ecosystem services.
[20] TEEB (2009).
[21] Conservation International (2008)
[22] Costanza et al (2008).
[23] Costanza et al (2008).
[24] ProAct Network (2008).
[25] Emerton and Bos (2004), see also Emerton and Kekulandala (2003).
[26] Brenner et al (2010).
[27] ProAct Network (2008).
[28] Sudmeier-Rieux and Ash (2009); UNEP /UNISDR (2008).
[29] Adapted from UNEP / UNISDR (2008): p. 13.
[30] UNEP / UNISDR (2008).
[31] ISDR (2009).
[32] Sudmeier-Rieux et al (2006).
[33] Day et al (2007), Batker et al (2010), see also World Bank (2010).
[34] ISDR (2009).
[35] UNEP (2009a)
[36] Millennium Ecosystem Assessment (2005).
[37] Sudmeier-Rieux and Ash (2009: pp. 1-2).
[38] TEEB (2009 : p. 23).
[39] ISDR (2009).
[40] World Bank (2010); Campbell et al. (2009); Sudmeier-Rieux and Ash (2009); UNEP (2009a); Dolcemascolo (2004). For a review of literature on the links between biodiversity and climate change, see the Convention of Biological Diversity, Technical Series 42.
[41] ProAct Network (2008),Sudmeier-Rieux and Ash (2009),World Bank (2010).
[42] See, for example, the Alpine Convention protocol on mountain forests, http://www.alpconv.org/theconvention/conv02_en.htm
[43] Brang et al (2006), ProAct Network (2008).
[44] DEFRA (2005), Deltacomissie (2008), Parliamentary Office for Science and Technology (2009). See also http://www.deltacommissie.com/en/advies
[45] Département du Territoire (2009), see also http://etat.geneve.ch/dt/eau/renaturation-80-645.html
[46] World Bank (2010).
[47] WWF (2008).

[48] Based on the Romanian pilot projects, WWF estimates that dyke removal costs €50 – 200,000 per kilometre, depending on the type of dyke wall, plus compensation for changes in land use.
[49] Harakunarak and Aksornkoae (2005).
[50] van Ejik and Kumar (2009). See also www.greencoasts.org
[51] See http://www.mangrovesforthefuture.org/
[52] Intergovernmental Oceanographic Commission (2009).
[53] Dolidon et al (2009), Peduzzi (2010), Norris et al (2008).
[54] Bebi et al (2009), Dorren et al (2004).
[55] Bradshaw et al (2007), Krysanova et al (2008).
[56] See World Bank 2010.
[57] Campbell et al (2009).
[58] Batker et al (2010), Costanza et al (2008), Ramsar (2010a), Zhao (2005).
[59] See, for example Badola et al (2005), Batker et al (2010), Granek and Ruttenberg (2007).
[60] Campbell et al (2009), Ramsar (2010b), UNEP-WCMC (2006), World Bank (2010).
[61] Mazda et al (1997), Möller (2006), Vo-Luong and Massel (2008).
[62] Campbell et al (2009).
[63] Intergovernmental Oceanographic Commission (2009), UNEP-WCMC (2006).
[64] Campbell et al (2009), Krysanova et al (2008).
[65] Campbell et al (2009).
[66] World Bank (2010).
[67] WWF (2008).
[68] World Bank (2010) ; Sudmeier-Rieux and Ash (2009).
[69] Campbell et al (2009), Sudmeier-Rieux and Ash (2009).
[70] FAO and CIFOR (2005), van Dijk et al (2009).
[71] See, for example, FAO (2007a), Feagin et al (2010), Campbell (2009).
[72] See, for example Chatenoux and Peduzzi (2007), FAO (2007b), Feagin et al (2010), Iverson and Prasad (2008), Kerr et al (2009), Olwig et al (2007), Osti et al (2009).
[73] See Sudmeier-Rieux and Ash (2009), TEEB (2009), UNEP (2010), World Bank (2010).
[74] Batker et al (2010), Campbell (2009), Ramsar (2010), World Bank (2010).
[75] Campbell et al (2009).
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ANNEX – GAR PEDRR paper
Case studies

1. Community-Based Forest Rehabilitation for Slope Stability, Bolivia

2. Resilience to Drought through Agro-ecological Restoration of Drylands, Burkina Faso and Niger

3. Building the Capacity of Coastal Zone Managers on Protecting Coastal Ecosystems to Reduce Disaster Risk

4. Reducing Fire Disasters through Ecosystem Management in Lebanon

5. Integrated Fire Management in South Africa

6. Benefits of Healthy Forest Ecosystems, Agroforestry and Mangroves for Disaster Risk Reduction: Southeast of Mexico During Hurricane Dean 2007

7. Integrating disaster risk reduction into the strategic environmental assessment of Sri Lanka's Northern Province

8. Making Space for Water - Developing a New Government Strategy for Flood and Coastal Erosion Risk Management in England

9. Integrating DRR and NRM priorities from a local livelihoods perspective in the Indian Ocean Tsunami Early Warning System

10. Landslides and Vegetation Cover in the 2005 North Pakistan Earthquake: a GIS and statistical quantitative approach

11. Integrating ecosystems and climate change factors in risk and vulnerability assessments: The case of RiVAMP in Jamaica

12. Impacts from the 2004 Indian Ocean Tsunami: Analysing the potential protecting role of environmental features

13. Vulnerability assessment and protective effects of coastal vegetation during the 2004 Tsunami in Sri Lanka

Case Study 1

Community-Based Forest Rehabilitation for Slope Stability, Bolivia

Authors: Carmenza Robledo[1*], Martin Fischler[1], Alberto Patiño[2]

Abstract:
The PROFOR reforestation project (*Programa de Repoblamiento Forestal*), supported by the Swiss Development Cooperation, was conducted for 15 years in rural areas of the Bolivian Altiplano. PROFOR used a community forestry approach for slope stabilisation and income generation. 80 hectares of forest plantations were established in one of the project areas, Khuluyo Village, where environmental degradation had increased the risk of landslides from surrounding hillsides. In 2003, PROFOR results in Khuluyo were assessed through community consultations and social mapping. Results indicated that PROFOR project activities had diversified livelihoods and improved both slope stability and the condition of watersheds. This in turn, increased community resilience to climatic risks, including resilience to extended dry periods and landslides. The case suggests that addressing climate change adaptation within development cooperation should include sustainable management of natural resources as a strategy to improve resilience in rural livelihoods.

Key words: community forestry, afforestation, slope stability, landslides, drought, community resilience, climate change adaptation
Hazards: Landslides, (drought, floods)
Ecosystems: mountain
Location: Khuluyo Village, Cochabamba, Bolivia
Dates: 1984 – 1998, project assessment in 2003

1. Introduction

Khuluyo Village is located in a temperate sub-Andean Valley of Bolivia, where elevation ranges between 2000 and 3000 meters above sea level. Depending on altitude, average annual temperatures in the valley area range between 15-26 ºC and average annual rainfall amounts between 400 and 600 mm. Prior to the project, most original forest cover had been removed and naturally replaced by low shrubs and bushes. High demand for agricultural land, pastures and fuelwood had led to land degradation on the hillsides.

At the start of the project, there were close to 300 inhabitants in Khuluyo. Their main livelihood activity was agriculture (potatoes, barley, oats) and, to a lesser degree, livestock raising. While approximately one third of the total area of Khuluyo is suitable for cultivation, the rest is grassland suitable only for grazing and forestry. Agricultural lands belong to individual small-scale farmers; whereas, the higher altitude grasslands are communally owned.

Overall, climate change scenarios for Bolivia identify agricultural systems and water resources as highly vulnerable sectors to climate change. This is due to expected extreme weather events, such as extended dry periods or storms, which cause forest fires, floods and landslides. Vulnerability in Bolivia is made more acute by the high level of poverty.

2. General description

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The Swiss-Bolivian cooperation project PROFOR (*Programa de Repoblamiento Forestal*) supported the establishment of 7,000 ha of tree plantations in the department of Cochabamba between 1984 and 1998. Project activities were implemented jointly between the Development Corporation of Cochabamba (CORDECO) and the Swiss Development Corporation (SDC) and subsequently delegated to the Swiss foundation Intercooperation.

When the project began, primary forest was non-existent on the hillsides of PROFOR's area of intervention, and young secondary forests were overharvested to meet local woodfuel needs. The project worked with communities in establishing fast-growing tree plantations to provide wood, promote soil conservation, recreation and environmental protection and to simultaneously reduce pressure on secondary forests. This case study analyses the process and results of PROFOR in Khuluyo Village, one of the project implementation areas. In this village, erosion and landslides, caused by overgrazing and inadequate agricultural practices on steep slopes, were major threats to farmland, housing and other infrastructure.

3. Process of implementation

The main approach in PROFOR was communal forestry. Training and technical assistance in forestry and agroforestry practices and management were provided to rural families to improve their economic situation and reduce the risk of landslides. This assistance included support in planting site selection and windbreak establishment for land stabilisation. Tree plantations were established using *Pinus radiata, P. patula, P. montesuma, P. pseudostrobus* and *Eucalyptus globules*, while agroforestry and wind barrier systems included native species, such as aliso (*Alnus acuminata*), kiswara (*Buddleja coriacea*) and ciprés (*Cupressus macrocarpa*). The project also assisted in strengthening community organisation through the creation of forest committees. In Khuluyo, women have a strong participation in the forest committee, which also includes the majority of members of the local agrarian committee. The municipal government, in contrast, showed less interest in participating in project activities.

To ensure appropriate maintenance and use of the plantations, the project established contracts between communities/individual landowners and PROFOR to define the rights and responsibilities of both parties from the time of planting to the time of forest product use. PROFOR also used incentives for the establishment of tree plantations: initially these consisted of food rations, tools and tree seedlings. In moving to a more participatory approach, however, the program eliminated most of these incentives, except the provision of tree seedlings.

4. Outputs and Outcomes

From 1984-1998, the project established 16 ha of eucalyptus plantations and 64 ha of pine forests in Khuluyo. During a post-project assessment in 2003, most of the plantations continued to be appropriately managed through pruning and thinning.

One of the most important impacts of PROFOR in Khuluyo has been improved slope stability through planting of trees on steep hillsides, and subsequent reduction in soil detachment and landslides. Reduced soil movement on upper slopes has also led to further community-based revegetation efforts. With the support of PROFOR technicians, the community has increased the planting of the native aliso, an important nitrogen-fixing tree species. In addition, wind barriers established with cipreses and kiswara have reduced wind and water erosion and protected agricultural crops during storms and against morning frosts (*heladas*). The community of Khuluyo also reduced human-induced fires for clearing agricultural land. Community members now practice soil conservation on communal land and promote the succession of secondary forests.

Both wood (timber, fuelwood and construction materials) and non-wood forest products (e.g. eucalyptus oil) are now significant supplementary income sources for local families and are especially important alternative activities during extended dry periods when agricultural activities cannot follow the usual schedule. Timber revenues have allowed the community to acquire seeds and fertilisers for agricultural production. This has resulted in new plantations, new work and, thus, income generating opportunities, which, in turn, has led to an increase in population and rural property value, as well as decreased temporal migrations.

PROFOR promoted social organization in Khuluyo by establishing an operational (as confirmed during the post-project assessment) forest committee as the local entity responsible for the administration of forest activities. Members of the committee received capacity in planning, implementing and managing forests using appropriate techniques. The forest committee has been responsible for managing reforested communal lands and defining rules for the distribution of benefits. Furthermore, the committees took the lead in issuing land titles for community land.

5. Discussion

Prior to the project, landslides and flooding following strong rainfalls were the main threats to the population of the area. Local perception is that these risks have been largely controlled by tree plantations with hardly any recent landslides occurring. Tree plantations in Khuluyo have also reduced pressure on woody species in secondary forests. Nevertheless, this has not led to an increase in secondary forest areas as neighbouring communities. This is because neighbouring communities did not participate in PROFOR activities and continue to collect fuelwood from forest stands.

Project activities related to tree plantations have increased the resilience of the Khuluyo community to climate risks and natural hazards. Other activities directly related to PROFOR, such as the natural seeding of secondary aliso forests or the establishment of windbreaks, have also contributed to increased resilience. However, to ensure sustainability of the plantations, the community may benefit from more training and support on regenerating plantations, including thinning, forest harvesting and transforming timber into marketable products.

Apart from the stabilisation of hillsides, the project had major social effects with increased local capacity and social organisation that improved the negotiation skills of the community. An evaluation conducted by PROFOR showed that those communities that maintained forest committees better maintained their tree plantations and helped to market some of the first products, which have distributed benefits throughout the communities. In contrast, observations of current vulnerabilities of communities outside PROFOR involvement showed a lower level of community organisation, frequent human-induced fires to clear land and gradual watershed degradation.

6. Conclusions

Poor communities in mountain areas are particularly vulnerable to climate-related risks. Settlements in marginal or unstable lands, such as steep slopes or floodplains, increase their exposure to hazards. In addition, these communities are heavily dependent on natural resources for their livelihoods. Climate adaptation and disaster risk reduction of poor communities requires actions that reduce the vulnerabilities they currently face, especially in terms of livelihoods. Given the reliance of the poor on natural resources, a central element of vulnerability reduction should be ecosystem management and restoration activities, such as watershed rehabilitation, agroforestry, forest restoration and enhancing ecosystem services for hazard mitigation (e.g. slope stability).

Social organisation also plays a definitive role in increasing resilience. Moreover, organised communities are more likely to sustainably manage their natural resources, reducing vulnerability and increasing community resilience to climate risks and natural hazards.

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Case Study 2

Resilience to Drought through Agro-ecological Restoration of Drylands, Burkina Faso and Niger

Authors: Chris Reij[1*], Gray Tappan[2], Melinda Smale[3]

Abstract:
Two different, but almost simultaneous, agro-ecological restoration processes started 30 years ago in the Sahel area of Africa to increase water availability, restore soil fertility and improve agricultural yields in degraded drylands. These initiatives were led by poor farmers from Southern Niger and Central Plateau of Burkina Faso whose livelihoods had been increasingly affected by drought and land degradation. With very little external support, local farmers experimented with low-cost adaptations of traditional agricultural and agroforestry techniques to solve local problems and exchanged knowledge with others. Three decades later, hundreds of thousands of farmers have replicated, adapted and benefited from these techniques and have transformed the once barren landscape at an unprecedented geographical and temporal scale. In Burkina Faso, more than 200,000 hectares of dryland have been rehabilitated, now producing an additional 80,000 tons of food per year. In Niger, more than 200 million on-farm trees have been regenerated, providing 500,000 additional tons of food per year, as well as many other goods and services. Women have particularly benefited from improved supply of water, fuelwood and other tree products. By supporting poverty reduction and increasing the coping and adaptive capacity of local populations, the initiatives have significantly reduced risks associated with frequent droughts in the region.

Key words: drought, drylands, innovation, land reclamation, Sahel, traditional knowledge, livelihood security
Hazards: Drought
Ecosystems: Drylands
Location: Southern Niger and the Central Plateau of Burkina Faso
Dates: 1980s - ongoing

1. Introduction

The Central Plateau of Burkina Faso and the Maradi and Zinder regions of Southern Niger are located in the Sahel drylands, a region characterised by a single short yearly rainy season, extreme poverty and recurrent drought. Water scarcity and increasing population pressure have resulted in severe environmental degradation. Deforestation, overgrazing and agricultural expansion in unsuitable areas are common as people struggle to meet their food and energy needs. In both countries, sharp declines in crop yields have forced farmers to shorten the traditional fallow period and extend agriculture into marginal areas, causing further land degradation and declining yields. Land degradation exacerbates the vulnerability of women and children during drought periods. Due to lower water tables and dry wells, they have to walk increasingly longer distances to fetch water. They are also directly affected by drought-induced migration as lack of alternative work opportunities and the risk of famine often forces the male family members to leave in search of income. In this context, restoring degraded farmland, improving soil fertility and enhancing water conservation for crop production with effective, replicable and economically accessible methods is fundamental.

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2. General description

As an autonomous local response to drought, land degradation and lack of livelihoods, two different but almost concurrent small-scale agro-ecological restoration processes started during the 1980s in the Central Plateau of Burkina Faso and the Maradi and Zinder regions of Southern Niger. The initiatives were based on local innovation of traditional dryland farming techniques and driven by individual farmers with initial support from some non-governmental organisations. As degraded land was being restored and the benefits of appropriate agro-ecological management became evident, the models were rapidly replicated and adapted by other communities. Throughout three decades of implementation, farmer-led initiatives have gained recognition and support of national governments, through policy changes and supporting public investments, as well as obtaining scale-up funding from international donors.

3. Process of implementation

After the devastating droughts of the 1970s and 1980s, extensive areas of barren land and empty fields were common in the Central Plateau of Burkina Faso. Several farmers began experimenting with modifications of traditional planting pits to fight against land degradation. Traditional planting pits (*zäi*) were dug wider and deeper than normal and organic matter was added. This 'improved' *zäi* enhanced soil fertility and agricultural production by concentrating water and nutrients, trapping windblown organic matter and attracting termites. Termites act as 'ecosystem engineers', digging small channels that improve water infiltration and retention, availability of nutrients. Improved z*äi* pits retain water for long periods, permitting crops to survive dry spells. Another advantage to these planting pits is that farmers do not need to wait until the rain arrives to prepare them, as it can be done in anticipation.

In early 1980s, another traditional farming practice was transformed in Yatenga Province of Burkina Faso when an agroforestry project of Oxfam shifted its focus from tree planting to food production. Local farmers and project staff began building stone contour bunds[3] to harvest rainwater and improve soil fertility and structure. The major constraint in the traditional contours technique was that without tools, it was difficult to ensure the stones were placed following the same terrain elevation throughout the plot, as required for optimal results. Assisted by Oxfam, a simple and low-cost tool for measuring water levels was introduced to farmers to correctly position the contour lines. Through time and further local experimentation, some farmers started using *zäi* and stone contour buds simultaneously and used the combined method not only to produce food crops but also for tree planting and fodder production, by assisting natural regeneration of shrubs and grasses within the plots.

