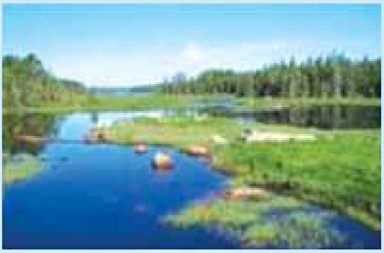





nidm
Towards a disaster free India

Ecosystem Approach to Disaster Risk Reduction

Ecosystem Approach to Disaster Risk Reduction

Edited by

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Towards a disaster free India

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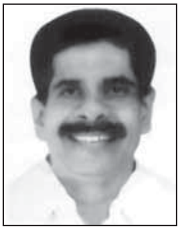

MULLAPPALLY RAMACHANDRAN

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Message

Environment wisdom may be from traditional knowledge or by use of advance technologies, offers sustainable solutions to development. Integration of environmental safeguards and disaster risk reduction is an emerging area of concern for planning at district, state and national levels. This is important in particular context to prevention and mitigation of hydro-meteorological hazards like floods, drought, coastal hazards, epidemics, forest fire and the community's vulnerability to their impacts. Besides this, post-disaster environmental issues like water & sanitation, disaster waste management, and concerns of green recovery are the recent concerns of humanitarian and environmental agencies worldwide.

Countries like India, posed with the challenge of densely inhabited land and growing menace of environmental devastation, is suffering the growing trends of natural disasters and their catastrophic impacts. Impacts of environmental devastations and refugees are also seen in form of conflicts, social unrest and violations and are, therefore, a security concern as well. Management of environment – its resources like climate, water, ecosystems and associated activities need to be managed in a planned way so that hazards and vulnerabilities are curbed to the extent of people's indigenous coping capacity. Role of higher education and research institutions in promoting environment based disaster management is equally important besides the policy environment for facilitating a more sustainable approach.

It is my pleasure to write this message for the special publication brought out on the occasion of the International Training Workshop on the Ecosystem Approach to Disaster Risk Management, organized by the National Institute of Disaster Management in Collaboration with Partnership for Environment & Disaster Risk Reduction (UN-PEDRR) and United Nations Environment Programme (UNEP, Geneva). The chapters contributed by luminary experts on the subject are excellent, worth reading and I extend my best wishes for the success of the venture.

(Mullappally Ramachandran)

Foreword

Available data regarding disasters and their impacts during last decade clearly indicate an exponential increase in the vulnerability of the society and land to disasters Environmental degradation epitomized by deforestation, loss of biodiversity, deterioration of drainage pattern, unscientific development, etc have been some of the major factors for the increased vulnerability of the society and the land to natural disasters besides aggravating their causative hazards.

The capacity of a society to resist the impact of these forces decides the degree of loss to it by hazard and this depends on the precautions the society has taken during various stages of development. Thus, disasters are inextricably linked to the development and it is up to an extent on how the development pattern takes concern of environment. A development ignoring environmental aspect always lead to disastrous situation. The deterioration of overall environmental sustainability is one of the main causes of increase in both physical and socioeconomic vulnerability. Environmental degradation increases the intensity of natural disasters and is often the factor that transforms a natural hazard or climatic extreme into a disaster. In the recent past the unscientific developmental activities all over the world and especially in the developing countries, without giving much consideration to the local geo-climatic conditions and other socioeconomic issues have very adversely affected the environment, resulting into exponential increase in fragility of ecosystem making it more susceptible to climate related disasters. The deforestation and degradation of forests during the last few decades has been the most prominent and major reason for the present state of deteriorated environmental situation. The tremendous population pressure and increasing needs and greed has diminished our most valuable natural resources, below the threshold level resulting in increase of vulnerability to natural disasters.

NIDM and The Partnership for Environment and Disaster Risk Reduction (PEDRR) are jointly organising a 4 days International Training Programme on “Ecosystem Approach to Disaster Risk Reduction (Eco-DRR)” during 12-15 December 2011 at NIDM, New Delhi. It is pleasure to present this edited volume developed by our faculty members by inviting expert contributions on various aspects of Ecosystem based Disaster Risk Reduction. I am sure that this publication shall be of practical use for training, research and policy-planning related activities at various levels, especially in guidly the main streaming of disaster reduction in to environment and developmental planning.

