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Current Opinion in Environmental Sustainability

The role of ecosystem services in climate change adaptation and disaster risk reduction

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This paper analyzes the vicious spiral between climate change impacts, ecosystem degradation and increased risk of climate-related disasters; secondly, it defines the central role of ecosystem management in climate change adaptation and disaster risk reduction and their multifaceted linkages; and thirdly, it assesses the challenges for enhanced ecosystem management for climate change adaptation and disaster risk reduction. Given the increasing importance of ecosystem services and management in adapting and responding to climate change impacts and associated disaster risks, the paper concludes that political commitment at the highest level is urgently needed if ecosystem management is to have the adequate weight it deserves in the post-2012 climate change agreement. It is further recommended that adequate financial, technological and knowledge resources be allocated for integrating ecosystem management in the climate change and disaster risk reduction portfolios, including within national policy-setting, capacity building, planning and practices, particularly in developing countries vulnerable to climate change impacts and increased risks of climate-related disasters.

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Current Opinion in Environmental Sustainability 2013, **5**:xx–yy

This review comes from a themed issue on **Terrestrial systems**

Edited by **Bojie Fu**, **Martin Forsius** and **Jian Liu**

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http://dx.doi.org/10.1016/j.cosust.2013.02.002

Context

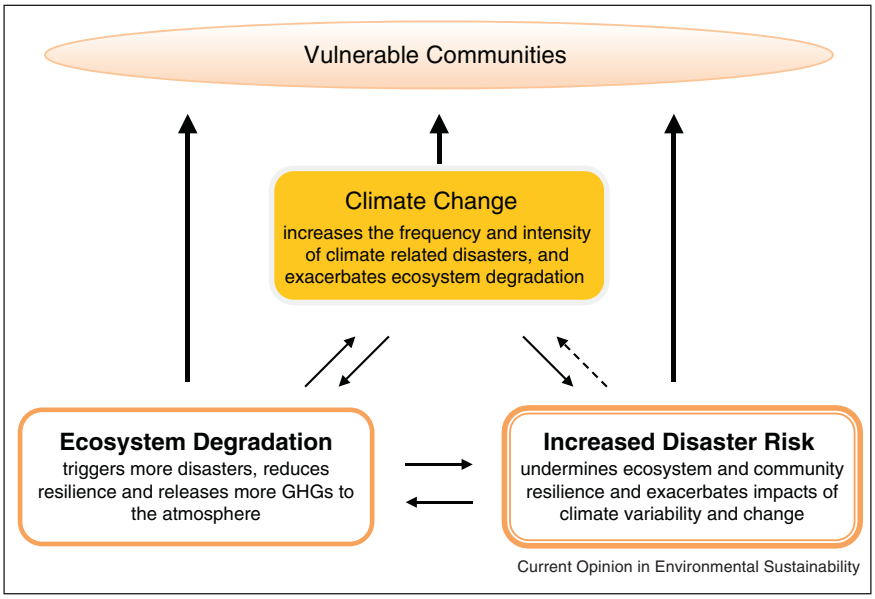
Science has established that global climate change increases the frequency and intensity of climate-related disasters such as floods, fires, and droughts [1], and causes ecosystem degradation. This in turn reduces the resilience of ecosystems and human societies against the impacts of climate change and the increased risk of disasters. People derive indispensable benefits from 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. Approximately 60 per cent of all ecosystem services and up to 70 per cent of regulating services are being degraded or used unsustainably [2]. Ecosystem degradation compromises the carbon sequestration ability of natural systems, and may turn these systems from carbon sinks to sources, thus exacerbating the downward spiral. Unwise use of ecosystems by human beings aggravates this vicious cycle as illustrated in Figure 1 below.

Climate change increases the risks of climate-related disasters, which cause the loss of lives and livelihoods, and weaken the resilience of vulnerable ecosystems and societies. Communities around the world are already vulnerable to the impacts of climate related hazards. 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 1527.6 billion [3••]. Disaster impacts undermine livelihoods and progress toward 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 [4]. Figure 2 shows a sharp increase in the occurrence of natural disasters such as floods, droughts, extreme temperatures, and wildfires from 1960 to 1989, and an even more rapid increase since 1990. While this trend may not be wholly attributable to climate change, the increase in the frequency and intensity of climate related hazards does correspond to temperature increase, and is projected to continue even if greenhouse gas emissions were to be stabilized today[1] [5••], thus further aggravating the vulnerability of communities, assets and livelihoods [6].