Around the same time in neighbouring Southern Niger, farmers were testing traditional agroforestry practices for restoring tree cover in agricultural lands. This farmer-managed natural regeneration (FMNR) process is a low-cost way for growing and planting trees and shrubs for food, fuel and fodder. The original model, developed in the 1970s, and since then adapted by individual farmers, consisted in using tree stumps present in agricultural fields to regenerate individual trees. Based on the usefulness of the species for fuelwood and fodder production, farmers chose tree stumps and promoted the growth of best stems by regular pruning and removal of other stems. Farmers periodically harvested one of the original stems and selected a new emerging stem as a replacement. Tree regeneration activities were conducted alongside crop production.

[3] Stone contour bunds are lines of stones that follow the contour, or the approximate contour, across fields or grazing land. Water runoff spreads evenly around the contour bunds and trickles though small holes in the stones, slowing runoff and increasing infiltration and water availability to crops. This rainwater harvesting technique also improves of soil fertility and structure, as stone bunds trap sediments and organic matter within the plots.

Charismatic leaders (both farmers and external development agents), have played key roles in promoting and diffusing these local land management innovations. Their 'extension service' has had an enormous impact by permitting scaling up technical innovations from scattered villages to regions, bringing environmental, social and political change and attracting the attention of governments and international donors. Since the mid-1980s, major donors (e.g. Netherlands and Germany) and projects in Burkina Faso have promoted contour stone bunds, *zäi* planting pits or both. Farmer-managed natural regeneration played an important role in the forestry policy reform of Niger.

4. Outputs and Outcomes

It is estimated that improved *zäi* and stone contour bunds, together with other rainwater harvesting techniques used at a smaller scale, have rehabilitated 200,000-300,000 hectares of farmland, and produce at least 400 additional kg of cereals per hectare every year (or approximately 80,000 tons of extra food per year for the entire rehabilitated area) in the Central Plateau of Burkina Faso. Some of the families that adopted the innovations have now complete food security while the period of food shortages has substantially reduced (from 6 months/year to 2-3 months/year) for most others.

Farmer-managed natural tree regeneration has completely changed the environmental and social landscape of Southern Niger. Five million hectares have a greater tree cover now than thirty years ago. With over 200 million new on-farm trees, soil erosion has been reduced and cereal yields in the tree-covered agricultural plots have increased by at least 100 kg per hectare/year. In addition, since increased fodder and crop residues in the farming plots are in many cases sufficient to feed livestock, farmers have started to keep their animals near and use manure as fertiliser in the fields. Even in areas where manure used to be the main source of cooking fuel, it is now invested in the fields, replaced by fuelwood that is collected sustainably from managed local trees.

These agro-ecological restoration processes have substantially reduced the vulnerability and increased the resilience of communities to drought. With increasing cereal yields and ‘additional foods’ (e.g. fruits and edible leaves produced by the trees) in their farms, families can complement cereal-based diets with other nutritive items and, during good years, are able to stockpile grains for difficult periods. New income generating activities have reduced the need for migration. For example, the availability of tree products (fuel, poles, leaves, fruits) in Southern Niger has resulted in the emergence of local markets and new lucrative activities, such as trading and processing of medicinal plants, fodder and construction materials. Testimonials from families indicate that during drought years, the trees in their farms have helped them ‘make ends meet’ through consumption and sale of tree products. During the harsh 2005 drought, no drought-related infant mortality was reported in a village with a long history of tree regeneration, as income from tree products sales was sufficient to buy expensive cereals.

Restoring degraded land through farmer innovations has contributed to poverty alleviation, livelihood security and resilience to drought, with women receiving the greatest benefits. Besides reducing water and fuelwood collection times significantly, agro-ecological techniques have awarded women with a better economic position through additional income-generating activities. For example, in the Central Plateau of Burkina Faso, men focus on crop production in *zäi* on hard soils, and leave sandy soils to women to cultivate groundnuts and profit from their sales. In Southern Niger, women own trees that produce edible products, and have free access to deadwood and crop residuals to feed livestock purchased with earnings from their farm activities.

5. Discussion

The unprecedented extent of agricultural land restoration has been a product of local farmers' determination to regain their livelihoods in a degraded and drought-prone region. Agro-ecological restoration of degraded farmland has alleviated poverty and decreased vulnerability to drought. However, diffusion and implementation of soil and water conservation techniques and tree regeneration alone will not solve all problems. Some of the techniques are labour-intensive, or require outside funding for purchase or transportation of materials, as in the case of stone bunds. Nonetheless, initial economic estimates suggest that the benefits by far surpass costs. For example, the 200 million regenerated new trees in Niger are estimated to provide at least US$ 280 million per year in goods and ecosystem services. The economic benefits of reclaiming degraded (and practically unproductive) farmlands in Burkina Faso are also evident. As an example, the gains in cereal yields obtained on *zäi* alone are estimated to be worth at least US$ 19.2 million per year for the whole region, whereas the cost of the entire agro-ecological restoration has been estimated at US$ 40 million[4]. This shows that farmers' efforts in preparing *zäi* have paid off in a relatively short timeframe and that their intervention was clearly an economically superior choice compared to the baseline scenario that kept the soils sterile. While providing an initial idea of the economic significance, these estimates omit many ecosystem management benefits that are fundamental to local communities, such as increased biomass, groundwater recharge and stimulation of local markets. One of the most important, though unaccountable benefits has been the process of exploration, experimentation and exchange among farmers.

Several important lessons can be learned from this social and environmental transformation, including:

- Simple and low-cost adaptation of traditional techniques that responded to local needs proved to be widely accepted and replicable. As farmers played an active role in the design and implementation of technical innovation, they felt ownership of the reclamation process, which has ensured its sustainability.
- A single technique or practice alone may not suffice to achieve meaningful environmental and economic impacts but can act as a trigger for other innovations. More rapid environmental improvements occurred where farmers undertook multiple innovations simultaneously.
- Large-scale restoration activities can follow a single set of technical options as long as these are flexible and adaptable to fit local conditions and only if farmers can decide which techniques best suit them.

6. Conclusions

Driven by recurrent drought and low agricultural yields, even during times of good rain, farmers in the West African Sahel experimented and adopted small changes in traditional soil and water conservation techniques to restore their farmlands. During the past thirty years, these changes have transformed once barren dry environments into areas that offer a more reliable resource base for rural livelihoods through increased crop yields, provision of ecosystem goods and services previously lost to degradation and alternative income generating activities. These simple and low-cost local initiatives have significantly improved the life of women and children and have strengthened the natural, social, economic and political capital of poor farming communities. Furthermore, the farmer-led agro-ecological transformation observed in Burkina Faso and Southern Niger has proven to be one of the more sustainable and successful attempts to fight desertification, reduce poverty and buffer the impacts of recurrent drought in Africa.

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[4] The costs of standard rehabilitation techniques (estimated at USD 200/ha) were used as a proxy.

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Case Study 3

Building the capacity of coastal zone managers on protecting coastal ecosystems to reduce disaster risk

Authors: Serena Fortuna[1*], Loy Rego[2+] and Arghya Sinha Roy[2++]

Abstract:
Healthy ecosystems play a vital role in supporting livelihoods of coastal communities and in reducing risk in coastal areas, which are often impacted by natural hazards. With climate change, this risk is expected to increase, even in areas not historically prone to natural hazards. Coastal zone managers could play a crucial role in enhancing resilience of coastal areas, if equipped with necessary knowledge and skills. It is, therefore, essential to build the capacity and knowledge of coastal managers on measures which can protect human lives, as well as ecosystems and infrastructure against the impact of natural hazards, ensuring the sustainability of a wide range of coastal ecosystem services. At the same time, it is important to work with disaster risk reduction practitioners and authorities to enhance their understanding of the services and benefits healthy ecosystems can provide, including disaster risk reduction. This initiative attempts to bring together disaster risk reduction practitioners and coastal zone managers in South and Southeast Asia to increase their understanding, enhance their skills and improve practices related to coastal ecosystem-based measures for disaster risk reduction.

Key words: capacity building, coastal ecosystems, disaster risk reduction, ecosystem-based disaster risk reduction
Hazards: coastal hazards (drought, flood, storm surge, landslide, tropical cyclone, tsunami)
Ecosystems: coastal ecosystems
Location: South and Southeast Asia
Dates: 2007-2009

1. Introduction

Asia is one of the regions hardest hit by natural hazards, with vast populations settled in vulnerable urban and rural coastal areas. With climate change predictions of increasing hazard frequency and intensity, early warning systems and preparedness plans are necessary but insufficient to reduce risk. It is clear that additional measures must be taken to address underlying vulnerabilities. Protection and sustainable management of ecosystems plays a vital role in this regard.

Coastal ecosystems and associated watersheds provide a wide range of services to coastal communities, including food, medicine and fuelwood, as well as shoreline protection against storms, floods and other hazards. Therefore, in areas prone to the impact of natural hazards, using coastal ecosystems as natural protective "infrastructure" can both decrease exposure and enhance livelihood options for local people. However, coastal ecosystems in the region are threatened by uncontrolled logging, land conversion, unplanned development, pollution and, in certain areas, sea level rise and land subsidence. Because a large number of stakeholders and institutions are involved in the management and/or development of coastal areas, protecting coastal ecosystems and reducing disaster risk in these areas requires active participation and engagement of communities, coastal

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zone managers and developers, the private sector, disaster risk reduction practitioners and environmental professionals.

2. General description

This initiative, implemented between 2007 and 2009 in South and Southeast Asia, aimed at building the capacity of coastal zone managers on disaster risk reduction approaches that maintain and enhance ecosystems services. It also aimed at increasing understanding among disaster risk reduction practitioners of the multiple services and benefits healthy ecosystems can provide, including disaster risk reduction.

The initiative was implemented by the United Nations Environment Programme (UNEP) with financial support from the United Nations International Strategy for Disaster Reduction (UNISDR) and the European Commission AIDCO programme. It was carried out in partnership with national environmental institutions and disaster management organisations in India, Indonesia, Sri Lanka and Maldives, and, at the regional level, with the Asian Disaster Preparedness Center (ADPC). The initiative also worked in collaboration with Mangroves for the Future (MFF), a multiagency, multi-country initiative working for ’healthy coastal ecosystems for a more prosperous and secure future for coastal communities’.

3. Process of implementation

At the *national* level, the initiative's objective was to work with national agencies responsible for disaster risk reduction (DRR) and with coastal zone management/ecosystem management institutions[1], to co-develop and undertake a national interactive and participatory training course on DRR for coastal zone managers.

At the *regional* level the initiative developed, with the assistance of ADPC, a ‘Regional Training Manual on DRR for Coastal Zone Managers’, however, no regional training course could be provided within the scope of the project. Through the regional component the project offered country-to-country learning opportunities, with representatives of the national partners participating in regional events (e.g. project mid-term review) and in key consultation meetings in other project countries, sharing experiences, knowledge and challenges encountered. Through collaboration with MFF and IUCN, the project was involved in training modules and short learning/special sessions offered in regional and global events (e.g. World Conservation Congress 2008) This allowed the initiative to reach stakeholders from Malaysia, Maldives, Seychelles, Pakistan, Thailand, Viet Nam and various international organisations.

4. Outputs and Outcomes

[1] Key national partners were:

- India: Centre for Environmental Education (CEE), Ministry of Environment and Forests (also chair of MFF National Coordinating Body), National Institute of Disaster Management (NIDM);
- Indonesia: Gadjah Mada University (GMU), Disaster Management National Agency (BNPB), Directorate of Marine and Coastal Affairs (DKP), Ministry of Environment (KLH), National Development Planning Agency (BAPPENAS) (DKP, KLH, and BAPPENAS are part of the MFF interim National Coordinating Body);
- Sri Lanka: Coast Conservation Department (CCD), Ministry of Fisheries and Aquatic Resources (also MFF National Coordinating Body), Disaster Management Center (DMC).

Additionally, in each country, several other entities were involved in the preparation and delivery of the training modules. Maldives participated in the training course delivered in Sri Lanka.

At the national level (India, Indonesia, Sri Lanka), direct outputs included three national training manuals on DRR for coastal zone managers and their related training courses given to coastal zone managers, disaster risk reduction practitioners and, in certain cases (e.g. India) to the private sector. Through this process, the project also contributed to enhancing collaboration between environmental institutions and national disaster management organisations. In total, 44 environmental institutions and authorities received training on various aspects of disaster risk reduction, including: i) ecosystem-based DRR; ii) contribution of coastal management towards safer coasts; iii) delivery of an interactive training methodology; and iv) inter-agency collaboration. Likewise, national disaster management organisations built their knowledge on integrated coastal zone management and the value of ecosystems in mitigating hazards in coastal areas. During each national training course, preliminary ideas/concept notes were also developed for potential new DRR projects in the target countries.

At the regional level, the main output was the Regional Training Manual on DRR for Coastal Zone Managers, which proposes a seven-day training course structured into eight modules. Modules highlight the economic importance of coastlines, the critical services coastal ecosystems provide, and the importance of environmental management for achieving the goals of Hyogo Framework for Action. The course also presents structural, ecosystem-based and integrated measures to reduce risk in coastal areas and helps participants in identifying actions which should be undertaken in their respective organisations to ensure that their initiatives in coastal areas are hazard resilient and do not add risk.

Long-term results of the project's institutional capacity building activities could include autonomous replication of training courses by national institutions, higher engagement of coastal zone managers in disaster risk reduction initiatives and planning and continuous collaboration between national disaster management and coastal zone management/environmental institutions.

5. Discussion

Facilitated by UNEP and ADPC, active collaboration between disaster management and environmental agencies at the country level, was one of the project's key elements of success. Project linkages with large on-going initiatives and international events increased outreach of the training material and allowed the project to reach stakeholders beyond the three target countries, without additional funding. In addition, building on a regional platform, such as MFF, increases the possibility of incorporating the training materials produced into larger frameworks. Mutual feedback between regional and national project components reinforced the quality of outputs at both levels, by bringing international experience and knowledge from experts and partner countries into the process, and by establishing a regional product (training manual) based on national needs. National implementing partners benefited significantly from the exchange of knowledge between country representatives, through participation in mid-term reviews and other regional events.

At the national level, the content of the training course differed depending on the type of organisations involved in its development. In Sri Lanka, the key agency involved was responsible for national coastal zone management, allowing for the final output to adequately capture coastal zone management policies, plans, regulations and measures, and the need to deliver the course at a sub-national level for district officials in charge of coastal zone management and disaster management was made clear. In the case of India, the training course brought in experience from government authorities, non-governmental organisations and the private sector. In a large and strongly decentralised country like India, institutionalisation of a training course also needs to be decentralised and taken up more closely with state level agencies. In the case of Indonesia, where the development of the course was led by a research institution, the use of tools, such as GIS, for undertaking coastal risk assessments was highlighted.

The project attempted to strengthen partnerships between national disaster management agencies and national coastal zone management agencies. The actual level of partnership differed between countries, ranging from participation at project consultations to sharing the development and delivery of training course modules at the national level.

Sustainability was built into overall project design through emphasis on national level capacity building, translation of material into national language(s), and integration into the larger MFF initiative and other regional programmes. The selection of national and regional partners was done not only according to their technical skills and success history, but also on the basis of their involvement in facilitating training of coastal managers and/or DRR practitioners as part as their routine work to ensure further delivery of training courses after project completion. In addition, specific sessions in national and regional training courses were dedicated to the preparation of concept notes for future projects on DRR & integrated coastal zone management.

6. Conclusions

Although the importance of healthy coastal ecosystems for reducing disaster risk is increasingly recognised, necessary actions to integrate sustainable ecosystem management and disaster reduction strategies are not yet well understood in the two traditionally most relevant practitioners' schools - coastal zone managers and disaster reduction practitioners. Capacity building targeting different levels is essential to build understanding, enhance skills and improve practices.

The initiative described in this case study supported the development of national level training courses aiming at building capacity of both coastal zone managers and disaster risk reduction practitioners. However, it needs to be rooted within existing national institutions, as well as reach practitioners at sub-national and local levels. At the regional level, the training course should be offered for all countries in the region and support should be given to countries to ensure the course is tailored to their national contexts.

Further reading

ADPC (2009). Regional training manual on disaster risk reduction for coastal zone managers.
http://www.preventionweb.net/english/professional/publications/v.php?id=13190

Case Study 4

Reducing Fire Disasters through Ecosystem Management in Lebanon

Authors: Radhika Murti[1], Marcos Valderrabano[2] and Pedro Regato[3]

Abstract:

Fire is the main cause of forest loss in the northern Mediterranean with considerable impact on properties and livelihoods. Forest fires in Lebanon have increased in scale and intensity in recent years due to changes in land use management practices and extreme temperature events. In April 2008, IUCN, WWF, FAO and other regional IUCN members and partners agreed on a common position – the Athens Statement – for climate change adaptation in Mediterranean forest conservation and management with a special focus to increase resilience to major disturbances. Following the statement, a new forest fire strategy was adopted in Lebanon in 2009 through a participatory process with the government, which incorporated a climate change adaptation goal: “Reducing the risk of intense and frequent forest fires whilst allowing for fire regimes that are socially, economically and ecologically sustainable”. IUCN supported the development of the strategy and is currently supporting pilot actions that build ecological and social resilience of local communities. Land restoration through planting of fire resilient native species, a joint fire management plan for all farmers and the setup of a nursery to produce seedlings for the restoration have been some successful achievements of the project thus far.

Key words: fire, forest, adaptation, ecological resilience, social resilience, integrated land-use planning
Hazards: Fire
Ecosystems: Forest
Location: Lebanon, Mediterranean region
Dates: April 2008 -ongoing

1. Introduction

Fire is the main cause of forest loss and damage in the northern Mediterranean. Over 67,000 fires burnt on average more than 400,000 ha per year between 1995 and 2004 with a massive 751,798 ha burnt in 2003. The fire season of 2007 significantly added to these numbers. The fire situation in the Mediterranean basin is driven by a climate of long dry summers with low rainfall, high temperatures and low atmospheric relative humidity, making forest and vegetation fuels highly combustible and leading to conditions of very high to extreme fire danger.