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Dr. Satendra, IFS
Executive Director

Editorial

Evolution in the paradigms of disaster management concept and framework from ‘response and relief’ to ‘mitigation and preparedness’ has brought in the light four major approaches, namely –

(1) Engineering based solutions, (b) Community based disaster risk reduction, (c) Ecosystem approach to disaster risk reduction, and (d) Externality based response and relief approach. The interception of ‘top-down’ and ‘bottom-up’ approach manifests conflicting situations in ground despite of visible synergies in top level policies. ‘Sustainability quest’ is the emerging concern in disaster management as a consequence of improved understanding of ‘disasters’ as environmental processes or rather as ‘environmental extremes’. Challenges of water, climate-change and increasing pressure over the finite land have intricately woven the natural geo-environmental processes to aggravate and turn into disasters.

Recognizing the benefits of the new epoch of 2nd paradigm shift in disaster management, that is ‘ecosystem approach to disaster risk reduction (Ecodrr)’ offers the benefits of community based approach as well due to its emphasis on livelihood, health and food security within the framework of vulnerability reduction. The suggested planning framework at district level, to have an integrated district plan, opens avenue for a much awaited ‘environmental action plan’ mandate at state, district and local levels. This shall help facilitate the DRR infusion with sustainable development agenda in much acceptable sense – in the governance as well as in community actions. It aims at reducing externality in dependence, improving self-reliance and local strengths for disaster mitigation and preparedness.

India has the credit, indeed, to have initiated the ‘Environment Based Disaster Management Module’ formally starting in 2009 at National Institute of Disaster Management, addition to ‘climate-change and disaster management’ module launched in 2007. The simultaneous global initiative formalized as an agenda during UN-PEDRR (Partnership for Environment and Disaster Risk Reduction) meeting at UN Campus in Bonn in 2010. First ecoDRR course was piloted in Sri Lanka in 2011 May which was also an occasion for release and recognition of Strategic Environmental Assessment (SEA) for the North-province area for disaster reduction based sustainable development in Sri Lanka. The international course by UNEP and NIDM during 2011 December opened the door for journey towards ‘sustainable disaster management’ and ‘green recovery mechanism’. The book developed with the invited chapters on different aspects of ecoDRR is an attempt to offer standard literature for the practitioners, academicians, students, researchers and policy makers.

Contents

Understanding Eco-DRR: Introduction to the Book

Anil K. Gupta and Sreeja S. Nair

After decades of neglect, the importance of protecting and improving ecosystems for reducing disaster risk started receiving attention in the recent years. Until now the term 'ecosystem' and 'ecosystem services' were primary been dealt by biologist only. Human activity poses significant impact on the biodiversity of world ecosystems, reducing both their resilience and capacity. Humanity is, therefore, all set to experience the impact of ecosystem devastations in the form of increasing climate vulnerability and risk of hydro-meteorological disasters.

The Millennium Ecosystem Assessment 2005 (ME) refers to natural systems as humanity's "life-support system" providing essential "ecosystem services" for existence and socio-economic well being. In the ME 2005, twenty four services are classified under 4 major categories, viz.

- provisioning services, the material that people extract directly from ecosystems such as food, water and forest products,
- regulating services which modulate changes in climate and regulate floods, drought, diseases, waste and water quality;
- cultural services, which consists of recreational, aesthetic and spiritual benefits; and
- supporting services, such as soil formation, photosynthesis and nutrient recycling.

The assessment measures 24 ecosystem services, concluding that only four have shown improvement over the last 50 years, fifteen are in serious decline, and five are in a stable state overall, but under threat in some parts of the world (Millennium Ecosystem Assessment 2005).