[1] http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-front-matter.pdf.

Please cite this article in press as: Munang R, et al.: The role of ecosystem services in climate change adaptation and disaster risk reduction, Curr Opin Environ Sustain (2013), http://dx.doi.org/10.1016/j.cosust.2013.02.002

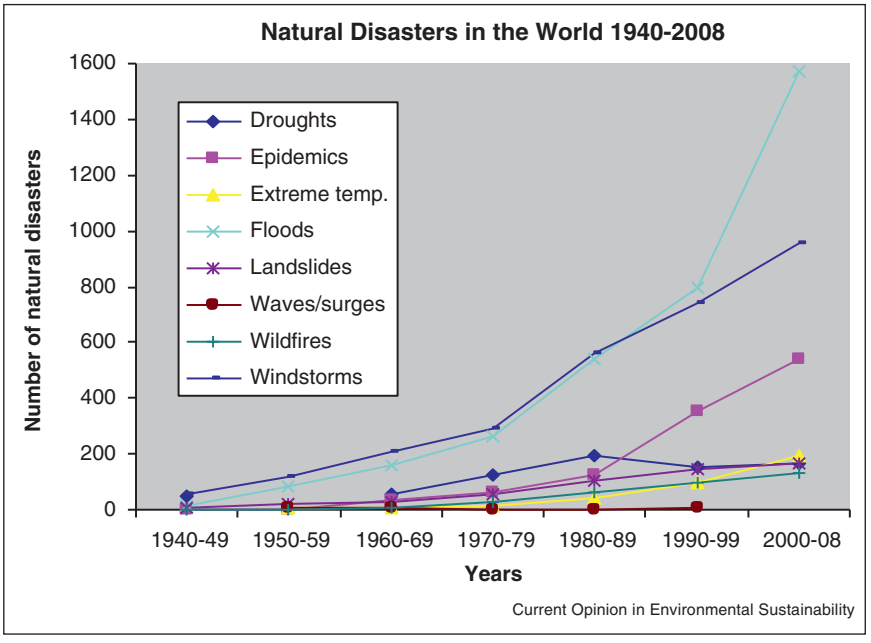
Figure 1



Simplified illustration of the complicated interactions between climate change, ecosystem degradation and increased disaster risk.

(a) **Climate change exacerbates ecosystem degradation.** The IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report (AR4) projected, '*The resilience of many ecosystems is likely to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g. land-use change, pollution, over-exploitation of resources) (high confidence).*' Tundra, boreal forest, mountains, Mediterranean-type

Figure 2



Number of natural disasters in the world, 1940–2008.
Sources: The OFDA/CRED International Disaster Database: www.em-dat.net and 'EM-DAT: The OFDA/CRED International Disaster Database www.emdat.be — Université Catholique de Louvain, Brussels, Belgium'.

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ecosystems, mangroves and salt marshes, coral reefs and the sea-ice biomes are amongst these vulnerable ecosystems. Substantial changes in the structure and function of terrestrial, freshwater and marine ecosystems are very likely to occur. In particular, 20–30% of species assessed so far are likely to be at an increasingly high risk of extinction as global mean temperatures exceed 2–3°C above pre-industrial levels. If the temperature increases by more than 4°C, few ecosystems will be able to adapt, more than 40% of global ecosystems are projected to be transformed, and major extinctions will occur around the globe.

(b) **Ecosystem degradation triggers more disasters and reduces nature's and societies' resilience against climate change impacts and disasters**. Ecosystem degradation is a process which will eventually lead to the collapse of the ecosystem. The degradation process reduces the capacity of the ecosystem to buffer the impacts of climate change [7], for example, more frequent heavy rains, droughts, melting glaciers and sea level rise. Biodiversity loss from ecosystem degradation could cause the breakdown of food chains and eventually the collapse of the ecosystem, leading to biological disasters such as the invasion of new species [8]. Hence ecosystem degradation also increases the vulnerability of natural and human systems to the impacts of disasters such as floods, landslides and storm surges. The worst case scenario is the collapse of the ecosystem, leading to the total loss of its buffering ability and other services to human well-being.