Vegetation patterns in the Mediterranean basin have been heavily influenced by human activities and land uses throughout history. Recently, countries in the region have experienced heavy migration of people from rural to urban areas, increased agricultural mechanisation and reduced pressure for grazing and fuelwood collection. In combination, these factors have led to the expansion of vegetation across the landscape in many places, increasing vegetation fuels and the risk of harmful fires. With changing land use patterns and rural communities no longer relying on the forests for their livelihoods, the involvement of local communities in forest and rural landscape management has reduced. Local fire management has been replaced by fire fighting systems that

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rely increasingly on technology and that focus primarily on suppressing fires once they start with limited attention paid to risk reduction (including fire prevention) and land-use management.

Forest fires are the main source of forest degradation in Lebanon, where on average of 2000 ha of forests burn annually. Loss of forests leads to acceleration of soil erosion when compounded with seasonal rainfall and steep topographies. Harmful fires tend to take place in the summer when temperatures are high and air humidity and fuel moisture are low. Climate change scenarios for the Mediterranean basin suggest a future with increased air temperatures, reduced summer rainfall and more intense and frequent extreme heat wave events. National strategies allocating major efforts and resources to fire fighting (i.e. buying of hydroplanes and helicopters) have proved to be inefficient in light of the growing trend of large-scale devastating fires.

The disastrous forest fires of 2007 raised social alarm in Lebanon. This led the Prime Minister to establish a national forest fire prevention and forest restoration committee. The urge from the community, especially from municipalities with forested land, led to the elaboration of the National Strategy for Forest Management by the Council of Ministers. Following consultations with farmers and communities, dialogue with relevant national stakeholders and a review of existing fire management plans, the National Forest Fire Strategy of Lebanon was formally approved.

IUCN has since 2008 supported pilot actions for developing and currently also implementing the new National Forest Fire Strategy. Covering an approximate total area of 215,000 hectares, the project is located in southern Lebanon in the western range region. The project area extends from North to South, parallel to the Mediterranean coastline and ranges in altitude from sea level to 2000 m at Barouk Mountain and ends at 900 m in the semiarid Bekaa Valley. Most rainfall in the area occurs between November and March. The average annual rainfall on the coast ranges between 700 and 1000 mm. The central part receives up to 1600 mm annually. In the Beqaa portion, the rainfall is approximately 800 mm/year.

The project involves multiple activities in addressing fire resilience through both restoration of degraded forest areas and developing and adopting land-use practices through innovative, as well as traditional practices. The project also aims to ensure participation from all relevant stakeholders, long-term capacity building for the restoration and sustainable management of agricultural landscapes and facilitation of enabling policy frameworks. Key activities include:

- Developing a participatory planning process to design landscape patterns (type of uses and territorial distribution) for resilience to fire and for preventing land use changes which may increase fire risk (i.e. the current trend of intensification of pine plantations).
- Identifying fuel load reduction opportunities through traditional (i.e. promoting livestock grazing in high fire risk areas) and innovative land uses (i.e. supporting bio-energy production using agriculture and forest waste products and dry biomass from shrub-land).
- Developing and exploring opportunities (e.g. innovative management systems, economic incentives) to help adopt fire resilient land uses and landscape patterns.
- Ecological restoration of healthy forest conditions, diversifying forest land with a number of native species which regenerate better after fire and fruit trees/shrubs, which attract seed-dispersal fauna. Restoring riparian forest corridors supports species migration needs and reduces the capacity of fire to spread over the landscape. Riparian plant species possess adaptations to fluvial disturbances that facilitate survival and re-establishment following fires, thus contributing to the rapid recovery of many streamside habitats (A. Dwire, 2003).
- Preventive forest and fuel management practices aiming at reducing high forest fuel litter loads and the landscape susceptibility to fires; this includes, but is not limited to, grubbing (clearing stumps and roots of trees) and pruning, tree thinning, prescribed burning, controlled grazing and species selection.

2. Process of implementation

The multi-phased project has setup a tree nursery in Lebanon for production of seedlings for the restoration of degraded forest areas. Selection of appropriate native species followed scientific research and the use of traditional knowledge in identifying appropriate species to enhance the health of the forests and fire resilience of the landscape.

Local municipalities, civil society organisations, environment NGOs, national ministries, agriculture enterprises and other private sector partners are involved in the development and implementation of this project. IUCN provided technical knowledge to local stakeholders in order to plan and develop the restoration activities of the area. A technical expert provided information and training to a local NGO coordinating the project, IUCN Lebanese members and other local stakeholders (i.e. NGOs, communities, public administration and municipality professionals). Training topics included seed collection techniques, native plant propagation in nurseries and planting methodologies. Selection of native species for restoration and the establishment of a tree nursery were also facilitated by IUCN. In addition, under the scope of the “Mediterranean Mosaics Initiative” and the ‘Forest Landscape Restoration” project, three workshops were conducted for participatory planning and capacity building. Local communities took ownership of the project as the losses from the fires of 2007 were devastating. An understanding of the need to prioritise prevention gained support for the project. People appreciated having a better understanding of how healthy forests sustain their livelihoods through direct revenues (e.g. pine nut collection and aromatic plants) and indirect revenues (e.g. tourism).

3. Outputs and Outcomes

Consensus building and participatory processes enabled the development of the National Strategy for Forest Fire Management of Lebanon that is understood and recognised by stakeholders. The Strategy provided an enabling policy environment to establish and implement practical actions for fire prevention and forest restoration.

Establishment of the tree nursery and production of seedlings of selected native species demonstrate capacity building in nursery techniques. Ongoing work currently involves replanting the landscape using the seedlings, collating knowledge and understanding how to improve the activities. At such an early stage of the project, it is challenging to evaluate the impacts in terms of reduced fire numbers and losses. Since the occurrence of fires (and area burned) is mainly affected by external factors (long drought periods or strong dry winds) indicators of success must include indirect measures (e.g. establishment of fire risk classification or combustibility models).

4. Discussion

The project is owned and implemented by a multi-sectorial group of national stakeholders who understand and acknowledge the long-term benefits. While ongoing financial and technical support is critical in successfully concluding the project, ownership, regular gatherings to discuss progress and challenges and local capacity building have played a key role in implementing the project thus far. Local people have often a low level of awareness concerning their attitudes to forest fires. They often burn forests by accident, using fire as a tool in the wrong time and at the wrong place. People also burn forests on purpose to replace them with land uses that may bring short-term profit. This indicates that people are not aware of the long-term value of forests and the services they provide. They are not connecting the forest with their own quality of life. While the link between forest fires, poverty and land-uses should be properly addressed, community participation is crucial at all levels of forest fire management.

The recent heavy losses due to fire prompted the communities to become proactive in finding solutions to address the causal factors and employ strategies to reduce risks. Highlighting the cost-effectiveness of prevention over firefighting and investing in a joint firefighting plan which pools resources was also key to getting local stakeholder commitment. A joint plan enables each farmer to use their limited resources for fire fighting on a smaller area of land while allowing all areas to be covered using everyone's resources. Moreover, farmers would prefer to plant species which produce pine nuts as a source of income. Thus, education and awareness raising on the cost-effectiveness of other species in reducing losses to fires was also carried out.

Integration of traditional knowledge and current science to find local solutions for prevention (instead of investing in new technologies to enhance firefighting capacities) was also an important factor in successfully developing a feasible fire management project. Involving local communities in activities related to post-fire management need to identify socio-economic opportunities to link forest restoration and local development (i.e. local tree nurseries for the production and marketing of aromatic/medicinal native plant species).

5. Conclusions

While the project is ongoing, it is evident that an understanding of the cost-effectiveness of natural solutions (ecosystem management) is critical in establishing local ownership of the project. Small holder farmers prioritise planting species that yield revenue, so cost-benefit analyses were important in obtaining support for forest restoration and use of native species and are key to influencing stakeholders in the decision process to create "smart fire" landscapes.

The involvement of national government is very important in future implementation of successful strategies within other areas of the country. Dissemination of knowledge and lessons learnt, together with identification of further activities (e.g. improving mapping systems for fire hazards) that enhance implementation capacity for project activities should be facilitated by the government.

This approach is likely to be used in other areas of the Mediterranean as they have similar fire prevention issues. However, this will require further understanding of local plant communities, microclimatic issues and challenges and constraints of the communities.

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Case Study 5

Integrated Fire Management in South Africa

Authors: V. Charlton[1], A. Held[1*],

Abstract:
Approximately 70% of the ecosystems covering South Africa are fire-adapted: they need to burn in order to maintain their ecological integrity. Losses due to unwanted fires have increased as a consequence of climate variations, fuel build up through neglected land management and invasive alien plants and human-induced ignition. Working on Fire (WoF) was founded in 2003 to develop and implement Integrated Fire Management as a response to the phenomenon of wildfire in South Africa – fires caused naturally, fires caused by people and fire used as a landscape management tool. It functions as a major job creation programme that is supported by national government. WoF firefighters are recruited from marginalized communities and trained in fire awareness and education, prevention and fire suppression, including undertaking prescribed burning, creating fire breaks, developing fire management plans and providing training. WoF was also tasked with fire awareness and education programmes with the aim of creating Firewise Communities. A Firewise Community takes collective ownership of its ignition potential and individuals take steps to reduce risks and hazards within the community by planned reduction of fire fuel. WoF has demonstrated how an environmental problem and hazard can be addressed in a developmental fashion that supports structured employment and training, alleviating poverty.

Key words: fire management, poverty relief, job creation, natural resources
Hazards: Fire
Ecosystems: fynbos, savannah, forestry plantations
Location: South Africa
Dates: 2003 -ongoing

1. Introduction

In South Africa, fires occur as a natural phenomenon in grasslands, woodlands, fynbos[2] and sometimes in indigenous forests. Currently, however, most fires are started by accident by people careless with open flames or indifferent to the consequences of their carelessness. Uncontrolled fires pose risks to lives, property and the environment. Losses due to wildfire damage have increased over the past years, partly due to climate variations and fuel build up through neglected land management. In addition, invasive alien plants like Eucalyptus and Pines, increase fire fuel load hazards; implying that frequently people are both the cause and the victims of unwanted fires.

Wildfires do not respect property or boundaries. Without preventive measures, fires will ravage the land when the weather is favourable and there is a fuel load to burn. South Africa has two fire seasons according to rainfall patterns: the dry summer months in the Western Cape and the dry winter months in the rest of the country. Under anticipated conditions of climate change, temperatures over parts of the interior of South Africa are projected to increase by as much as

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[1] Working on Fire (WoF), South Africa, [*]alex@wof-int.com
[2] The major vegetation type of Cape Floral Kingdom, one of the six floral kingdoms of the world, situated in southern and south-western Cape, South Africa. Fynbos is dominated by shrubs and has high biodiversity value (high number of species, high degree of endemism).

3-5°C by the end of the century. Eastern South Africa is expected to experience summers with more intense rainfall events, whilst drier winters are projected for the South-Western Cape. Notwithstanding the possibility of more intense rainfall events during summer, dry spells of relatively long duration may be expected to occur more frequently during all seasons. Increasing temperatures and increased drought frequencies combine to exacerbate the incidence of fire risk. Approximately 70% of South African ecosystems are fire-adapted and need burning to maintain their ecological integrity. But because of human activity, there is a need to manage fire in a manner that is appropriate for land-use needs while maintaining natural processes and patterns as much as possible. This calls for resources – firefighters, equipment, organisational skills and financial backing - to be deployed to protect people and their assets, as well as to protect, manage and conserve the environmental heritage whenever fire is used as a tool. The same resources are also vital when it comes to fighting uncontrolled large-scale fires.

2. General description

Working on Fire (WoF), primarily a government funded job creation initiative is a national government response to the phenomenon of veld[1] fires in South Africa – fires caused naturally, fires caused by people and fire used as a landscape management tool. It is also an initiative that enables implementation of the legislation practically and responsibly. The Veld and Forest Fire Act of 1998 places the responsibility for fire management explicitly on the land-user and encourages land-users to form Fire Protection Associations.

3. Process of implementation

Working on Fire was founded in 2003 to develop and implement Integrated Fire Management practice in South Africa. It functions as a major job creation programme that is supported by national government. WoF firefighters are recruited from marginalized communities and trained in fire awareness and education, prevention and fire suppression skills. The Working on Fire expanded public works programme is implemented by the Forest Fire Association (FFA), a private public benefit company.

The recruited teams are primarily hand crews, fit and capable of assisting with fire suppression, but with the added skills of being able to educate communities in fire awareness and prevention. Because the country has two main fire seasons and there are huge tracts of land requiring prescribed, controlled burning, the hand crews remain active in fire awareness, prevention and suppression work throughout the year. During serious or extended fires, when local resources are exhausted and outstripped, WoF crews and aircraft are mobilised from all over South Africa to assist.

4. Outputs and Outcomes

The programme has 74 fire-fighting bases with a range of local partners across the country with a planned increase to 107 bases in 2010. Each base in the eight fire-prone regions is manned by a team of 10-25 people, known as a Hot Shot crew. The hand crews use mainly hand tools to fight fires. A standard operating procedure governs their response when called out to a fire. The benefit of this modular and replicable system is that at the fire line, WoF crews work as a homogenous firefighting unit under their respective crew leaders and supervisors. Crews are provided with the correct tools, equipment and Personal Protection Equipment (PPE) to maximize their efforts. Outside of the fire season ground crews undertake fire prevention work,

[1] Open country in Southern Africa that is used for pasturage and farmland.

such as fuel load reduction, prescribed burning and the clearing of fire breaks. They also teach fire awareness at local schools and at rural community gatherings.

WoF provides dignified work with financial security for a number of years, skills acquisition, accredited training, support, mentoring, upliftment, sound human resource and operational health and safety practices, qualified management and has a placement strategy. In recognition of its success, WoF has been awarded several national prizes for contributing towards environmental sustainability, poverty reduction and addressing development issues.

5. Discussion

Among the significant successes of the programme has been the ability to create a skills pool and to find employment for people in that pool either with partners, municipalities, local government and the public sector. One part of this strategy is the establishment of Integrated Fire Management Services, which undertakes contract work, such as prescribed burning, creating fire breaks, fire management plans and providing training for private and public sector clients. Thus the cost and effort of training WoF crews becomes an investment, which benefits both the individual and greater society.

Media and Community Liaison Officers are deployed as part of WoF teams in all provinces to develop and maintain relationships with local, provincial and national media. They explain and promote the interests of the WoF partnership, particularly with regard to fire awareness and through the press by keeping the public informed about wildfires, which may or may not pose a risk to them. They also teach fire awareness at schools and in communities. WoF was tasked with creating and executing a fire awareness and education programme as part of Integrated Fire Management implementation. Two main precepts underpin the resulting Firewise Community campaigns, projects and modules that have been developed and provided to a broad spectrum of end–users. Firstly, from a land management perspective, land-users must take responsibility for their land, understanding that fire, used safely, is a good tool that it should be used as one of many land management techniques, but uncontrolled fire can cost lives and financial ruin for the land-user that neglects this aspect of responsible land management. Secondly, a desired outcome is to reduce the number of unwanted, damaging fires, and this requires an ongoing education campaign targeting the general public and schoolchildren.

Working on Fire has maintained a high media profile, building good relationships with media and providing them with regular, accurate information during major fire events. The resulting media coverage has in turn helped to raise awareness on the need to reduce unwanted ignitions and the danger of unwanted fires. Together with partners, a variety of materials have been developed ranging from curriculum-based workbooks used by educators and learners, billboards, educational posters and booklets providing layman-friendly information about the weather, the Veld and Forest Fire Act of 1998, steps on how to start a Fire Protection Association and how to create a Firewise Community. The Firewise Community concept is based upon best international practice, modified to allow for the disadvantaged rural poor communities at risk from fire in the South African situation. The Firewise Community principles can be easily adapted to suit both wealthy communities in the wildland/urban interface, as well as very poor rural communities who stand to lose everything that they have during a wildfire event. A Firewise Community takes collective ownership of its ignition potential and individuals take steps to reduce risks and hazards within the community by planned reduction of fire fuel. As evacuation in a wildfire scenario is not an option in poor rural Africa, the alternative is called “stay and defend”. To be able to do so, Firewise is educating communities to become part of the solution, manage their risks and hazards and prepare the community to survive a fire unharmed. Ideally, Firewise Communities are nested within local Fire Protection Associations. Generally, a Firewise Community has a positive relationship and open communication between community members and local firefighting agencies or Fire Protection Associations.

6. Conclusions

At a time when the world is suffering from economic depression, Working on Fire has demonstrated how an environmental problem and hazard can be addressed in a developmental fashion that supports structured employment and training, alleviating poverty. Great interest in the WoF model is being shown by other African countries. We anticipate WoF to expand into the sub-Saharan region, providing assistance and mentorship.

Working on Fire remains in essence and in spirit, an agent of government. The core of its business is primarily geared towards assisting governments to fulfil its job creation and social upliftment promise to the people of South Africa. Secondly, WoF is mandated to implement Integrated Fire Management with appropriate prevention activities both in managing natural resources and creating community awareness. WoF has proven that it is one of the best social upliftment models in the country, and it will continue developing and trying out new employment models.

Further information

www.workingonfire.org

www.firewisesa.org.za

www.fire.uni-freiburg.de/GlobalNetworks/Africa/Afrifirenet.html

Case Study 6

Benefits of Healthy Forest Ecosystems, Agro-forestry and Mangroves for Disaster Risk Reduction: Southeast of Mexico during Hurricane Dean 2007

Authors: Xavier Moya[1], William Ancona Valdez[1], Manual Rabasa[1]

Abstract:
Frequent hurricanes combined with high levels of vulnerability have caused large losses and jeopardized local development processes in the Southeast of Mexico. A quantitative assessment revealed substantial differences in the damages caused by Hurricane Dean in 2007 in two ecoregions within the same distance of the hurricane's eye but with different levels of tree cover and ecosystem integrity. The results indicate that coastal areas protected by healthy mangroves and inland areas with healthy forest ecosystems, extensive tree cover and agro-forestry/polycultures, as well as appropriate construction methods and materials for housing, had a much lower level of damage. In addition, the case study reveals additional enabling factors like capacity development and awareness-raising that contributed to the effective use of ecosystems for disaster risk reduction.