Anthropogenic modification and simplification of the biosphere to increase the supply of services from the agro-ecosystems has seriously affected the productivity of other ecosystems. Increase in the provisioning services resulted in decline in biological diversity, example introducing the high yield crop varieties affected the biodiversity. Decline in the ecosystem services influence the resources available to the people and hence lead to increasing vulnerability to hazards and also will affect the human well being. Regulating ecosystems services are crucial for enhancing resilience of the human ecosystems by moderating the extreme weather events like heat wave and cold wave, protecting the coastal areas from tsunami and storm surges and so on. Decline of these services can lead to increased exposure to hazards and also decrease the disaster resilience. Decline in the regulating systems also reduce the ability of the human beings to adapt to climate change. Similarly decline in cultural and recreational services can affect the Small Island Groups and the countries where the economy is depended primarily on tourism.

Decline in cultural ecosystems can lead to decrease in solidarity of the several communities. This can lead conflicts among the community. Decline in the supporting services can lead to decrease in productivity of the land and can lead to savannisation, land degradation and also desertification. Hence the decline in ecosystem services can lead to increase in disaster vulnerability.

Now the concept of 'Eco-DRR' is grown in richness and it has been associated with the concept of disaster risk reduction more often. This volume on Eco-DRR comprises of the three sections and twelve chapters. The volume is intended to provide an overview concept of Eco-DRR, natural resource management and disaster linkages, incorporating Eco-DRR concepts in various phases of disaster management including post disaster recovery in wide range of human and natural environmental settings. The case studies cover coastal, mountain and urban ecosystems and specific hydro-meteorological risks like floods, forest fire, epidemics and landslides.

Chapter 1 is excerpted from the PEDRR Background Paper to the 2011 ISDR Global Assessment Report on Disaster Risk Reduction. This chapter highlights the importance of sustainable ecosystems management as an effective approach for achieving both disaster risk reduction and climate change adaptation priorities. The World Bank recommends adaptation programmes to integrate an ecosystem-based approach into vulnerability and disaster risk reduction strategies. Risks posed by climate change and variability, in conjunction with globally widespread ecosystems decline, require solutions that are not only cost-effective but also locally accessible and applicable. Ecosystems-based approaches that local communities already practice as part of their livelihood strategies and clearly provide risk reduction services and, 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. The chapter is extremely helpful in understanding linkages between environment, disasters and development.

Chapter 2 is focused on the Natural Resource Management for Disaster Management and importance of natural resources (ecosystem services) in human well being. The inter-dependencies among natural resources, viz., water; land, animal, human beings and vegetation resources determine the nature and kind of livelihood supporting systems particularly in rural areas. The depletion of natural resource base and increasing biomass demand of rising human and livestock population are attracting attention of all concerned: farmers, technicians, scientists, administrators, and policy makers. Management of natural resources is essential for the survival of humankind because life depends on air, water, soil, rocks, forests and water bodies; the ultimate purpose of management is to maintain all these in a healthy operating condition. Management of natural resources has economic, aesthetic, and scientific value leading to reduction in risk of disasters for the communities.

Chapter 3 is based on the documentation of community practices helping them to cope with the floods in eastern Uttar Pradesh, conducted by Gorakhpur Environmental Action Group and local NGOs. This chapter highlights the importance of people's indigenous environmental knowledge, as can be seen in their practices of treatment of sick cattle, seed preservation and storage, seed improvement, grain storage, house construction, water purification, etc. This knowledge together with their generational experience and memories enables many people to anticipate events, make accurate forecasts and prepare themselves accordingly.

Chapter 4 highlights the importance of environmental management for coastal hazard mitigation. The importance of understanding the coastal environment and the unique ecosystem services they deliver to perceive the impact in reducing the risks of coastal communities to the coastal hazards and development at large is emphasized in this chapter. Coastal ecosystems are unique because land and water meet here to create an environment with a distinct structure, diversity and flow of energy. They encompass a diverse array of habitats than any other ecosystems.

Coral reefs, mangroves, tidal wetlands, sea grass beds, barrier islands, estuaries, peat swamps, and a variety of other habitats - each provides its own distinct bundle of goods and services.

Chapter 5 shows that the Hindu Kush-Himalayan (HKH) region is affected by increasing frequency of flash flood and river-line flood which are among the more devastating types of hazard as they occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. People living in fragile eco-system of HKH region have been subject to the increasing frequency and intensity of disasters in mountain areas. Therefore, Disaster Risk Reduction requires a comprehensive approach combining engineering based mitigation with environmental sustainability, socio-economic development and regional cooperation efforts.