(c) **Ecosystem degradation reduces carbon sequestration in the ecosystems** and may turn them from carbon sinks to sources [9,10], exacerbating the vicious spiral. The IPCC projects that '*the terrestrial biosphere is likely to become a net carbon source by 2100, while ocean buffering capacity begins saturating, thus amplifying climate change, given continued greenhouse gas emissions at or above current rates and other unmitigated global changes, such as land use changes (high confidence).*'

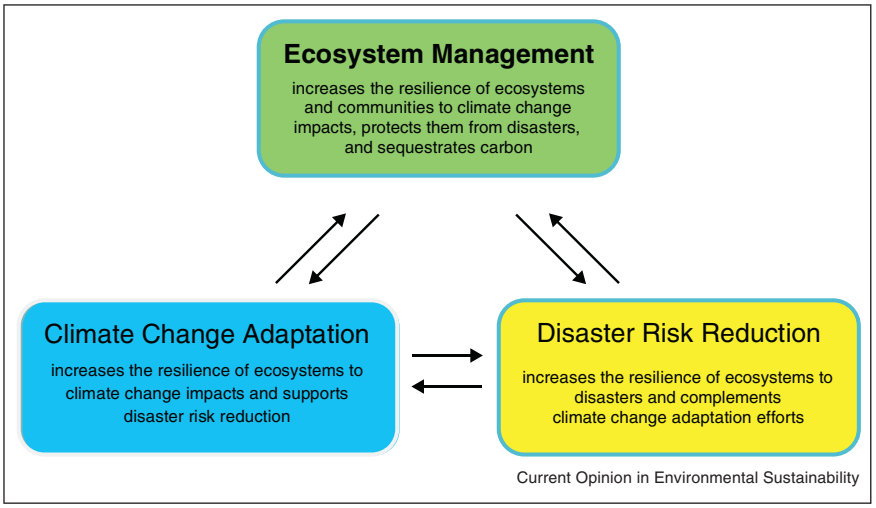
Breaking the vicious spiral: the multiple benefits of ecosystem management

In a world where climate change is resulting in more unpredictable weather patterns, sea-level rise and more frequent and extreme storms, the regulating services provided by ecosystems are critical for climate change adaptation and disaster risk reduction. Examples of these services include climate and water regulation, protection from natural hazards such as floods and avalanches, water and air purification, carbon sequestration, and disease and pest regulation. These services determine the central role of ecosystem management in climate change adaptation and disaster risk reduction as shown in Figure 3.

The definitions of the three cornerstones in Figure 3 are listed in Box 1.

(a) **Ecosystem management increases the resilience of natural systems and human societies to climate change impacts.** 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 [11,12]. Well managed ecosystems can provide natural protection against common natural hazards,

Figure 3



Central role of ecosystems in disaster risk reduction and climate change adaptation.

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Box 1 ***Ecosystem management*** is defined in this paper as 'an integrated process to conserve and improve ecosystem health that sustains ecosystem services for human well-being.' It is a summary of many definitions covering two streams of thinking: maintaining or improving ecosystem health; and ensuring the delivery of ecosystem services to human well-being.

Climate change adaptation is defined by the IPCC as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.'

Disaster risk reduction is defined by UNISDR as 'The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.'

such as landslides, flooding, avalanches, storm surges, wildfires and drought. Managing ecosystems to conserve and improve their health is crucial for sustaining the various ecosystem services important to human well-being. Healthy ecosystems also act as buffers, increasing the resilience of natural and human systems to climate change impacts and disasters [13].

Ecosystem-based adaptation strategies cut across all sectors. Some examples of these strategies include using mangroves for coastal defense, flood plain management for flood defense, and maintaining genetic diversity for adaptation in the agricultural sector [14••]. Good practices already exist on the ground, such as wind-sheltering and breaks to increase resilience of rangelands in Sudan, reforestation of mangroves to protect shorelines from storm surge and sea-level rise in the Philippines, sea-level rise land acquisition programmes in the US, and drought adjustment of planting dates and crop varieties in Mexico and Argentina. However, these practices are limited and very much on an *ad hoc* basis, and much more needs to be done. Two major approaches for adapting to and managing climate risks are already in place to enhance the role of ecosystem management, and full advantage should be taken of them: Integrated Water Resource Management (IWRM) [15••] to manage increasing water scarcity, and Integrated Coastal Zone Management (ICZM) [16] to manage the threat of sea level rise.