Key words: Hurricane, agro-forestry, healthy ecosystems, mangroves
Hazards: Hurricane, flood, storm surge, landslide
Ecosystems: Coastal
Location: Quintana Roo, Southeast Mexico
Dates: December 2009 – February 2010 (Programme evaluation)

1. Introduction

In Southeast Mexico, the impact of multiple hazards, including hurricanes, storms, cold fronts and forest fires, combined with high vulnerability of communities have caused great losses and interrupted local development processes. On 14 August 2007, Hurricane Dean struck the area, emerged into the Bay of Campeche and re-strengthened before making a second landfall in the state of Veracruz. Strong winds and rainfall caused devastating landslides in Veracruz and Tabasco with 14 people killed and damages estimated at US$184 million in Mexico.

Through its long-term engagement to disaster prevention, mitigation and preparedness, the UNDP Disaster Risk Management Programme has developed risk analysis, identified hazards and vulnerabilities and built local capacities to manage disaster risk. Between 2003 and 2009, 500 communities in 32 ecoregions were part of the Programme; good practices are being collected and systematised in order to influence public DRR policies. In Mexico, UNDP works in coordination with the National Centre for Disaster Prevention (CENAPRED) to develop local risk mapping and risk scenarios for the South and Southeastern regions. The Programme carried out disaster risk reduction activities in the states of Chiapas, Tabasco and Yucatan, with a focus on safeguarding local investments and productive and social projects. The Programme also advocated for participatory formulation of public DRR policy by facilitating negotiation platforms with municipalities and state governments and by supporting the interaction between NGO networks, civil society and the government.

In this context, a quantitative assessment revealed substantial differences in the damages caused by Hurricane Dean in 2007 in two ecoregions within the same distance of the hurricane's eye but with

[1] UNDP Mexico

different levels of tree cover and ecosystem integrity. The results indicated that coastal areas protected by healthy mangroves and inland areas with healthy forest ecosystems, extensive tree cover, agro-forestry and polycultures and using appropriate construction methods and materials for housing, had much less damage. In addition, the assessment revealed additional enabling factors, such as capacity development and awareness-raising that contributed to the effective use of ecosystems for disaster risk reduction.

2. General description

This case study compares the damages caused by Hurricane Dean in two municipalities, Felipe Carillo Puerto and Othón P. Blanco, located at the same distance from the eye of the hurricane (50-150 km) and exposed to approximately the same speed of winds. Both municipalities spread from the coast to the interior, sharing similar geological features, but both have different ecosystem conditions due to human activity. The hypothesis of this study is that environmental, economic and social damage and loss caused by extreme weather events, such as hurricanes are considerably low in ecologically well-managed areas. The indicators used in this case study comprise: the state of vegetation of coastal mangroves, wetlands and subtropical forests, type of production systems, and the degree of use of adaptive practices in production and social systems. The data for this study is derived from the "Damage Analysis and Needs Assessment" carried out by UNDP Mexico's Disaster Risk Management Programme, civil society counterparts and the government of Quintana Roo state. The Programme used a unified methodology for damage assessment, which facilitated the comparative analysis.

The municipality of Felipe Carrillo Puerto comprises the Sian Ka'an Biosphere Reserve, which includes two of the most important fishery bays, different types of forest, marshes, mangroves and both freshwater and brackish water lagoons. The coastline is used by fishermen organised in cooperatives to catch fish, lobster and other seafood. Additionally, the area relies on maize cultivation, alternated with fifteen other species of vegetables, legumes and fruits. These agricultural products are mainly produced for local consumption and local trade. Honey production is increasingly directed towards national and international markets. The population of Felipe Carrillo Puerto is around 65,000 people, of which 62.7% is Maya indigenous.[1]

In contrast, the ecoregion of Othón P. Blanco, further to the South and bordering Belize, is dominated by sugar cane, coconut and maize plantations, directed towards international markets. Intensive monocultures seriously affect the aquatic environment and the fishing industry, especially through the use of different agro-chemicals. With 220,000 inhabitants, urban development has led to deforestation of coastal areas. The deterioration of mangrove forests has increased local vulnerability and exposure to the recurring impact of natural hazards (hurricanes, floods, forest fires, droughts and tectonic movements).[2]

3. Process of implementation

The quantitative assessment of the damage from Hurricane Dean revealed substantial differences between the two ecoregions. Before Hurricane Dean struck, the UNDP Disaster Risk Management Programme had conducted disaster prevention and preparedness activities in the Felipe Carrillo Puerto municipality. As part of the activities, local experts were trained and emergency plans in high-risk areas were developed; at the municipal level, coordination with authorities was ensured

[1] http://www.inafed.gob.mx/work/templates/enciclo/qroo/Mpios/23002a.htm

[2] Espinoza Ávalos, Julio, Gerald Alexander Islebe and Héctor Abuid Hernández Arana. 2009. *El sistema ecológico de la bahía de Chetumal / Corozal: Costa occidental del Mar Caribe*. El Colegio de la Frontera Sur (ECOSUR). http://w2.ecosur-qroo.mx/cna/julio/libbahia.pdf

for the evacuation of the population. To reduce economic damage, preparatory measures for different productive sectors (beekeeping, forestry, fishing, crafts), including provision of tips and good local practices in mitigating the impacts of previous hurricanes were disseminated through radio spots in native languages.

4. Outputs and Outcomes

The damage Hurricane Dean caused to homes in Felipe Carrillo Puerto was three times lower than in Othón P. Blanco while the damage to crops was almost half (Table 1).

Table 1: Damage caused by Hurricane Dean		
	Felipe Carrillo Puerto: Healthy forest ecosystems surrounding polyculture plots and villages.	Othón P. Blanco: Degraded forest patches and ecosystems surrounding villages and monoculture plots.
% of area of crops destroyed	15.3%	28.8%
% of area destroyed where maize was planted	24.1%	29.5%
% of homes destroyed	6.1%	16.5%

It is estimated that several factors contributed to the reduced damage in Felipe Carrillo Puerto. In coastal and lagoon areas, mangroves had an important dampening effect against wind and high waves. Local population used mangroves to protect their homes by building their houses behind mangroves rather than on the coastal dunes. Furthermore, mangroves were used to protect fishing boats. Special shelters were built to store small boat engines while the boats themselves were sank in tunnels dug into the mangroves. By doing so, boat destruction was reduced by 98% from one hurricane year to the next, securing income for hundreds of families after the disaster.

Another major factor contributing to the reduction in the impact of the hurricane was the maintenance of healthy forest ecosystems and tree cover. Forest vegetation next to productive agricultural land and populated areas provided effective protection. The analysis indicates that damages were much higher in areas where forests had been substituted by monocultures.

Furthermore, agro-forestry and other polycultures (a combination of vegetables, cereals, fruits and forestry products) in multi-layer arrangements were considerably less affected than single-layer monocultures (e.g. citrus fruits, sugarcanes, papayas and jalapeño peppers). Also timber and other forestry activities (extraction of latex, apiculture) suffered substantially less damage.

Houses that were protected by the combined effect of forest vegetation as windbreaks and adequate construction methods and materials were the least damaged. Indigenous wooden and thatched houses built with traditional stone masonry foundations were more resistant than modern houses built in the area with block walls without cement plaster and with roofs made of cardboard or corrugated iron.

5. Lessons learned

This case study demonstrates the benefits of healthy ecosystems for mitigating the impacts of major disasters. In coastal areas, the maintenance of extensive belts of mangroves helped to protect fishermen's livelihoods and coastal infrastructure. Inland, well placed forests and agro-forestry helped to reduce hurricane damages. Indigenous knowledge on agro-forestry and home building plays a decisive role in maintaining resilient ecosystems and livelihoods and developing productive systems that withstand better major natural hazards. Another contributing factor was the existence of emergency preparedness plans not only at the municipal level, but also at the level of vulnerable communities.

By reducing the social and economic impact of hurricanes like Emily and Wilma (2005) and Dean (2007), the UNDP Disaster Programme has been recognised as a success in the Mexican states of Yucatan and Quintana Roo. Local authorities, NGOs and social leaders are considering major shifts from cattle breeding activities, which led to large-scale ecosystem destruction, to a model based on sustainable ecosystem management, including beekeeping, timber and non-timber related forest activities, agro-forestry and ecotourism. It seems there are not many other alternatives, considering that 40% of cattle died during hurricane Dean, which, apart from a serious economic loss, also created a serious health hazard.

Governmental early recovery plans in Quintana Roo after hurricane Dean privileged environmentally sustainable activities to foster employment and economic growth, recognising that healthy ecosystems not only help save lives and infrastructure, but also contribute to reducing vulnerability vis-à-vis future contingencies, as well as speeding up recovery processes. For instance, in coastal areas fishermen recognised that fish catch, after a hurricane, is much better in areas where mangroves are well conserved.

6. Conclusions

The analysis points out that the good practice of sustainable forest management is strongly correlated with reduced impact of extreme weather events. The practices highlighted in this study are:

- Maintaining the coverage and quality of mangroves in coastal and lagoon systems can result in buffer areas for wind and waves. In the case of hurricane Dean, low pressure wind caused 4-7 meter waves for over 14 hours. Local population protected their housing infrastructure by building behind the mangroves rather than on the coastal dunes and saved their boats in mangrove channels during the storm.
- Maintaining healthy forest ecosystems should be a priority, i.e. protecting the coverage and quality of forest vegetation in both wetlands and flooded pastures, and in areas of deciduous and evergreen forest inland. A good practice is to spatially alternate forest cover with location of housing, animal husbandry and apiculture infrastructure. It was observed during the assessment that healthy inland forests protected people's assets better than monocultures.
- Agro-forestry and other polycultures in multi-layer arrangements can offer greater protection and, as observed in this study, be less affected by extreme events than monocultures.
- Timber-related and non-timber-related forest activities (e.g. the extraction of latex and organic beekeeping) suffered much less damage than large tracts of agricultural plantations. UNDP and the Government of Mexico have selected forestry activities for early recovery of local economy and livelihoods because they generate revenue in the short-term and also fit very well within the traditional family structures and food production activities.
- In addition to locating public and private infrastructure in the vicinity of healthy forest areas, using traditional construction methods and combinations of materials, such as stone masonry foundations, can prevent losses to natural hazards.

The key recommendations from this case study are:

- Aim to combine traditional, indigenous knowledge with modern techniques;
- Preserve ecosystem integrity and combine agriculture with forestry (e.g. agro-forestry);
- Look for creative solutions (e.g. sinking fishing boats in between mangroves);
- Work together with different stakeholders to create awareness and capacity for DRR.

Case Study 7

Integrating disaster risk reduction into the strategic environmental assessment of Sri Lanka's Northern Province

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Abstract:
Following the cessation of hostilities in Northern Sri Lanka, the National Government launched an accelerated development initiative known as *Uthuru Wasanthaya* (Northern Spring), involving new settlements, urban and rural infrastructure and livelihood development. Since 2009, at the request of the Sri Lankan Government and the UN country team, UNEP has been collaborating on the preparation of an Integrated Strategic Environmental Assessment (ISEA) in Sri Lanka's Northern Province. The ISEA is intended to produce a sustainable development framework for the region that meets environmental criteria and contributes to disaster risk reduction and climate change adaptation. The assessment brings together multiple stakeholders – planners, implementers and users including the public and private sectors as well as civil society– from the start of new projects, thereby providing an opportunity for development plans to incorporate disaster risk reduction and environmental conservation measures. The framework establishes a system that facilitates optimum use of natural resources, community development and improved service delivery.

Key words:	SEA, GIS, Sri Lanka, Northern Province, climate change adaptation, land-use planning
Hazards:	Drought, floods, storm surges, tropical cyclones, tsunami
Ecosystems:	coral reefs, seagrass beds, wetlands, forests
Location:	Northern Province, Sri Lanka
Dates:	January 2010 – present (on-going)

1. Introduction

In May 2009, the Government of Sri Lanka pledged to bring redevelopment, reconstruction and investment to the Northern Province through an accelerated development programme known as *Uthuru Wasanthaya* or Northern Spring. The Northern Province was once a stronghold of the Liberation Tigers of Tamil Eelam (LTTE), and following the cessation of hostilities, there is a climate of optimism of producing lasting peace. The Sri Lankan Government is proposing new development in this region which will involve new settlements, urban and rural infrastructure and livelihood development. Although not yet fully articulated, there are also private sector plans for fisheries, tourism and industries.

To facilitate and strengthen the development process in the Northern Province, the United Nations Development Programme (UNDP) Sri Lanka and the United Nations Environment Programme (UNEP), in collaboration with the Central Environment Authority and Ministry of Disaster Management, have initiated an Integrated Strategic Environmental Assessment (ISEA). The ISEA takes into account environmentally-sensitive and disaster prone areas in establishing a sustainable development framework for the region.

Strong government endorsement and support for the ISEA may be viewed within the wider national policy context that has promoted the mainstreaming of disaster risk reduction in development. Following the devastating floods and landslides in 2003 and the Indian Ocean Tsunami in 2004 which significantly impacted the northern and eastern parts of the country, the government recognized the urgent need for a more systematic approach to disaster risk reduction and produced a landmark Road Map for Disaster Risk Management. The Road Map identifies a range of activities that integrate both risk reduction and environmental management objectives. These include undertaking disaster impact assessments within environmental impact assessments and establishing “green belts” for coastal protection.[1]

Given Sri Lanka’s high exposure and vulnerability to coastal hazards, high priority has been given towards integrating disaster risk considerations in coastal zones. The 2010 revision of the National Coastal Zone Management Plan of 2004 seeks to incorporate disaster risk management activities at the lowest levels of government through Integrated Coastal Zone Management (ICZM) and Special Area Management (SAM) planning processes. An expected outcome is identifying highly exposed, hazard-prone areas to guide land-use planning for human settlements.

The ISEA contributes towards strengthening these on-going national efforts to reduce disaster risk especially in hazard-prone and environmentally sensitive coastal areas. Thirty years of conflict between the LTTE and government forces have left the Northern Province’s highly diverse natural environment largely intact. While the area is predominantly flat, it contains wide stretches of forests, wetlands, lagoons, coral reefs, sand dune systems, and sea grasses. The area supports important wildlife, such as birds and wild elephants. At the same time, it is also highly exposed and vulnerable to a range of hazards, especially flooding, coastal storm surges, strong winds and tsunamis.

The thrust towards reconstruction in the Northern Province has made development through social and economic investments a major priority, especially for the largely Tamil population displaced as a result of the war. With the resettlement of displaced populations and ad hoc development activities already taking place, striking the appropriate “mix” of development that is both environmentally-sustainable and disaster resilient is therefore imperative.

2. General description

Initiated in January 2010, the ISEA aims to achieve the following:

(i) To create a process through which the proposed development plans and projects in the Northern Province can be reviewed for individual and cumulative environmental impacts and establish greater coordination in project implementation;
(ii) To establish environmental baseline information for the Northern Province which will identify the unique environmental features and environmentally-sensitive areas and which will then be used as a benchmark for assessing future development impacts;
(iii) To analyse the development options through a framework of disaster risk reduction, climate change adaptation, energy efficiency, low carbon and green growth; and
(iv) To strengthen the institutional and regulatory framework for environmental management in the area in order to monitor ecosystem changes due to expected rapid development.

The ISEA essentially serves two main purposes: firstly, to map environmentally-sensitive areas in order to determine their optimum use including for conservation as well as development purposes, and secondly and most importantly, to support integrated land-use planning.

The geographical scope of the ISEA is limited to the five administrative districts in the Northern Province which include Jaffna, Kilinochi, Mannar, Mullaitivu and Vavuniya. Encompassing a total of 8,884 km², these five districts comprise a total of 33 divisions, 931 sub-divisions and 3,235 villages.

[1] Government of Sri Lanka (2005).

3. Process of implementation

In order to create a common platform that facilitates inter-agency collaboration, the Central Environment Authority (CEA) under the Ministry of Environment, the Disaster Management Centre (DMC) under the Ministry of Disaster Management, and the Urban Development Authority (UDA) function as the main implementing partners of the ISEA, with CEA as the lead agency as it has the mandate to undertake SEAs. UNDP Sri Lanka and UNEP / Post-Conflict and Disaster Management Branch (PCDMB) provide technical and financial support.

The assessment process is designed to establish broad cross-sectoral analysis that will involve multiple stakeholders including national government agencies, local government authorities and the private sector. Efforts will be made to eventually consult with local communities and identify local priorities; however, many localities remain inaccessible due to land mines, unexploded ordnance and population displacement.

The approach consists of three different – but interlinked – components which will be initiated in parallel and will feed into each other. The first component involves mapping of environmentally-sensitive areas (i.e. resource mapping), which will provide baseline information to indicate where potential development activities and new infrastructures could take place and where to extract raw material for construction with minimum environmental impact. At the same time, the resource mapping will also help identify hazard-prone areas and the current ecosystem services that contribute to hazard mitigation. To date, information on water, forest, wildlife and coastal ecosystem resources, major hazards as well as important archaeological sites and sources for construction material have been identified by the relevant technical agencies known collectively as the "Baseline Group".[1] Data has been compiled and translated into visual maps by the UDA using Geographical Information System (GIS) software. These baseline maps will then serve as the basis for assessing proposed development projects.

The second component involves identification of current and proposed development/investment plans and projects, including for industry, tourism, roads, electrification, telecommunication, and agriculture (including fisheries and crop production), prepared by the relevant agencies known as the "Development Group".[2] This information has been translated into GIS maps and compiled together with the baseline resource maps, producing a preliminary "Opportunity Map", which was presented before participating agencies in Colombo in July 2010.

The draft Opportunity Map provides a first glimpse of the spatial distribution of natural resources and proposed development initiatives and creates initial dialogue to address potential conflict between environmental "hot spots" and development. For instance, proposed quarrying activities were seen to encroach on identified wild elephant pathways, facilitating further discussions between the respective agencies on how best to adjust overlapping boundaries.

More technical work needs to be undertaken, however, before the ISEA is completed. Baseline maps require further refinement, including the prioritization of the most critical environmental resources and more in-depth understanding of water resource supply and needs (i.e. water budgets).

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[1] The Baseline Group includes the Water Resources Board, Forest Department, Department of Wildlife Conservation, Geological Survey and Mines Bureau, Archaeology Department and the National Aquatic Resources and Research Development Agency.