Chapter 6 emphasizes on landslides patterns recognizing it an environmental challenge, and their mitigation & management measures using the ecological techniques. Landslide restoration using ecological tools is difficult on landslide surfaces because of the high degree of spatial and temporal heterogeneity in soil stability and fertility. Promotion of the recovery of self sustaining communities on landslides is feasible by stabilization with primary colonizing and native ground cover, applications of nutrient amendments, facilitation of dispersal to overcome establishment bottlenecks, emphasis on functionally redundant species and promotion of connectivity with the adjacent landscape.

Chapter 7 is on the impact of urbanization on ecosystems on the case study of a rapidly urbanizing city, Bangaluru in India facing growing menace of flooding. Key manifestations of rapid and unplanned urbanization are loss of wetlands and green spaces and depleting groundwater table. Common consequences of urban development are increased peak discharge and frequency of floods as land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall i.e. the infiltration capacity. Increasing runoff and decline in the capacity of the ecosystems resulted in increasing vulnerability and risks due to floods in urban areas.

Chapter 8 deals with the problems of fire and pests in forest ecosystems and implications of biomass burning on climate-change. Chapter highlights on causes, impacts and control strategies for fire and pests to maintain forest-health in terms of structure and productivity. Typology of forest fire has also been discussed. A thorough understanding of past stand history and an ability to judge potentially dangerous conditions is invaluable and can make the difference between successful and disastrous use of prescribed fire as a management tool. More prudently, it is the prior assessment of risks and vulnerabilities of these disastrous occurrences in terms of litter and fire weather, plant injuries, pest infestation climate, etc. that feed into the planned action for effective forest management, the paper highlights.

Chapter 9 reveals the importance of managing water environment and aquatic ecosystems since it is one of the key provisional ecosystem service. An integrated approach for natural resources management, on a watershed basis has emerged as the cornerstone of rural development in dry and semi arid regions. Integrated watershed development draws strength from its inherent interconnectedness of the biophysical, the social and the economic elements of ecosystem processes. It recognizes that human activities within a watershed are motivated by multiple and often conflicting objectives and/or constraints, such as maximizing farm income, protecting soil and water resources as well as securing and maintaining drinking water supplies. In the Indian context, more than half of its land is degraded due to various factors like water and wind erosion, ravines, gully erosion, salt affected lands, water logging, shifting cultivation etc.

Chapter 10 emphasizes on the ecological aspects of disaster risk reduction and post-disaster recovery planning. The value of ecosystem services was clearly demonstrated during the Indian Ocean Tsunami of December 2004 where natural protective shields helped in decreasing impacts of the extreme event in majority of situations. Mangrove forests reduced the impact of the tsunami by reducing the velocity of the storm after it entered into the mangroves due to friction created by thick mangrove forest. Post disaster recovery planning often provides opportunities for creating sustainable livelihoods and resilient ecosystems which may decrease vulnerability to future disasters. Sustainable livelihoods are dependent upon healthy ecosystems. Efforts should be made to allow and support ecosystem recovery without putting further stresses on already damaged ecology of the area. The hasty decisions taken for rapid response during the initial rescue and relief phase without taking care of environment may bring adverse impacts on the ecosystem services in the future.

Chapter 11 discusses the potential of Environmental Impact Assessment in (EIA) and other policy instruments in facilitating disaster risk reduction and in improving the ecosystem services. EIA, in pre-disaster prevention and mitigation phase, helps in precise decisions regarding planning risk reduction and choices of mitigation methods, technology and locations for activities, whereas Rapid EIA of disasters (REIA) help ensure sustainability concerns in relief, reconstruction and recovery process. Risk analysis and/or a disaster management plan are often a part of EIA process, besides the information generated by EIA of direct use to the disaster management system and in Cost-Benefit Analysis (CBA) of a developmental project. Paper recommends wider application of EIA principles and methodologies as decision support system for policy-planning covering the entire disaster management cycle.