(b) **Ecosystem management also maximizes co-benefits of mitigation of climate change** by reducing emissions and fixing carbon through good practices such as Land Use, Land Use Change and Forestry (LULUCF) activities and Reduced Carbon Emissions from Deforestation and Forest Degradation (REDD), reducing the loss of natural habitat and deforestation as well as increasing or maintaining carbon stocks in ecosystems. Managing ecosystems to enhance biological carbon sequestration (biosequestration) is a promising tool in the efforts to mitigate climate change, and may often also support the achievement of other societal goals. The discussion about possible ways of reducing carbon emissions in various land uses, such as forestry and agriculture, is gaining momentum [17,18]. Given the high rates of global forest loss and associated GHG emissions (18–25% of annual emissions), reducing emissions from deforestation and forest degradation would make a major contribution to meeting emission stabilization targets [19••].

(c) **Ecosystem management provides physical defense from climate-related disasters**. Healthy ecosystems protect societies from disasters and improve their ability to cope with the impacts. Mountain meadows, bushes and forests protect people in the downstream from landslides and flash floods from glacier lake outbursts due to the accelerated melting of high mountain glaciers and snows. Coral reefs provide offshore breakwaters which reduce the impacts of sea surges and tropical storm waves before they reach the shoreline. Mangrove forests act as revetments or dikes: depending on their health and extent, mangrove forests can mitigate 70–90% of the energy from wind-generated [20,21••].

(d) **Climate change adaptation and disaster risk reduction increase the resilience of ecosystems.** There is a need for proactive adaptation and disaster management measures to reduce the negative impacts of climate change and disasters on ecosystems. Well-designed adaptation measures can increase the resilience of ecosystems, and also reduce the risk of climate-related disasters. Adaptation is a process starting from identifying and projecting climate change impacts to fully responding to these impacts by reshaping the development pathways and ways of ecosystem management. It helps disaster risk reduction in terms of being prepared for and protected from future climate-related disasters. On the other hand, disaster risk reduction contributes to the overall adaptation process, and if done well, can enhance the adaptation process by establishing the foundation for addressing long-term climate change impacts. Climate change adaptation and disaster risk reduction are both dependent on the regulating services provided by ecosystems, and contribute to building their resilience [22,23].

Enhancing ecosystem management: from science to policy to action

The facts shown above make clear the central role of ecosystem management in climate change adaptation and disaster risk reduction, both of which are significant priorities in the international environmental and political agenda such as those of the UNFCCC (United Nations Framework Convention on Climate Change) and Hyogo Framework for Action. However, while the science is clear, corresponding policy needs to be more explicit and action on the ground needs to be enhanced.

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The science is clear and calls for action, yet there is no explicit recognition of the role of ecosystems or actionable policies set in the UNFCCC or its Bali Action Plan agreed at COP13. While the Hyogo Framework for Action [24] recognizes ecosystem management as an essential element of reducing underlying risk factors, efforts at environmental management for disaster risk reduction have been largely on an *ad hoc* basis. Amongst the multilateral environmental agreements, only the Convention on Biological Diversity (CBD) through its Ad Hoc Technical Expert Group on biodiversity and climate change has started addressing the linkages between ecosystem management, climate change adaptation and disaster risk reduction.

National policies and local actions taking an integrated approach to address the downward spiral of climate change impacts, ecosystem degradation and increased climate-related disasters are largely lacking. The current National Adaptation Programmes of Action (NAPAs) under the UNFCCC are limited to least developed countries and merely include a vague role of ecosystem management. It is of paramount importance to prioritize the role of ecosystems across all countries. Climate change can trigger a broad shift toward a global civilization that is sustainable, but only when we seize the opportunity and start acting now. A few vulnerable countries are taking action despite the slow political processes in the international negotiations.