[2] The Development Group includes the Board of Investment, Road Development Authority, Ceylon Electricity Board, Tourist Development Authority, Ministry of Industries and Commerce, Department of Agriculture, telecommunications Regulatory Commission, Coast Conservation Department, among others.

As water scarcity appears to be the most critical environmental issue in the North, water is likely the key determinant of development. Additional opportunity maps need to be developed and assessed according to different alternatives (e.g. ad hoc development/resettlement) and proposed/planned development and tested according to different scenarios (e.g. disaster events, sea level rise and climatic variability).

Finally, the third stage of the ISEA involves establishing an Assessment Group led by the CEA to undertake a formal evaluation of the various opportunity maps once developed, identify areas where there are potential conflicts between environmental and development priorities, and propose environmental mitigation measures as required.

Another critical component of the ISEA involves institutional capacity-building to support and sustain the mapping processes and the integrated development framework for the North. This component seeks to strengthen capacities of national, provincial, and district-level authorities for data collection as well as assessment. Capacity development is incorporated through the entire ISEA process, with comprehensive stakeholder engagement envisaged. Technical briefings, consultations and on-the-job training will be provided to ensure that the ISEA is institutionalized and fully-owned by national stakeholders. UNEP conducted the first of a series of SEA trainings which was held in Colombo in July 2010 drawing approximately 50 participants from different agencies including the CEA. Additional hands-on training exercises are planned targeting sub-national authorities and technical agencies.

4. Discussion

The ISEA process so far has been regarded by national stakeholders as a major success in terms of providing a neutral platform that is able to pool together different sectoral agencies. Sharing of information and initial discussions on merging development and conservation priorities are already taking place, which typically pose major challenges for agencies. Sustaining the collective enthusiasm and commitment to the process will be a critical test to institutionalizing ISEA practice.

There are multiple factors that make the ISEA process particularly challenging. Firstly, there is a real sense of urgency to demonstrate a positive peace dividend in the North, forcing the rapid implementation of development projects and delivery of critical services. Environmental as well as disaster risk considerations may not be regarded as a priority. Already ad hoc development and resettlement are taking place on the ground without adequate coordination. Hence, "fast-tracking" the ISEA process will be critical if it is to be relevant. Secondly, the environmental administration in the Northern Province is not yet well-established, facing a real threat of being inundated with development activities in the area. It is therefore important that the ISEA involve provincial and district level authorities in the planning stages to strengthen capacities and ensure coordinated development decisions. Finally, very little environmental baseline information exists for the Northern Province due to the prevailing security situation; thus, decisions may have to be taken based on insufficient or outdated data.

Nonetheless, the current situation in Sri Lanka offers a huge opportunity for guiding the province towards a sustainable development course. Central government is clearly focused on the North, with a multi-ministry task force committed to plan and steer the development process. There is significant opportunity to shape development, with environmental sustainability, disaster prevention and resilience criteria integrated into the decision-making process.

The case for creating a framework for sustainable development in the context of accelerated development in Northern Province is clear. What is needed is a process through which development actors can be engaged and agree on a common framework for sustainable development, which the ISEA initiative provides. Successful outcomes from this initiative could feed into similar on-going development processes taking place in the Eastern Province and be replicated in other parts of the country.

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Case Study 8

Making Space for Water - Developing a New Government Strategy for Flood and Coastal Erosion Risk Management in England

Source: Department for Environmental, Food and Rural Affairs, Environment Agency

Abstract:
In 2005 the UK's Department for Environment, Food and Rural Affairs (Defra) launched the Government programme *Making Space for Water* which developed an innovative country strategy for flood and coastal erosion risk management. This initiative was triggered by the severe 2005 flooding event in Carlisle and the previous floods in 1998 and 2000. Various projects are taking place throughout England to assess how natural resources and processes can help to protect against floods, improve urban drainage and reduce coastal erosion. In the past, there was heavy reliance on rigid, man-made structures for flood risk management along England's river banks and coastlines which required constant repair and costly upgrades. The new approach to risk management adopts the use of natural infrastructure and ecological processes for hazard mitigation. This programme aims to address future development pressures, rising coastal hazards as a result of climate change and mitigation costs.

Key words: flooding, coastal erosion, floodplains, adaptation, U.K, policy
Hazards: Flooding, coastal erosion
Ecosystems: Coastal, river basins
Location: England
Dates: 2005- present

1. Introduction

The UK's densely populated, highly urbanized areas are increasingly experiencing severe flooding and coastal erosion as a result of sea level rise and coastal storm surges. Mitigation measures adopted in the past included heavy river engineering and the use of hard defenses such as seawalls.[1] In light of the increase in devastating floods such as in 2005 and 2007, the Department for Environment, Food and Rural Affairs (Defra) called for a review of the 1993 Strategy for Flood and Coastal Defense.[2] The 2008 Pitt Report entitled "Learning lessons from the 2007 floods" recommended that Defra and the Environment Agency (EA) aim to develop sustainable flood catchment management plans and shoreline management plans that work alongside natural processes. The EA acknowledged the need to protect, restore and emulate natural regulating functions of catchments, rivers, floodplains and coasts.

The UK's flood mitigation strategy, Making Space for Water (MSfW), falls in line with the European Union's Flood Directive which requires member states to regard floodplains as natural retention areas and adopt flood risk management plans that support sustainable land use practices.[3] Through MSfW, the Government aims to have flood and coastal erosion risk management embedded across a range of policies in urban and rural development, agriculture, transport, and environment sectors.[4]

2. General description

[1] Hall, J.W., Sayers, P.B., Walkden, M.J.A., Panzeri, M. (2006).
[2] Defra. (2008b).
[3] Brooks and Huggett (2010).
[4] Defra (2005).

The MSfW programme consists of 25 nation-wide pilot projects that explore various flood and coastal erosion management activities at the catchment and shoreline scale.[1] The projects involve local governments and community stakeholders in collaborative partnerships. Since April 2003, the Government has invested approximately £ 2.2 billion in managing risks of flooding and coastal erosion, a further £ 600 million was invested between 2007 and 2008 and £800 million is intended between 2010 and 2011.[2]

The various pilot projects are financed through the Flood and Coastal Erosion Risk Management Innovation Fund.[3] One such project is the 2007 *Ripon Multi-objective project* which focused on integrating flood risk management with sustainable land use at the catchment scale. It was a joint initiative between Defra, the Environment Agency, English Nature, UK River Restoration Centre and the Forestry Commission.[4] The project covered an area of approximately 140km^2 of the Laver and Skell west of Ripon on North Yorkshire. The project further aimed to provide other benefits such as protection of wildlife habitats and improving water quality. Activities included planting trees as shelterbelts, establishing vegetative buffer strips along riverbanks, creation of woodland and fencing off existing woodland from livestock, hedge planting, and creation of retention ponds and wetlands for increased flood storage capacity.[5] These activities reduced surface flow during floods by trapping, retaining or slowing down overland flow. The strategic placement of vegetation and other natural protective defences was highlighted as especially important to maximize their potential in reducing peak flows.[6] Stakeholder involvement was identified as necessary to gain local local support and maintenance of sustainable land-use practices and flood management activities.

Another pilot project involves the development of the Slapton Coastal Zone Adaptation Plan in South Devon which aimed to develop and implement an innovative and sustainable community-based adaptation programme for the Slapton coastal zone. Slapton Sands, located seaward adjacent to the Slapton Ley Nature Reserve, is a five kilometre stretch of shingle beach[7] facing east into Start Start Bay and the English Channel. It is vulnerable to coastal erosion as witnessed in 2001 when storms severely eroded the shingle barrier. The strong winds, high spring tides and low beach shingle levels closed off the main coastal road for three months, severing a vital link between between Kingsbridge and Dartmouth.[8] The storms also partially damaged the old coastal defences and the nearby visitor car park shared with the nature reserve.[9] Nearby local communities, such as Torcross, were affected, as traffic was disrupted and several local businesses suffered losses. The pilot initiative involved conducting a risk analysis of flood and erosion threats to property and infrastructure within the community of Torcross. An environmental evaluation of adaptation options involving community consultations concluded that it was not economically or environmentally acceptable to defend the road and beachhead from future erosion using engineered, coastal hard defences. Building a hard structure would interfere with beach geomorphology and cause accelerated erosion. Accommodating coastal change through managed retreat was identified as the overall long term solution. Funds were thus invested towards short-term community-driven solutions, such as the localised movement of shingle to provide temporary protection along short lengths of the road to repair storm damages.[10] This was intended to prolong the life of the road and

[1] Defra (2007b): p2.
[2] Defra (2008c): p.11.
[3] Environment News Service (2007).
[4] Wharton and Gilvear (2006).
[5] Darlington and Stockton Times (2009).
[6] Posthumus, Hewett, Morris, and Quinn. (2008).
[7] A shingle beach is a beach which is armoured with pebbles or small to medium sized cobbles.
[8] BBC (2002).
[9] Defra (2007a); Slapton Line Partnership (2007a).
[10] South Hams District Council (2005); SWCCIP (2009).

keep the damaged section of the sea defences protected. However, alternative options in preparation for the future permanent breach of the main coastal road were identified, including the landward realignment of specific sections of the main road in the event of future breaches.[1] In addition, Slapton's coastal management policies were incorporated into the management plan of the Slapton Ley Nature Reserve, maximizing it for natural protection against coastal hazards as well as for eco-tourism and recreation.[2]

3. Discussion

Through the MSfW strategy, the UK Government is proactively exploring ecosystem-based approaches towards flood and coastal erosion management that yield multiple benefits, including for local development (e.g. tourism) as well as biodiversity protection. This marks a dramatic shift away from costly structural defenses that were designed to keep water out towards more low-cost, minimal environmental impact approaches that accommodate flood waters through the use of natural defenses.[3]

The two pilot projects described in this case study illustrate how ecosystems and land-use decisions can be effectively managed for flood and coastal erosion mitigation. Both these projects highlighted the importance of involving multiple stakeholders across different sectors at the community level, which helps create local consensus and ownership of decisions made towards implementing project goals and activities.

The challenge now is how to replicate and scale-up these pilot efforts. External funding is still regarded as critical to successful project implementation. There is also need for long-term monitoring to measure the long-term flood mitigation benefits of the MSfW pilot initiatives. More approaches need to be explored and tested at field-level in order to identify best practices and the most effective flood mitigation options. Finally, the Government should continue to find ways to incorporate MSfW strategies across various sectoral and development policies.[4]

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Case Study 9

Integrating DRR and NRM priorities from a local livelihoods perspective in the Indian Ocean Tsunami Early Warning System

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Abstract:
The 2004 Indian Ocean Tsunami was one of the worst disasters in recorded history, which triggered an unprecedented humanitarian response. In this case study, we consider the Indian Ocean Tsunami Early Warning System (IOTWS) as one of the major responses to this tragedy to reduce future tsunami risk, covering three affected countries: Sri Lanka, Thailand and Indonesia. In 2008, a multi-stakeholder participatory assessment process was undertaken to take stock of efforts by local practitioners. The assessment concluded that local practitioners should be given a greater role in determining the establishment of early warning systems in local communities based on a livelihoods perspective that allows for better integration of disaster risk reduction and natural resource management priorities.

Keywords: tsunami, early warning, coastal ecosystems, livelihoods, Sri Lanka, Indonesia, Thailand
Hazards: Tsunami
Ecosystems: Coastal ecosystems
Location: Sri Lanka (Hambantota district), Thailand (Krabi Province), Indonesia (Bande Aceh)
Dates: Jan. – Dec. 2008

1. Introduction

The 2004 Indian Ocean Tsunami was one of the worst disasters in recorded history, which triggered an unprecedented global humanitarian response. One of the major responses to reduce the catastrophic impacts of future tsunamis in the region was the Indian Ocean Tsunami Early Warning System (IOTWS), under the auspices of the Intergovernmental Oceanographic Commission (IOC).

Early warning is an integral component of disaster preparedness and thus considered also an important element in disaster risk reduction (DRR). Early warning systems (EWS) require a well-functioning communication system between actors who are part of the entire warning chain. Three sets of actors are typically discerned: originators, intermediaries and disseminators or recipients of warning messages.[6] End-to-end early warning means that "information must flow from one end (detection) to the other (community response) without interruption or ambiguity".[7] It consists of four key elements: hazard detection and forecasting, national threat evaluation and alert formulation, dissemination at national and local levels, and local preparedness and response. In this regard, there has been significant investment in the evaluation/forecasting (the scientific and technical dimension) and warning/dissemination (the institutional and political dimension). However, national authorities, UN agencies and development organizations widely recognize that in

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[5] Asian Disaster Preparedness Center, Bangkok, Thailand
[6] Davis, et al. (1998).
[7] Elliot (2006): p. 5.

all three countries insufficient attention has been paid to the final element of the response: the human dimensions of risk perception and decision making.[1] This case study aims to focus on this aspect of response to early warning and highlights the importance of addressing local livelihoods and natural resource use priorities in order to mobilize community support in implementing early warning systems.

2. General description

In 2008, a multi-stakeholder participatory assessment was conducted in Sri Lanka, Thailand and Indonesia to improve understanding of the enabling conditions needed by community-based disaster risk management (CBDRM) practitioners to implement DRR policies and initiatives. Among other issues considered, the assessment process reflected on the challenges practitioners faced in setting up effective EWS at the community level while addressing livelihood and natural resource management (NRM) priorities of communities. The assessment was implemented collaboratively by the Stockholm Environment Institute, Asian Disaster Preparedness Center, and Raks Thai Foundation (CARE Thailand), through consultations with government agencies involved in disaster management, coastal resource management, and community development at different administrative levels, and with international and national non-governmental organisations (NGOs), community-based organisations (CBOs), and communities. Substantial desk-based reviews of regional and national efforts to promote disaster risk reduction and early warning were undertaken to complement the assessment and consultation process.

3. The need for co-benefits between DRR and NRM

In resource poor areas, the motivations for CBOs to undertake EWS activities are centrally concerned with the potential "co-benefits" for natural resource management and livelihoods improvement. This generally means seeking to achieve both long-term sustainability and immediate benefits for people, who often struggle for daily survival. In Krabi, Thailand, where fisheries and tourism are the two most important economic sectors for households, one village-level disaster risk management (DRM) committee developed a multi-hazard EWS for sea-based transport that directly improves safety and protects income generation through fishery and trade.

Although considerable international funds have been provided for the development of national EWS in the region, implementation has limited flexibility in addressing linkages to livelihoods and NRM concerns. Innovative ways have recently emerged in the form of micro-credit arrangements to address this disconnect between disaster risk reduction priorities and livelihood or NRM concerns. In Krabi Province, the establishment of Revolving Loan Funds provides a major entry point for the Raks Thai Foundation to integrate NRM and DRM projects, working through community-based groups. One particular initiative in Krabi involved the restoration and expansion of mangrove ecosystems which had dual objectives: improve food security and reduce physical exposure to coastal hazards.

4. Discussion

Following the multi-stakeholder consultation process in 2008, it is possible discern three main issues that challenge the effective implementation of national EWS – and by extension other related DRR activities – at the community level:

Disconnect between disaster reduction and livelihood priorities

[1] This is largely based on the authors' own consultations with respective stakeholders. See also Smith (2005) and Hamza (2006).

National implementation of EWS is generally prescriptive and top-down, especially with respect to what may be considered as relevant risk knowledge. This means that more holistic definitions of risk that may be locally-negotiated and generated, which take into account ecosystem services, livelihoods, food security, public health and social unrest, is often not considered. This case study has illustrated the capacity of CBDRM practitioners to overcome these constraints through innovative partnership building and reframing of policy priorities. Greater room for flexibility is therefore needed by local practitioners to implement disaster preparedness activities through an integrated approach that enables them to address livelihood and natural resource issues. This more integrated approach becomes a more effective way to gain local ownership and support of DRR-related activities.

Exclusion of local knowledge

IOTWS policies generally make a clear distinction between 'people with information' and 'people at risk', which outlines the transfer of information from national warning centres to communities.[1] This distinction disqualifies the competencies of local stakeholders, who are not considered 'knowledgeable'. Women, in particular, often are given less opportunities to participate in disaster risk reduction and preparedness activities. For instance, women's knowledge of local ecosystems, hazards and their inter-linkages is usually not represented in the generation of risk information. As a result, in managing risks from coastal hazards, there is danger of having only partial understanding of risks, especially associated with livelihood practices and the unsustainable use of natural resources.

Local governance

The assessment process in 2008 further highlighted the importance of addressing local governance issues, not only in terms of securing local political support but also building trust amongst often competing local interest groups.

Despite the increased importance given to disaster preparedness at the national level, decision makers at provincial, district and village levels have to weigh these new demands for disaster preparedness together with a range of other interests and priorities. The value sets, willingness and priorities of sub-national government administrators, therefore, determine to what extent EWS and other disaster risk reduction policies and strategies are implemented. This is particularly true in decentralised governance systems, where ultimate fiscal and managerial responsibilities lie with city and district governments.

In addition, EWS development in the three countries also exposed problems of trust between CBOs (including village DRM Committees and village leaders) and higher levels of government, stemming partly from pre-existing conflicts over natural resource management and asset distribution even prior to the tsunami. Moreover, there are a host of competing factions amongst natural resource users, namely fishers, farmers, small-scale business entrepreneurs, private investors, among others. Competition for donor support in the aftermath of the tsunami has also contributed to undermining community-based partnerships. For example, in Sri Lanka, the government implemented a highly-contested coastal buffer zone policy following the 2004 tsunami, which has led to resource conflicts and increasing disparities between social groups. This has

[1] US-IOTWS (2007).

severely dampened community motivation to participate in EWS development and other DRR-related activities sponsored by government.[1]

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[1] Ingram, et al. (2006).