Chapter 12 gives a description of ecological approach to post disaster recovery planning with the objective of mitigating future risks. The author argues the need for research and policy studies on the inherent link between Disaster Risk Reduction & Environment particularly in the context of livelihood security, food , water and other environmental services. Influence of climate change on recovery planning has also been discussed in the paper with the view point of disaster ecology and risk ecology. The ecological model of disaster risk reduction presented in the paper emphasizes on the sustainability of ecosystem services and systems. Investments in maintaining healthy ecosystems, are seven fold cost effctive than the costs incurred by disasters (World Bank Report, 2004). The author also suggest that the use of ecosystems as bioshields should be accompanied by other measures such as early warning systems and other structural interventions.

References

Schipper, E.L., & Burton, I. (Eds.) (2008). Understanding Adaptation: Origins, Concepts, Practice and Policy. In The Earthscan Reader on Adaptation to Climate Change (pp.1-8)., London: Earth Scan.

Peterson, G. (2009). Ecological limits of adaptation to climate change. In W. Neil Adger, Irene Lorenzoni & Karen L. O'Brien (Eds.), Adapting to Climate Change- Thresholds, Values and Governance (pp 64-78). Cambridge: Cambridge University Press.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Washington, DC: Island Press.

1

The Role of Ecosystems Management for Disaster Risk Reduction

Marisol Estrella and Nina Saalismaa

Introduction

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.[1] 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.[2] 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.[3]

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 change-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)[4], the first global agreement on disaster reduction, recognized the importance of sustainable ecosystems and environmental management in reducing disaster risk. Both the 2009 and 2011 Global Assessment Report on Disaster Reduction identified ecosystems decline as a major driver of risk and called for greater protection and enhancement of ecosystem services. Ecosystem management for disaster risk reduction has been prioritized in both the 2009 and 2011 ISDR Global Platform for Disaster Risk Reduction Chair Summary, and cited most recently in the latest IPCC release of the *Summary for Policy Makers of the new Special Report on Extremes* (SREX).[5]

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

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

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.[6]

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.

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. It is largely a review of literature, supported by a compilation of selected case studies from around the world. Although the 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.

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.[7] 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.[8] 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.

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.[9] "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.[10] Unfortunately, approximately 60 percent of all ecosystem services and up to 70 percent of regulating services are being degraded or used unsustainably.[11]

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.[12] 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.[13] 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[14]

Ecosystem	Hazard	Hazard mitigation value (US$)
Coral reefs (global)	coastal	189,000 per hectare/year[15]
Coral reefs (Caribbean)	coastal	700,000– 2.2 billion per year (total value)[16]
Coastal wetlands (United States)	hurricane	8,240 per hectare/year[17]
Coastal wetlands (United States)	storms	23.2 billion per year (total value).[18]
Luzňice floodplain (Czech Republic)	floods	11,788 per hectare/year[19]
Muthurajawela marsh (Sri Lanka)	flood	5 million per year (total value); 1,750 per hectare/year[20]
Coastal ecosystems (Catalonia, Spain)	disturbance protection, including storms	77,420 per hectare/year[21]
Mountain forests (Switzerland)	avalanche	up to 170,000 per hectare/year in high-value built up areas[22]

Ecosystems, Livelihoods and Disasters

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.[23]

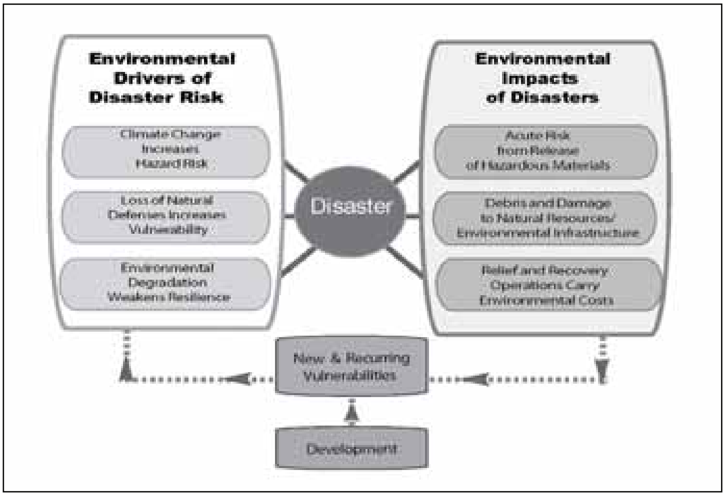

Figure 2.1. Environmental causes and consequences of disasters[24]