Key message

- **Recognize the multiple functions and services provided by ecosystems at multiple spatial scales**. 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.
- **Link ecosystems-based risk reduction with sustainable livelihoods and development**. There must be clear social and economic incentives for investing in ecosystems management options. 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.
- **Address risks associated with climate change and extreme events and reduce their impact on ecosystem services**. Climate change is expected to exacerbate disaster risk. More frequent and intense disaster events can erode community capacity to prepare, respond and rebuild after successive hazard events reducing the capacity of ecosystems to restore, protect and maintain human well-being and livelihoods.
- **Involve local stakeholders in decision-making**. Local stakeholders clearly have a role to play in promoting risk reduction through sustainable ecosystems management.

Urgent need for highest level political commitment

It is obvious that many countries have been quick to show commitment to climate change adaptation and disaster risk reduction. However, the role of ecosystem management, though central to both climate change adaptation and disaster risk reduction, has yet to be well recognized at the political level. In recent years, several Parties to the UNFCCC have started to recognize the central role of ecosystem management in climate change adaptation and disaster risk reduction, and called for ecosystem-based adaptation in the context of the Long-term Cooperative Actions (LCA) at the 14th Conference of the Parties in December 2008. On June 20–22, 2012 global leaders gathered in Rio de Janeiro for the Rio+20 United Nations Conference on Sustainable Development and for the first time governments and businesses explicitly recognized that ecosystems are the core element of addressing climate change impacts and paving the way toward achieving sustainable development as sustainable development has its roots in ecosystem maintenance. More work however needs to be done before this recognition becomes the consensus of all the Parties to the UNFCCC. 2015, a year in which the world is eagerly expecting a post-2012 climate change agreement, will provide a crucial opportunity for increasing the profile of ecosystem management and highlighting its important role in climate change adaptation and disaster risk reduction.

Given the increasing importance of ecosystem management in adapting and responding to climate change impacts and associated disaster risks, political commitment at the highest level is urgently needed if ecosystem management is to have the adequate weight it deserves in the post-2012 climate change agreement. Political support is also needed for the systematic integration of ecosystem management into climate change adaptation and disaster risk reduction policy frameworks and practices. It is further strongly recommended that adequate financial, technological and knowledge resources be allocated correspondingly for integrating ecosystem management in the climate change and disaster risk reduction portfolios, including in national policy-setting and awareness raising, capacity building, planning and practices, particularly in developing countries vulnerable to climate change impacts and increased risks of climate-related disasters.

The UNFCCC Secretariat at its Vienna conference (2007) on 'Investment and financial flows to address climate change' estimated that by 2030 developing countries will require additional financial support between 28 and 67

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billion USD a year to enable adaptation to climate change. Globally, overall additional investment and financial flows needed for adaptation in 2030 amount to several tens of billion USD. There are allocations in this estimation for various sectors, yet adequate financial resources should also be explicitly allocated for ecosystem management in the climate change portfolio. The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN REDD), supported by the Government of Norway, has set a very good example of the use of ecosystem management for biosequestration and reducing carbon emissions. It is recommended that the same approach be applied to ecosystem management for climate change adaptation and disaster risk reduction.

Meanwhile, knowledge and technology support to vulnerable countries should also be adequate and timely. For instance, there is a need to start developing guidance on mixed engineered/ecosystem-based adaptation and disaster risk management solutions [25••].

An unprecedented level of cooperation is urgently required from the policy and scientific communities to act on the combined threats of climate change, disasters and continuous ecosystem degradation. This will help foster closer links between ecosystem management, climate change adaptation and disaster risk reduction communities, as well as between science and policy such as the links between the IPCC and UNFCCC and IPCC, CBD and the IPBES[2] process, and catalyze North–South and South–South cooperation.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR, Mearns LO: **Climate extremes: observations, modeling, and impacts**. *Science* 2000, **289**:2068-2074.

2. Millennium Ecosystem Assessment: **Millennium Ecosystem Assessment Synthesis Report**. 2005. http://www.unep.org/maweb/en/Reports.aspx.

3. •• UNISDR: **Global Assessment Report**. 2009. http://www.preventionweb.net/english/hyogo/gar/2009/?pid:34&pih:2.

4. IPCC: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE*. Cambridge Univ Press, Cambridge, UK; 2007.

5. •• UNU: **Healthy ecosystems buffer against natural disasters**. 2006. http://archive.unu.edu/update/archive/issue41_20.htm.

6. Kelly PM, Adger WN: **Theory and practice in assessing vulnerability to climate change and Facilitating adaptation**. *Climatic Change* 2000, **47**:325-352.