Case Study 10

Landslides and Vegetation Cover in the 2005 North Pakistan Earthquake: a GIS and Statistical Quantitative Approach

Author: Pascal Peduzzi[1]

Abstract:
Continuing loss of ecosystem services is receiving increased global attention. Often with limited resources, national environmental agencies and environmental organizations need cost-efficient ways to quickly convince decision makers that sustainable management of natural resources can help to protect human lives and well-being. Using a simple, low-budget methodology, this study scientifically assessed the potential role of vegetation cover in mitigating landslides triggered by earthquakes, after accounting for other potential landslide-inducing factors such as slopes and distance from the active fault. The methodology was applied to the 2005 North Pakistan/India earthquake which resulted in high mortality and triggered hundreds of landslides. The study shows that if slopes and proximity to the active fault are the two main factors influencing susceptibility to landslides triggered by earthquakes in this area, the results clearly revealed that areas covered by denser vegetation suffered fewer and smaller landslides than areas with thinner (or devoid of) vegetation cover. Short distance from roads/trails and rivers also proved to be pertinent factors in increasing landslide susceptibility.

Key words: landslides, vegetation cover, earthquakes
Hazards: earthquakes, landslides
Ecosystems: mountain ecosystems
Location: Muzaffarabad, North Pakistan and the Neelum valley, India (Jammu Kashmir)
Dates: July 2006

1. Introduction

The importance of forests for local livelihoods is well-understood. Yet 13 million ha are deforested globally every year[2], and deforestation has been identified as a major trigger of the observed global increase in landslide disasters.[3] In order to influence policy decisions to arrest deforestation, tangible evidence is needed to demonstrate the benefits of sustainable forest management. Unfortunately, cost-effective methods that produce solid scientific evidence of the positive role of ecosystems, such as forests, for disaster risk reduction are not always readily available. This affects the work of environmental agencies and non-governmental organizations (NGOs), which, with very limited budgets, need to convince decision-makers of the importance of protecting ecosystems not just for livelihoods but also for reducing disaster risk.

Understanding the underlying causal factors of landslides can help identify the potential for future slope failure and determine whether landslide susceptibility could be attributed to human-induced forest degradation. In this regard, a scientific evaluation has been applied to study the multiple factors associated with the landslides that followed the 2005 earthquake in Northern Pakistan and India.

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[2] FAO (2005).
[3] Nadim, et.al. (2006).

In April 2005, IUCN Pakistan published a report which highlighted the risk of "a possible human catastrophe due to the growing danger of landslides…owing to heavy constructions, ruthless deforestation and massive quarrying."[1] Five months later, a devastating earthquake hit the region with a recorded magnitude at the epicentre of 7.6 M_w on the Richter scale. Approximately 75,000 people died, 134,622 were injured and 5.15 million were left homeless. The earthquake resulted in an economic loss of USD 6.2 billion.[2] The heaviest damage was sustained in the Muzaffarabad area area and Kashmir region, where entire villages were destroyed. More than 30 percent of all victims were killed by landslides triggered by the earthquake.[3] Remote sensing techniques identified more than 2,400 landslides following the October earthquake.[4] The biggest individual landslide was the 68 million m^3 Hattian Bala rock avalanche that killed approximately 1,000 people.[5]

2. General description

Part of a wider IUCN initiative[6], this study aims to scientifically assess the potential role of vegetation (i.e. forest cover) in mitigating landslides triggered by earthquakes, after accounting for other potential landslide-inducing factors, namely slopes and distance from the active fault. It undertakes a geospatial and statistical analysis, involving simple Geographical Information System (GIS) and remote sensing algorithms, and is based on free or very low-cost data.[7]

The study area, delimited by a 60 x 60 km square, covers Muzaffarabad, North Pakistan, and the Neelum valley, in the disputed Jammu Kashmir region bordering India. It is a rugged mountainous area, where altitude ranges between 552 and 4476 m and includes the location of the 2005 earthquake's largest recorded epicentre.

3. Process of implementation

To understand why different areas experienced landslides of different magnitudes after the 2005 earthquake, statistical analysis were performed on data extracted and derived through GIS techniques from mostly free-access sources (Table 1). Statistical analyses included correlation matrixes and multiple regression analysis and aimed at exploring the contribution of well-known landslide-influencing factors on landslide size variation observed after the Pakistan-India earthquake.

The hypotheses formulated and tested in the study were that slope failures, triggered by the earthquake, were positively related with slope, proximity from active faults or epicentres and proximity from rivers. The latter was included as a potential landslide contributing factor because preliminary satellite imagery analyses indicated that numerous landslides were located close to (or touching) rivers. Once the geophysical and morphological parameters related to slope failure were identified, the potential landslide mitigating or enhancing effects of vegetation density and proximity to trails (or roads) were tested. Proximity to trails was included in the analyses because

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[1] IUCN (2005).
[2] CRED (2007).
[3] Petley, et.al. (2006).
[4] Sato, et.al. (2007).
[5] Dunning, et.al. (2007).
[6] The initiative aimed at conducting an interdisciplinary risk assessment, which included a survey of risk perceptions and ground verification of 100 landslides triggered by the 2005 Pakistan-India earthquake. The focus of the assessment was the lower Neelum valley, north of the earthquake's epicentre, which has a largely forested left bank, in contrast to a heavily degraded right bank due to heavy grazing. The initiative involved the Global Resource Information Database (GRID)-Europe from the United Nations Environment Programme, the International Union for Conservation of Nature, the Institute of Geomatics and Risk Analysis from the University of Lausanne and the *Institut Universitaire d'Etudes du Développement* from the University of Geneva (Sudmeier-Rieux et al. 2007a).
[7] Complete methodological details can be found in Peduzzi (2010)

roads and trails could have contributed to landslides by allowing infiltrations or by destabilising the slope balance of the material. The role of soil type, a known determining factor for landslide susceptibility, could not be investigated due to major soil data gaps in the region.

Table 1. Most relevant data included in the analyses

Raw data	Source	Derived variables	Type of values recorded for each landslide
Detected Landslides	Humanitarian Information Centre for Pakistan (HIC). Data generated by SERTIT based on 5-m SPOT-4 images and by the National Engineering Services of Pakistan (NESPAK) at a lower resolution.	Area of landslides	Area, maximum width and length.
Digital Elevation Model	Shuttle Radar Topography Mission (SRTM version 3, obtained from the CGIAR Consortium) and ASTER (30m resolution), purchased from USGS.	Slope	Elevation difference, Maximum slope, average slope, standard deviation.
Epicentre locations	Advanced National Seismic System composite catalogue, and the Northern California Earthquake Data Center	Distance from epicentres	Minimum distance between either edge of the landslides or centre of the landslide area.
active fault	Manually digitalized[1] map, scale 1:100 000.extracted from Nakata et al. (1991).	Distance from fault line	Minimum distance between either edge of the landslides or centre of the landslide area.
Rivers	Data Repository of the Geographic Information Support Team (GIST, from USAID)	Distance from river	Minimum distance between either edge of the landslides or centre of the landslide area.
Road and trails	United Nations Joint Logistics Centre	Distance from road and trails	Minimum distance between either edge of the landslides or centre of the landslide area.
Landsat ETM+ image (from 7 Oct, 2002)	Landsat.org, Global Observatory for Ecosystem Services, Michigan State University	Normalized Difference Vegetation Index (NDVI), an indicator of vegetation cover	Maximum, minimum and average NDVI value.

4. Discussion

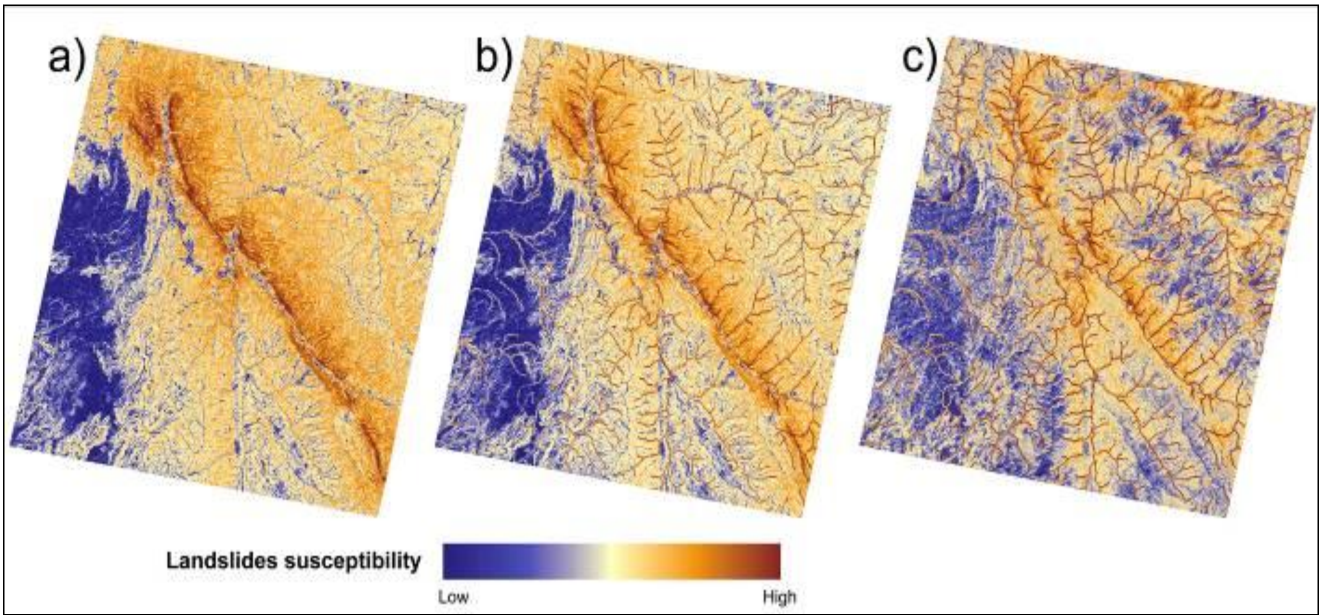
The statistical analyses performed demonstrated that slope, distance from active faults, trails and rivers, and vegetation cover were all significantly related to the extent of landslides that followed the 2005 Earthquake in Northern Pakistan and India.

Slope and distance to fault lines explained most of the overall variation in landslide size (34.9% and 35% respectively), with larger landslides occurring over steep slopes and at short distances to fault lines. 12.1 % of the overall landslide size variation was related to distance to rivers, 9% to vegetation cover and 8.6% explained by distance to trails. When all parameters were analyzed together, greater susceptibility to landslides was found to occur at short distances from rivers and trails and in less vegetated areas. However, detailed analyses showed that the relationship between these factors and landslide susceptibility is more localized. The link between trails and landslide size increases in river valley areas (21.2%). Similarly, the relationship between vegetation cover and landslide size is higher on hillsides (19.9%).

[1] By R. Klaus during an internship at UNEP/GRID-Europe

The statistically significant results of this study clearly indicate that the presence of denser vegetation has a mitigating effect on landslide susceptibility. The implications of this finding for risk reduction planning and forest management in the area are noteworthy and strikingly evident when comparing regional models of landslide susceptibility that include and exclude the positive effect of vegetation cover (Figure 1), as total landslide susceptibility in the area decreases by 15.1% when the protective effect of vegetation is added to the model. The findings of this study support those of Vanacker et al. (2003) who highlighted the role of vegetation in reducing landslide susceptibility, using a similar methodology. Vegetation can reduce landslide susceptibility by reducing water content in the soil,[1] or may reduce shallow landslides through the mechanical role of roots in anchoring the soil. It must be noted, however, that vegetation cover may sometimes indirectly contribute to landslides, for example, strong winds on exposed vegetation may destabilize physical forces on slopes.

Figure 1. Landslide susceptibility that include and exclude the positive effect of vegetation cover



The study results corroborated with IUCN's field-based assessments conducted in the lower Neelum Valley, just north of the earthquake's epicentre. Out of the 100 recorded landslides in the valley, 86 occurred on largely degraded banksides, while 14 landslides on the forested left bank were all located along the road. The field study revealed that forest vegetation had been cleared mainly for terraced farming and animal grazing, evidence of poor land-use planning and lack of enforcement of forest management regulations.[2] Results of both the scientific and field-based assessments were widely shared with policymakers in Pakistan and will hopefully lead to improved management of forest resources in the region.

5. Conclusions

The study supported the hypothesis that landslides in the region were more susceptible on steep slopes and close to rivers, trails, and active fault lines, with forest/vegetation cover functioning as a

[1] Popescu (2002).

[2] Sudmeier et al. (2007b).

stabiliser. These results were verified and discussed at the field level and targeted policies to protect vegetation and reforest hillsides were recommended. The study also demonstrated that globally available datasets can be used to analyze ecosystem-based linkages with natural hazard impacts.

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Case Study 11

Integrating ecosystems and climate change factors in risk and vulnerability assessments: The case of RiVAMP in Jamaica

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Abstract:
Ecosystems degradation is occurring globally at an alarming rate, contributing to increasing disaster risk. As ecosystems degrade so do the multiple services they provide to sustain human well-being, including protection and resilience against the impacts of natural hazards. The Risk and Vulnerability Assessment Methodology Development Project (RiVAMP) was therefore conceived to develop an assessment tool that takes into account ecosystems and climate change factors in the analysis of risk and vulnerability, specifically targeting Small Island Development States (SIDS) and other coastal areas. Piloted tested in the western coast of Jamaica, RiVAMP utilizes a scientific approach based on spatial and statistical analysis, which is complemented by a stakeholder consultation process at various levels including two selected communities. Results of the pilot clearly demonstrated the coastal protection values of coral reefs and seagrasses while at the same time pointing to increasing risk of beach erosion that is aggravated by ecosystems degradation.

Key words:	Jamaica, vulnerability assessment, livelihoods, beach erosion, sea level rise, GIS, remote sensing, hydrodynamic modelling, statistical analysis
Hazards:	Tropical cyclones/hurricanes, flooding, storm surges, accelerated sea level rise (climate change)
Ecosystems:	sea grass, coral reefs, mangroves, wetlands/peatlands, forests
Location:	Negril, Jamaica
Dates:	May 2009 – May 2010

1. Introduction

While population growth and migration to urban centres and coastal areas raise the number of people affected by hazards, ecosystems degradation is also an important driver of disaster risk. With climate change expected to contribute to rising disaster statistics, there is increasing global attention towards better understanding how environmental changes affect and influence risk and vulnerability.

Efforts to reduce the impact of natural hazards, however, often require risk information to identify potential hazards and vulnerability. Although numerous risk assessments are available, assessment methodologies do not yet adequately incorporate the role of ecosystems in risk and vulnerability analysis. As a result, these assessments fail to incorporate the environmental dimensions of risk and thus do not consider the potential of developing ecosystem-based management options for disaster risk reduction and adaptation to climate change-related risks.

2. General description

The Risk and Vulnerability Assessment Methodology Development Project (RiVAMP) was conceived to develop a methodology that takes into account environmental factors in the analysis of disaster risk and vulnerability. The purpose of RiVAMP is to use evidence-based, quantitative and qualitative research to demonstrate the role of ecosystems in disaster risk reduction, and thus enable policymakers to make better-informed decisions that support sustainable development through improved ecosystems management. In this regard, the targeted end-users of RiVAMP are national and local government decision makers, especially land-use and spatial development planners, as well as key actors in natural resource management and disaster management.

As a pilot initiative, the RiVAMP methodology is intended mainly for application in SIDS or coastal areas, and focuses on tropical cyclones and their secondary effects (coastal storm surges, flooding and strong winds). Accelerated sea level rise (ASLR) associated with climate change is also considered as an important factor contributing to risk of storm surges and beach erosion.

Jamaica was selected for the RiVAMP pilot for several reasons, including: its high vulnerability to tropical cyclones and sea level rise; diverse ecosystems which are under pressure as a result of population growth, economic development and a strong international tourism industry; and its high-level government commitment to hazard mitigation and climate change adaptation. Direct implementing partners included the Planning Institute of Jamaica (PIOJ), a national government agency, and the Institute of Sustainable Development at the University of the West Indies (UWI).

Negril located in the western end of the country was chosen as the study area for the pilot assessment. Over the last 40 years, despite its status as an Environmental Protected Area (EPA), Negril has experienced rapid growth in tourism which has led to accelerated urban and housing development as well as population increase. At the same time, Negril has been experiencing irreversible shoreline retreat (i.e. reduction of beach widths). For the period 1968-2006, average beach erosion rates have been estimated at 0.5 m per year for Bloody Bay and 1 m per year for Long Bay Beach. Known for its white sandy beaches, Negril's tourism industry, which contributes approximately 5% of the country's GDP, is thus under serious threat. Beach erosion is being driven by multiple factors, including worsening storms in the region, sea level rise, as well as urban and touristic development, and unsustainable farming and fishing practices. Both these external and locally-induced drivers adversely impact on coastal ecosystems, particularly coral reefs, sea grasses and mangroves, which in turn exacerbate the rate of beach loss.

3. Process of implementation: The RiVAMP methodology

The RiVAMP methodology combines the use of applied science, stakeholder consultations and interviews which allows for improved data triangulation, as the technical and quantitative analysis is balanced with local knowledge and experience. The science-based component consists of satellite imagery analysis and other remote sensing techniques (e.g. use of aerial photographs), Geographic Information System (GIS) mapping and analysis, statistical analysis and modelling the buffering effects of coastal ecosystems on the coastline under conditions of sea level rise and storm surges. The scientific assessment focused on identifying drivers of beach erosion and its associated hazards (storm surges, flooding).

The scientific analyses were complemented by stakeholder consultations undertaken at the national and parish levels involving national and local government authorities, the private sector (e.g. hoteliers, private consulting firms), academe and civil society organizations. Consultations were also undertaken in two selected communities in Negril, namely Whitehall (a semi-urban community located inland) and Little Bay (a fishing village located on the coast). Stakeholder consultations aimed to establish environment and disaster linkages, drivers of ecosystem degradation and the consequences for increased vulnerability and exposure to hazard impacts.

4. Results of the pilot assessment

Key findings of stakeholder consultations

Stakeholders including at the community level fully understood that ecosystems, namely coral reefs, mangroves, peatlands, forests and sea grasses, provide important services not only for economic development and livelihoods but also in terms of hazard mitigation, especially storm surges and flooding. With ecosystems in overall decline in Negril and throughout Jamaica, ecosystems degradation is contributing to increased local vulnerability and exposure to flooding and storm surges.

Based on stakeholder consultations, deforestation as a result of urbanization and housing development has increased flooding downhill affecting several sections of the Whitehall community. Hurricane impact on coral reefs, illegal sand mining activities and unsustainable resource practices (e.g. destructive fishing practices, removal of mangroves, sea grasses and other types of coastal vegetation, and agricultural runoff) have contributed to beach loss and increased storm surge vulnerability in Little Bay. For example, Little Bay residents note more frequent and intense flooding due to storm surges which cut off delivery of potable water supplies into the community, forcing households to rely on unprotected groundwater sources and exposing them to waterborne-diseases. Residents also resort to cutting mangroves for fuel supply and housing repair.

Key findings of the scientific assessment

Based on the scientific assessment results, coral reefs and sea grasses played a crucial role in supplying beach sand material and protecting the shoreline. Hydrodynamic modelling demonstrated how shallow coral reefs and sea grasses attenuate or dissipate nearshore wave energy and thus mitigate against beach erosion. Based on a previous study by UWI (2002), sea grasses were also found to be a major source of beach sand supply in Negril. The observed rate of maximum beach erosion from 1968-2008 was negatively correlated with the width of coral reefs and sea grass meadows. This means that beach areas shielded by coral reefs and thick sea grasses experienced less erosion, suggesting that these ecosystems provide important beach protection. The degradation of nearshore ecosystems will therefore result in diminished beach sediment supplies and increased vulnerability to beach erosion and storm surges caused by tropical storms and cyclones.

Multiple regression analysis further confirmed that both coral reefs and sea grass meadows are the main features that have a mitigating role on beach erosion. Based on the statistical model, coral reefs explain 83 percent of beach erosion, with the width of coral playing the main role (59%) in reducing erosion, while sea grasses explain 41 percent of beach erosion, with the width of sea grasses playing the main role (47%) in reducing erosion. However, the submarine beach slopes as well as the wave regime were also shown to influence beach erosion: areas with steep profiles and / or less steep waves result in milder beach erosion, whereas areas behind gentle submarine slopes are susceptible to erosion.

It is expected that long-term sea level rise, together with increasing frequency and intensity of storm waves and surges and diminishing sand supplies due to coastal ecosystem degradation, will exert an even higher toll on Negril's beaches. Even under the lowest projections of sea level rise for 2060, an extreme event (i.e. the 50-year return storm) will result in the total loss of approximately 35 percent of the beach (in terms of length), while another 50 percent of the beach will lose more than half of its present width. Moreover, taking into account sea level rise, modelled exposure to storm surges is expected to put approximately 2,500 people at risk during a 50-year return storm event.

Ecosystems degradation, coupled with beach erosion and the increasing impacts of tropical cyclones, may over time undermine resource-dependent livelihoods, namely fishing, farming and tourism, which are vital to the local and national economy. For instance, declining fish stocks in Little Bay over the past decade have forced many women and men out of the fishing sector, contributing to unemployment or underemployment. The tourism sector has provided *the* main source of alternative employment, but this sector is equally vulnerable to worsening environmental and climatic conditions. Ongoing beach erosion in Negril will therefore have drastic impacts on local livelihoods as well as the overall national economy.

Policy implications

Given the importance of ecosystems to shoreline protection and livelihoods and taking into account expected climatic changes, a "business as usual" approach is no longer viewed as a viable option. Significant corrective measures are required to avert not only the destruction of coastal ecosystems but also to protect lives and critical infrastructure. UNEP recommended that a forward-looking "no regret" strategy, based on restoring and maintaining healthy ecosystems as a key component of risk reduction, is necessary to establish a more sustainable development course in Negril.

There is a clear need to integrate increasing disaster risk and projections of climate change impacts as part of an overall strategy in coastal zone development. This calls for a multi-stakeholder approach involving the private sector (i.e. hoteliers and restaurant owners) and local communities, and a cross-sectoral mechanism or platform that engages disaster management agencies together with coastal development planners and environmental protection agencies. Given the formal protection status of Negril, there is great opportunity to bring the relevant actors together at both the national and parish levels. The challenge remains in convincing higher-level policymakers of the urgency for taking corrective action.

5. Lessons learned

In March 2010 results of the RiVAMP pilot were presented formally in Kingston and Negril by UNEP, which received national coverage in print media and radio. The Kingston event was well-attended drawing a wide spectrum of government agencies (including the Ministry of Tourism), international development partners, the private sector, academe and civil society.

One key factor that facilitated pilot implementation was support obtained from key government agencies, such as the Planning Institute of Jamaica (PIOJ), the National Environment and Planning Agency (NEPA), the National Spatial Data Management Division under the Office of the Prime Minister, the Office of Disaster Preparedness and Emergency Management (ODPEM), among others. Strong local support and ownership of the project stemmed from involving national agencies in project design from the outset. UNEP adjusted initial plans when government agencies requested that the pilot specifically address the problem of coastal beach erosion in Negril. Remaining flexible therefore proved critical. Future follow-up work in Jamaica will need to capitalize on national stakeholder ownership of the RiVAMP process and findings to achieve concrete policy outcomes.

Another success factor was the very high level of technical capacity and data available at the national level. In addition, previous technical studies on Negril's beaches[1] offered important baseline data to run additional modelling and statistical analyses. Such information may be less readily available in other SIDS, and low-cost and readily applicable methods will need to be developed.

[1] See University of the West Indies (2002) and Smith Warner International (2007).

RiVAMP also faced several challenges. Because of time constraints and limited resources, the assessment was not able to develop an economic valuation of ecosystem services for the study area, posing a major limitation in communicating RiVAMP findings to policymakers. Follow-up work will need to focus on developing a better communication strategy to reach higher-level decision makers.

In addition, the lack of post-hazard impact assessments in the study area represented a major data gap for the risk assessment, which was critical in order to "ground-truth" or test the tropical cyclone exposure model developed by UNEP. As a result, it was not possible to verify RiVAMP's model of storm surge impact and estimate risk more precisely based on past exposure to hazard events.

6. Conclusions

The RiVAMP pilot exercise has shown that a more integrated methodology for risk and vulnerability assessments can factor in ecosystem and climate change concerns, based on an evidence-based approach utilizing applied science and local knowledge and experience. The results of the pilot assessment may be applicable to other coastal, particularly tourism-dependent areas in Jamaica. By involving local stakeholders in the process, RiVAMP can potentially influence development policies and help establish a more risk-conscious and environmentally sustainable development course for the country.

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Case Study 12

Impacts from the 2004 Indian Ocean Tsunami: Analysing the potential protecting role of environmental features

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Abstract: The tsunami that struck the Indian Ocean shores on 26 December 2004 ignited calls for urgent rehabilitation of coastal infrastructures to restore the livelihood of local populations. A spatial and statistical analysis was performed to identify what geomorphological and biological configurations (mangroves forests, coral and other coastal vegetation) decreased or increased coastal vulnerability to the tsunami. The results indicate that the width of flooded land strip was, in vast majority, influenced by the distance to fault lines as well as inclination and length of proximal slope. Areas covered by seagrass beds were less impacted, whereas areas behind coral reefs were more affected. The mangrove forests identified in the study were all located in sheltered areas, thus preventing adequate assessment of the potential protective role of mangroves.

Keywords: Tsunami, Indian Ocean, impact assessment, GIS, bathymetry, vulnerability, coastal ecosystems
Hazards: 2004 Indian Ocean Tsunami
Ecosystems: coastal (coral reefs, mangrove forests, seagrass beds)
Location: Indonesia, Thailand, continental India, Sri Lanka and Maldives
Dates: March-June 2005

1. Introduction

Following the devastating impacts of the 2004 Tsunami, the international community called for improved coastal management and urgent rehabilitation of coastal infrastructures to restore the livelihood of local populations. The restoration and rehabilitation of coastal ecosystems, particularly mangroves, received international priority resulting in multi-agency initiatives such as the Mangroves For the Future (MFF). There has been greater recognition of the natural protective functions of coastal ecosystems, in addition to their importance to local livelihoods such as tourism, fisheries and aquaculture.

It was increasingly evident that some areas experienced less impact than others from the tsunami. While the geomorphological role in tsunami propagation is well studied[1] and the influence of small-scale submarine topography has already been modelled[2], less is known about the potential protective role of coastal ecosystems, such as mangroves, coral and seagrass beds. There remains considerable scientific debate specifically with respect to the role of mangrove forests in reducing the impacts of the tsunami.[3]

[1] For example, see Kowalik (2003).
[2] Mofjeld et al. (2000).
[3] Khor (2005), Friends of the Earth (2005), and many others have promoted the protective functions of mangroves, which have been refuted by other studies stating the negligible role of mangroves as they are mainly located in estuaries (Jimenez (1985), Lewis (1982), Field (1996)). Experiments conducted using in-door basins demonstrated how mangrove forests could decrease the height of a solitary wave in a channel (Harada *et al*. 2002), while Hiraishi and Harada (2003) point out that other coastal vegetation such as the

2. General description

In May-June 2005, UNEP/GRID-Europe carried out a statistical and spatial analysis for the UNEP Asian Tsunami Disaster Task Force. The aim of this study was to assess the potential protective role of mangrove forests, coral reefs, seagrass beds and other types of coastal vegetation, which could be distinguished from the near-shore geomorphological influence. This study seeks to improve understanding of the various factors influencing higher coastal vulnerability to the tsunami, and more specifically, test whether coastal ecosystems could provide effective coastal protection.

3. Process of implementation

Data on bathymetry (water depth), orientation of the coast, length of proximal slope, distance to tectonic features, presence of coral, seagrass beds, and mangrove forests, as well as type of land cover were extracted using GIS technologies. Then, the width of flooded land strip was evaluated either by interpreting high-resolution satellite images or from available ground measurements. Finally, multiple regressions were performed to identify the parameters that best explain the width of flooded land strip following a method already applied in previous studies.[1] Global datasets were used to provide a first-cut analysis as well as identify the key parameters that are linked to higher coastal vulnerability to tsunami.

Data collection

The 62 sites selected for the study are located in Indonesia, Thailand, continental India, Sri Lanka and Maldives, as little material was available from other affected areas.

Figure 1. Study area and selected site distribution taken perpendicularly to the coastline

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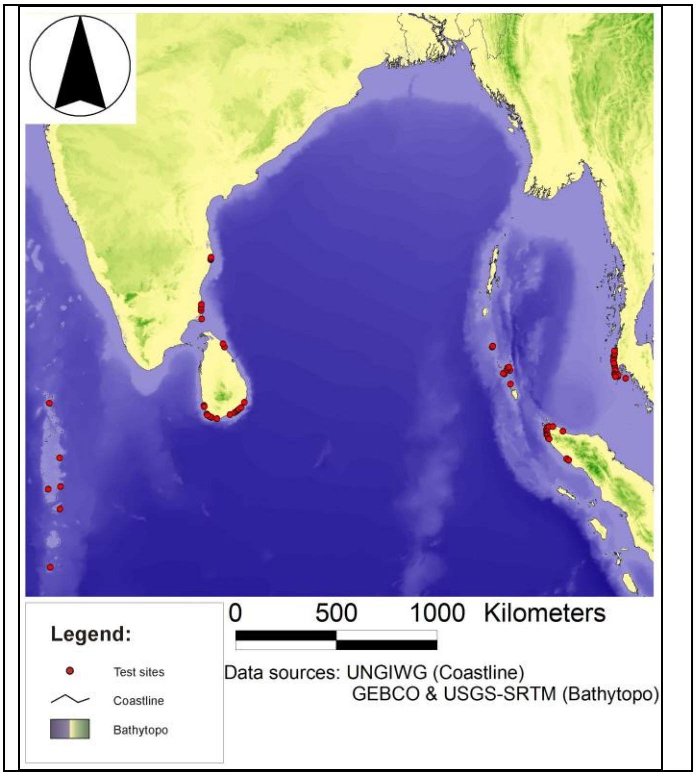
Hibiscus tiliaceus provide greater protection than mangrove forests, as the latter do not grow on sandy beaches. *In situ* observations have demonstrated the protective role of other vegetative species such as *Scaevola sericea* and *Pemphis acidula* (UNEP 2005b).

[1] Peduzzi et al. 2002; Dao and Peduzzi, 2004.



The tsunami impact was determined using the maximum flooded distance (D) in a given area. This information was derived using several types of data. High resolution satellite images that showed the extent of flooded area were analyzed, which was overlaid in comparison to pre-tsunami images. While the use of post-tsunami satellite images was extremely useful for assessing large D values (of several hundreds of metres), they are less useful for smaller widths. It was therefore necessary to complement the analysis with field surveys which were undertaken by the Research Centre for Disaster Reduction Systems (DRS) and the Disaster Prevention Research Institute (DPRI) of Kyoto University.

Table 1. List of variables computed or extracted

Abbreviation	Description	Units
AV10KM	Average slope until 10 km	Degrees
AV1KM	Average slope until 1 km	Degrees
AV2_5KM	Average slope until 2.5 km	Degrees
AV20KM	Average slope until 20 km	Degrees
AV25KM	Average slope until 25 km	Degrees
AV30KM	Average slope until 30 km	Degrees
AV50KM	Average slope until 50 km	Degrees
AV5KM	Average slope until 5 km	Degrees
CORAL	Percentage of protection from coral preceding the site	%age
COSORIEN	Cosinus of orientation	Scalar
DFEQ	Distance from main earthquake	Kilometres
DFF	Distance from subduction fault line	Kilometres
DFS	Distance from source	Kilometres
D	Width of flooded land strip	Metres
LDCOV	Land cover resistance index	Cardinal values 1 to 6
LDTO10M	Average slope until an inland height of 10 meters	Degree
LDTO30M	Average slope until an inland height of 30 meters	Degree
LENGDIST	Length of distal slope	Kilometres
LENGPROX	Length of proximal slope	Metres
MANG	Percentage of protection from mangroves preceding the site	%age
ORIENT	Orientation between the tsunami energy and a perpendicular to the coast	Degrees
PCAV10KM	Average slope until 10 km	%age
PCAV1KM	Average slope until 1 km	%age
PCAV2_5K	Average slope until 2.5 km	%age
PCAV20KM	Average slope until 20 km	%age
PCAV25KM	Average slope until 25 km	%age
PCAV30KM	Average slope until 30 km	%age
PCAV40KM	Average slope until 40 km	%age
PCAV500M	Average slope until 5 km	%age
PCAV50KM	Average slope until 50 km	%age
PCAV5KM	Average slope until 5 km	%age
PCLDTO10	Average slope until an inland height of 10 meters	%age
PCLDTO30	Average slope until an inland height of 30 meters	%age
PCSLDIST	Angle of Distal slope	%age
PCSLPROX	Angle of Proximal slope	%age
SEAG	Percentage of protection from Seagrass beds preceding the site	%age
SLDIST	Angle of Distal slope	Degree
SLPROX	Angle of Proximal slope	Degree

Assessment methodology

To explain the role of environmental parameters in reducing tsunami wave impacts, an *a priori* estimation and standardisation of the other parameters were required. The first step was to model the effect of geomorphology. During a tsunami, bathymetry has a direct link with wave height and velocity, a well-known process. When the water depth decreases, the wave slows down and the wavelength decreases accordingly. This compresses the wave, which then builds up in height. The wave breaks when water depth is reduced to 1.3 times the wave height.[1] Several other parameters were extracted. Shore elevation, length and slope of the proximal and distal slope, and depth at given distances from the coast were acquired for each test site using GIS techniques. In order to take into account the origin of the tsunami, distance from the fault line as well as the angle of the waves to the coastline were included in the dataset. Finally, the environmental parameters were integrated by estimating the percentage of coastline behind coral reefs, mangrove forests and seagrass beds.

To describe the GIS processing details is beyond the scope of this case study. More detailed description of the methodology can be found in Chatenoux and Peduzzi (2007).

4. Discussion

The five factors identified as having an influence on (D) fall into three categories, namely: distance from the fault line, geomorphology and environmental parameters.

Distance from the fault line

The results showed that the closer the coastal area from the fault line the larger was the value of D. This is consistent with description found in the literature: "*Tsunamis typically cause the most severe damage and casualties very near their source. There the waves are highest because they have not yet lost much energy to friction or spreading.*"[2]

Geomorphology of the near-shore

The average depth at 10 km is related to the average slope of the sea floor. A steep slope is known to block the energy of a tsunami, whereas a flatter slope helps build up a higher wave. A greater depth for the same distance means a steeper slope and reduced wave energy, while a smaller depth related to a flatter slope means higher, more powerful waves. Moreover, a longer proximal slope results in a larger width of flooded land strip. This is also related to the slope; the longer the length the lower the angle. Together with the average depth, the two parameters indicate a higher risk configuration when a long shallow area precedes the coast.

Environmental parameters

Seagrass beds (or seagrass substrate) appear to have a positive role in absorbing the energy of tidal wave; the higher the percentage of seagrass beds, the shorter the D values. Based on the statistical analysis, it is impossible to differentiate if the presence of seagrass beds has a mechanical influence that absorbs the energy of the waves, or if the area that seagrass usually colonise is already protected from the wave. The result, however, is that behind areas covered by seagrass, the distance of impact was in majority shorter than in other areas having similar geomorphology.