7. Folke C, Carpenter S, Walker B, Scheffer M, Elmqvist T, Gunderson L, Holling CS: **Regime shifts, resilience, and biodiversity in ecosystem management**. *Annu Rev Ecol Evol Syst* 2004, **12**:12.

8. Millennium Ecosystem Assessment: **Ecosystems and human well-being: biodiversity synthesis**. 2005. http://www.millenniumassessment.org/documents/document.354.aspx.pdf.

9. Fearnside PM, Laurance WF: **Tropical deforestation and greenhouse-gas emissions**. *Ecol Appl* 2004, **14**:982-986.

10. Fearnside PM: **Global warming and tropical land-use change: greenhouse gas emissions from biomass burning, decomposition and soils in forest conversion, shifting cultivation and secondary vegetation**. *Climatic Change* 2000, **46**:115-158.

11. IUCN: **Disaster Risk, Livelihoods and Natural Barriers, Strengthening Decision-Making Tools for Disaster Risk Reduction**. 2008. http://cmsdata.iucn.org/downloads/pk_gian_study.pdf.

12. Barbier EB: **Natural barriers to natural disasters: replanting mangroves after the tsunami**. *Front Ecol Environ* 2006, **4**:124-131.

13. Abramovitz J, Banuri T, Girot P, Orlando B, Schneider N, Spanger-Siegfried E, Switzer J, Hammill A: **Adapting to Climate Change: Natural Resource Management and Vulnerability Reduction-Background Paper to the Task Force on Climate Change, Adaptation and Vulnerable Communities**. 2002. http://www.iisd.org/pdf/2002/envsec_cc_bkgd_paper.pdf.

14. •• Colls A, Ash N, Ikkala N: **Ecosystem-based Adaptation: a natural response to climate change**. 2009. http://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf.

15. •• UNW-DPAC: **Integrated Water Resources Management — Reader Integrated Water Resources Management — Reader**. 2010. http://www.un.org/waterforlifedecade/pdf/05_2010_reader_iwrm_eng.pdf.

16. European Commission: **Coastal Zone Policy. European Commission**. http://ec.europa.eu/environment/iczm/home.htm.

17. Lal R: **Soil carbon sequestration impacts on global climate change and food security**. *Science* 2004, **304**:1623-1627.

18. Albrecht A, Kandji ST: **Carbon sequestration in tropical agroforestry systems**. *Agric Ecosyst Environ* 2003, **99**:15-27.

19. •• Miles L, Kapos V: **Reducing greenhouse gas emissions from deforestation and forest degradation: global land-use implications**. *Science* 2008, **320**:1454-1455.

20. UNDP United Nations Development Programme Bureau for Crisis Prevention and Recovery: **Reducing Disaster Risk: a challenge for development. A global report**. 2004. http://www.un.org/special-rep/ohrlls/ldc/Global-Reports/UNDP%20Reducing%20Disaster%20Risk.pdf.

21. •• UNFCCC: **Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007**. FCCC/CP/2007/6/Add.1. 2008. http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf.

22. O'Brien K, Sygna L, Leichenko R, Adger WN, Barnett J, Mitchell T: **Disaster Risk Reduction, Climate Change Adaptation and Human Security. A Commissioned Report for the Norwegian Ministry of Foreign Affairs**. 2008. http://www.adpc.net/DDRCCA/GECHS-08/GECHS_Report_3-2008.pdf.

23. Uy N, Shaw R: **The role of ecosystems in climate change adaptation and disaster risk reduction**. In *Community, Environment and Disaster Risk Management.* Edited by Uy N, Shaw R. Emerald Group Publishing Limited; 2012:41-59.

24. UNISDR: **Hyogo Framework for Action 2005–2015: Building the resilience of nations and communities to disasters**. 2005. http://www.unisdr.org/we/inform/publications/1037.

25. •• ProAct Network: **The role of environmental management and eco-engineering in disaster risk reduction and climate change adaptation**. 2008. http://www.proactnetwork.org/proactwebsite/media/download/CCA_DRR_reports/em_ecoeng_in_drr_cca.pdf.

[2] Intergovernmental Science Policy-Platform on Biodiversity and Ecosystem Services.

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