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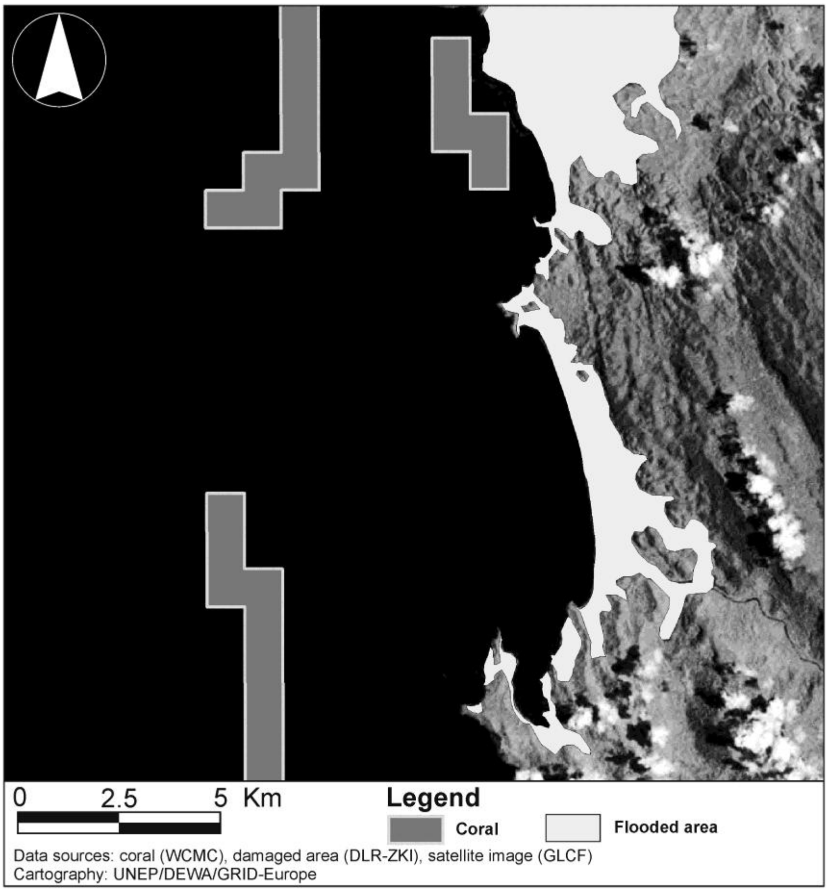
[1] Fox (2004).

[2] NOAA (2004b).

With respect to coral, the analysis yielded surprising results which showed that the higher percentages of coral resulted in larger D values. This was unexpected, as one would imagine water behind a coral reef to be somewhat sheltered. Visual confirmation of this phenomenon was gained using satellite images, which demonstrated larger D values behind corals. In Figure 2, despite facing a double barrier of coral reef, the area at the top of the map exhibited greater impacts than the area without reefs. However, the land elevation in those areas without coral reefs was steeper, which could explain the reduced tsunami wave impacts. One explanation could be the following: Since coral is located mostly in shallow areas, with a gentle slope continuing inland, these low-lying areas could already be predisposed to flooding. Conversely, areas without coral could be steeper and would therefore block the tsunami wave on a shorter distance in-land. Statistical verification, however, contradicted this seemingly logical explanation, showing no significant correlation between presence or absence of coral and in-land slope, at least not with the 90m resolution data used.

Figure 2. Example of coral influence in Lho'Nga, Sumatra (Indonesia)



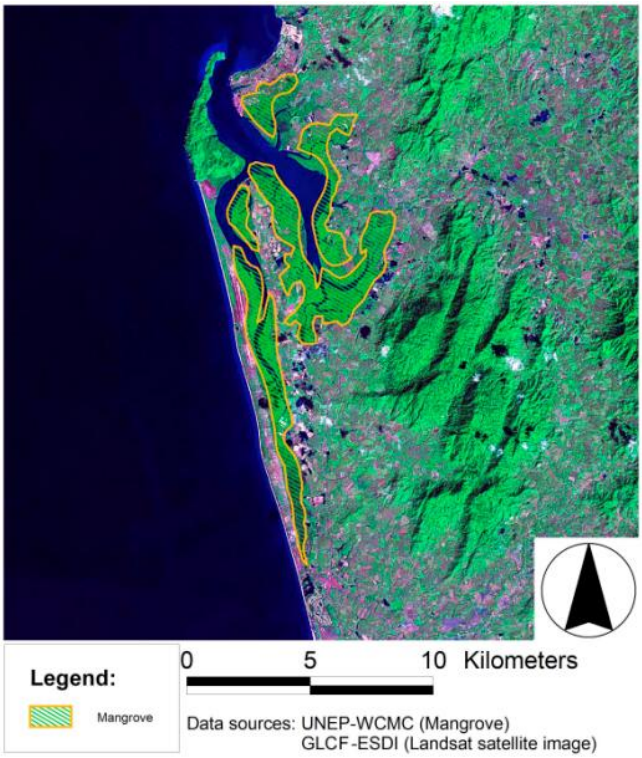
Another explanation for this phenomenon could be due to the length of tsunami waves, which are about 1,000 times longer than that of usual waves. If coral is able to offer protection for usual waves, an extreme event may not be stopped but would continue to build up on such shallow area.

This surprising result with respect to coral exacerbating the impact of tsunami waves was supported by UNEP ground assessments in Maldives and Seychelles, where the following observations were made: "*Fringing reef crests serve a protective role against normal waves. However, in the case of the tsunami, major terrestrial and coastline damage was located in areas sheltered by fringing* *reefs. At these locations, damage was focused near deeper channel that allowed the waves to break closer onshore."*[1]

To better understand how coral (or coral location slope) influences D, mathematical modelling or *in situ* observations should be performed. Pending further investigation, the results indicate that it would not be advisable to rebuild on coasts behind coral reefs.

With respect to assessing the protective functions of mangrove forests, the study found it impossible to find mangrove forests located on the coast directly facing open sea. Mangrove sites were identified using both WCMC datasets and satellite imagery, which show that mangrove forests were only present in estuaries, in areas sheltered by a stretch of coastline or in protected bays (Figure 3).

Figure 3. Example of mangroves forests location in Phangnga province (Thailand)



This finding was confirmed in literature which states that mangrove forests generally do not survive in areas with significant wave action.[2] An extract of an article from DIPE (2002) states that: "*mangrove establishment requires protection from strong winds and wind generated waves, as wave action prevents seedling establishment. As a consequence, mangrove communities tend to be located within sheltered coastal areas, surrounding highly indented estuaries, embayment and offshore islands protected by reefs and shoals*"[3]. Therefore, it could be argued that mangrove forests were less impacted by the tsunami simply because mangroves tended to be located within sheltered coastal areas.

This is not to say that mangroves can not protect coastlines, apart from their role in filtering land run-off and reducing coastal erosion.[4] In the case of tropical cyclones, mangrove forests could be

[1] UNEP 2005b: p.19.
[2] Jimenez (1985), Lewis (1982), Field (1996), Hiraishi and Harada (2003).
[3] DIPE (2002).
[4] Davis (1940); Thom (1967).

important in reducing the impact of storm surges generated by this type of hazard.[1] However, replanting mangroves should only be undertaken in areas conducive to their growth.

4. Conclusions

This study shows that there are limitations to what coastal ecosystems can provide with respect to shoreline protection in reducing tsunami wave impacts. In some cases, corals and vegetation are effective in reducing disaster risk (e.g. against storm surges or landslides). However, caution should be exercised and careful assessments undertaken to examine other influential factors that could mitigate hazard impacts. Instead of over-emphsizing the buffering or protective functions of ecosystems, greater appreciation is needed of their multiple roles especially with respect to supporting livelihoods which is equally critical for reducing socio-economic vulnerability. It is also important to note that this study is based on a single event; varying magnitudes and origins of tsunamis could result in drastically different wavelengths and thus induce varied effects in terms of coastal protection.

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Case Study 13

Vulnerability assessment and protective effects of coastal vegetation during the 2004 Tsunami in Sri Lanka[1]

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Abstract:
The tsunami of December 2004 caused extensive human and economic losses along many parts of the Sri Lankan coastline. However, there were large differences in terms of impacts and recoveries, even between areas adjacent to each other. The objectives of this study were twofold: to conduct an in-depth vulnerability assessment and detect differences in inherent vulnerabilities between different livelihood groups; and to determine the protective effects of mangroves and other coastal vegetation in a tsunami-affected coastal strip in southwestern Sri Lanka. The study consisted of household surveys in the case study area to determine vulnerability with respect to the hazard (ex-post assessment) and a coastal vegetation survey to assess their protective effects (if any). All data were analysed statistically. Results highlighted that fishermen were the most vulnerable group of people and that some vegetation types indeed reduced the impacts and afforded some protection to the populations (in relative terms).

Key words: vulnerability assessment, coastal vegetation, mangroves, tsunami,
Hazards: Tsunami
Ecosystems: coastal
Location: south-western Sri Lanka
Dates: 2006-2007

1. Introduction

The tsunami of December 2004 struck the entire eastern and southern coastline of Sri Lanka, as well as the western section up to the north of Colombo, causing extensive human and economic losses.[2] However, large differences in terms of impacts and post-tsunami recoveries were observed even between areas adjacent to each other, which remained unexplained. This study had two main objectives: (i) conduct an in-depth vulnerability assessment to detect differences in the inherent vulnerabilities between various livelihood groups; and (ii) determine the protective effects of mangroves and other coastal vegetation in a tsunami-affected coastal strip in south-western Sri Lanka.

[1] This case study is based on the following publication: Kaplan, M., Renaud, F.G., and Lüchters, G. (2009). "Vulnerability assessment and protective effects of coastal vegetation during the 2004 Tsunami in Sri Lanka", *Nat. Hazards Earth Syst. Sci.* (9): pp. 1479-1494.
[2] Liu et al. (2005); Wijetunge (2006).

The study area is the coastal strip along the city of Balapitiya (Galle District). The topography is flat. The population density of Galle District was 613 people per km^2 in 2001,[1] one of the highest rates of all districts in Sri Lanka. The southern border of the study region is marked by an inlet connecting the sea with Maduganga, an estuary at about 1.5 km distance from the coast. The inlet and the estuary are fringed by a thin belt of mangroves consisting mainly of *Rhizophora apiculata*. The inlet encloses a small island (Pathamulla), where the *Rhizophora* belt reaches widths of up to 40 m. The key occupations are a mixture of small-scale self-employment, public service, fishery, and, to a lesser extent, agriculture.

2. **General description**

Following the tsunami, anecdotal reports stated that coastal vegetation in general and mangroves in particular protected people and assets by reducing the energy of the waves. That coastal vegetation can diminish tsunami wave energy is still being debated scientifically.[2] While different methodologies such as statistical tests and biological surveys have been applied to prove the protective effects of coastal vegetation,[3] other studies have challenged these results.[4] However, it is agreed that, in addition to the structure of the vegetation, further influencing factors such as coastal bathymetry, exposure and topography have to be taken into account.[5]

This study seeks to contribute towards better scientific understanding regarding the natural buffering functions of coastal vegetation and examine other influential factors. Moreover, the study explores the use of a vulnerability framework, based on the multi-dimensional approach developed by Turner et al. (2003), to improve understanding of why various social groups experienced differing impacts and recovered differently following the tsunami.

Initiated in 2005 and completed in 2007, the study was carried out by the United Nations University (UNU) Institute for Environment and Human Security and the Center for Development Research at the University of Bonn. The International Water Management Institute was the main collaborating partner in Sri Lanka.

3. Process of implementation

The study comprised of two key segments: the vulnerability assessment and the coastal vegetation survey to assess its protective functions.

Vulnerability assessment

Based on Turner et al.'s vulnerability framework, the study aimed to generate a more comprehensive picture of vulnerability in the affected community by analyzing the linkages and feedbacks between social and ecological systems. The concept of vulnerability is not restricted to humans but rather recognizes the mutual dependence of ecological and social systems which is based on the dependence of communities on ecosystem services.

[1] DCS (2008).
[2] Kathiresan and Rajendran (2005); Kerr et al. (2006); Kerr and Baird (2007); Vermaat and Thampanya (2006); Cochard et al. (2008).
[3] Kathiresan and Rajendran (2005); Iverson and Prasad (2007); Danielsen et al. (2005); Dahdouh-Guebas et al. (2005).
[4] Kerr et al. (2006); Kerr and Baird (2007); Cochard et al. (2008).
[5] Cochard et al. (2008); Lacambra et al. (2008); Latief and Hadi (2006); Chang et al. (2006).

The vulnerability framework defines three main parameters for assessing vulnerability: exposure, which refers to the elements at risk (people, houses, infrastructure, etc); sensitivity or susceptibility, which relates to the internal structure of a society that shapes the ability of people to cope with and recover from hazards; and resilience which describes the ability of groups to cope with different types of external disturbances. Indicators for analyzing vulnerability were developed, with a special focus on assessing financial assets and occupational activities.

The vulnerability assessment was conducted through a detailed questionnaire that surveyed 157 households in September 2007. The questionnaire collected information on household social composition, types of assets before and after the tsunami, flood water levels at the house due to the tsunami, and extent of damage and recovery.

Coastal vegetation survey

To analyze the protective effects of coastal vegetation, detailed mapping was carried out on a coastal stretch approximating 1.7 km in length. A ground survey identified the boundaries of the vegetation types using a GPS device. Results of the ground survey were then mapped using GIS and examined visually to determine linkages between the width and composition of the vegetation belt and the flood water levels and magnitude of the damage behind these belts. The surveyed houses were divided into four different classes based on the extent of damage incurred, which followed classifications adopted by the Sri Lankan Government.[1]

The southern section of the vegetation survey with a length of about 1 km was then subdivided into three different sections according to the predominant vegetation type. Next, linear regression models were employed to detect whether the different vegetation classes influenced flood water levels at the house, damage to the house, and financial damage.

4. Results

Exposure (distance from the sea)
To analyze the influence of distance to the sea on water levels and extent of damage (as recorded at each household), the surveyed homesteads were divided into two groups according to their proximity either to the sea (group of 117 households) or to the inlet (group of 40 households). The results for the water level at the houses of the sea group according to information given by the interviewed household members clearly depicted the decreasing water levels and damages to the houses with increasing distance from the sea which is logical and expected. Similar results were seen amongst the sea group of households.

For the inlet group, two out of the 40 analyzed houses did not show any damage, 27 were partially damaged (26 could still be used), and 11 were destroyed completely. Amongst the completely destroyed houses of this group, the average distance to the sea was 623 m, while in contrast for the most severely affected houses of the sea group the average distance reaches only to 180 m. This clearly indicates the channelling effect of the inlet, resulting in significant flooding further inland. The width of the inlet is 50 to 70m for the first 500m and afterwards narrows down to 20 to 40m.

Sensitivity
The extent and condition of coastal ecosystems as a major factor of sensitivity are analyzed below. With regard to income before the tsunami, the survey revealed that there were no significant differences between the different occupational groups. Additional analysis of the household

[1] DCS (2005a).

structure did not produce any significant differences between the different livelihood groups. Other external factors such as institutions or economic structures were not considered in this survey.

Resilience

The results showed that unemployed and self-employed households and households receiving pensions have suffered the most from the tsunami in terms of income generation, having less financial resources available to them three years after the tsunami (even without adjusting for inflation). In contrast, employed households and households working in the government sector experienced increases in income between 2004 and 2007 (at the time of the survey). The study also investigated the length of the period without work after the tsunami. Households dependent on fisheries spent eight months on average without their main income, while it was only 2.7 months for the other occupational groups.

When testing differences in the amount of financial support given by the Sri Lankan Government to the various occupational groups, two main results were observed: Fishery households received 42% more support than the average household of this study, while labour households received 64% less. Financial support should also take into account support provided by the international community, which also identified fishers as a special target group. It is therefore surprising that fishers had not managed to recover better, three years after the tsunami. One explanation is that most fishing boats and nets were destroyed or lost, and although most fishers received new working equipment eventually, needs identification and delivery of support took some time. Some fishermen reported still not having appropriate fishing equipment and being forced to seek employment elsewhere or as labourers on other fishing boats.

While the average distance of all occupational groups to the sea is 355 m, this value is only 201 m for fisher households which were thus more exposed to the tsunami. 75% of all houses owned by fisher households were completely destroyed or could not be used after the tsunami, as compared to an average of 39% for the other groups.

Protective effect of coastal vegetation

Coconut trees, Pandanus, and different types of shrubs in various mixtures were the predominant vegetation types in the area. Three different vegetation classes were identified based on visual inspection. The *first* section just north of the inlet consisted of a belt of Pandanus backed by a loose coconut plantation without undergrowth, spanning a width of between 30 and 50 m. The *second* section consisted of only very few trees, but had a dense undergrowth of different shrubs with an overall density of 80 to 220m. Finally, the *third* section consisted again of coconut trees, with less Pandanus in the forefront but with denser undergrowth than the first class and a width of 100 to 220m. Density in this regard refers to a type of vegetation cover, which makes it more or less impossible to walk through.

In order to test and estimate the size of the vegetation effect on flow depth (water levels as reported by the households) at the surveyed houses, a simple linear regression model was chosen. The results showed significant differences between both the first and the second vegetation class in comparison to the third class, which was used as the reference category in the model, implying that flow depths were shallower for households living behind vegetation classes 1 and 2.

While no significant vegetation effect on financial damage could be detected, the regression on the effect of the vegetation on damages at the houses confirmed the findings of the first regression model described above. Results depicted significant differences between damage categories behind vegetation class 3 and the other two classes.

The models employed distance to the sea as the only adjusting factor. However, it is important to mention that in reality, there are additional factors that generally influence the impacts of tsunami waves, such as seafloor topography, particularly in near-shore areas[1], distance from the origin of the tsunami[2], and other environmental parameters.[3] For this study, we assumed these factors to be homogenous in the study area and therefore excluded them in our model.

5. Discussion and conclusions

These results, however, cannot be used as a general argument in favour of coastal vegetation as a protective shield against tsunami waves. Each location has to be analyzed independently, in order to consider particular conditions of the ecosystems under consideration and other influencing factors as well as different aspects of exposure (distance from the sea, construction material of houses, etc.). Nevertheless, the results of this study hint at the potential protective effects of coastal ecosystems under specific conditions and concur with observations made by other scientists in the aftermath of the tsunami. While the results are based on robust statistical analyses, these are only valid for specific local conditions.

The study highlights several policy directions. The maintenance of coastal vegetation could provide an added protection measure against coastal hazards, in addition to supporting livelihoods and biodiversity. This could pose a better alternative than relocating coastal populations further inland which would restrict access to coastal and marine resources, especially of fishers. In addition, given that the inlet in the study was shown to have wave channeling effects, measures to protect communities against future tsunamis and other related hazards such as coastal storm surges should not be limited along the coastline but consider vulnerable areas inland. Finally, further statistically-based assessments are needed to examine more carefully ecosystem-based coastal protection against extreme events.

[1] Chatenoux and Peduzzi (2005); Satheesh Kumar et al. (2008).

[2] Chatenoux and Peduzzi (2005).

[3] Chatenoux and Peduzzi (2005); Satheesh Kumar et al. (2008); Iverson and Prasad (2006); Baird et al. (2005).