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.[25]

On the other hand, environmental conditions themselves can be a major driver of disaster risk. 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.[26] 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.[27]

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.[28] 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.[29] 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.[30]

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.[31] 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 high casualties and generally have the least capacity to recover from disasters.[32] Poor communities tend to be more vulnerable, as their livelihoods often depend heavily on natural resources and ecosystem services.[33]

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 provide services. Human-induced climate change will also significantly compromise ecosystems' structures and functions, weakening natural resilience against hazards.[34] 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).

Why do ecosystems matter in 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.[35] For example, in the European Alps, mountain forests have a long history of being managed for protection against avalanches and rockfall.[36] 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.[37] Several countries in Europe, such as Germany, the Netherlands[38], the UK (Box 2.1), Eastern European countries bordering the Danube River (Box 2.2), and Switzerland[39] 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 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.[40]

Box 2.1 Making Space for Water - Government Strategy for Flood and Coastal Erosion Risk Management in the UK[41]

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 severe flooding events in 2005, 2000 and 1998. Various projects are taking place throughout the UK 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 UK's riverbanks and coastlines, which required constant repair and costly upgrades. The new approach to risk management adopts the use of natural infrastructure and processes for hazard mitigation. This programme aims to address future development pressures, address rising coastal hazards as a result of climate change, and reduce hazard mitigation costs.

Box 2.2 Danube Wetlands, Eastern Europe[42]

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 km2 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[43], 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.

Box 2.3 Community-Based Forest Rehabilitation for Slope Stability, Bolivia[44]

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. Eighty 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. This experience illustrates how climate change adaptation should include sustainable management of natural resources as a strategy to improve livelihood resilience.

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. 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.[45]

Table 2.2. Hazard mitigation functions of ecosystems

Ecosystem	Hazard mitigation
Mountain forests and other vegetation on hillsides	• Vegetation cover and root structures protect against erosion and increase slope stability by binding soil together, preventing landslides.[46]
	• Forests protect against rockfall and stabilise snow reducing the risk of avalanches.[47]
	• 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.[48]
	• 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.[49]
Wetlands and floodplains	• Wetlands and floodplains control floods in coastal areas, inland river basins, and mountain areas subject to glacial melt.[50]
	• 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.
	• Coastal wetlands, tidal flats, deltas and estuaries reduce the height and speed of storm surges and tidal waves.[51]
	• 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	● 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.[52] Research has highlighted several cases where coastal areas protected by healthy ecosystems have suffered less from extreme weather events than more exposed communities.[53]
	● 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.[54]
	● Coastal wetlands buffer against saltwater intrusion and adapt to (slow) sea-level rise by trapping sediment and organic matter.[55]
	● 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.[56]
Drylands	● 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.
	● Shelterbelts, greenbelts and other types of living fences act as barriers against wind erosion and sand storms.
	● 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.[57]
	● 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 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.[58] 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 2.4). 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.[59]

Box 2.4 Restoring wetlands for flood mitigation and local development, China[60]

In Hubei Province, a wetland restoration programme by WWF and partners reconnected lakes to Yangtze River and rehabilitated 448 km2 of wetlands with a capacity to store up to 285 million m3 of floodwaters. The local government subsequently further reconnected eight lakes covering 350 km2. 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 mitigation, restored lakes and floodplains have enhanced biodiversity, increased income from fisheries by 20-30 per cent and improved water quality to drinkable level. While central government was principally concerned to reduce flood risk, local communities and local authorities 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.

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, Little Bay, a local fishing community, relies heavily on groundwater springs when floodwaters cut off their potable drinking water supply (UNEP 2010). 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.

Well-managed ecosystems are considered more resilient to the impacts of extreme events and are able to recover more effectively than degraded ecosystems.[61] 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.[62] For example, forests do not seem to protect against large-scale flooding from severe events such as tropical cyclones or tsunami.[63] A small narrow belt of coastal vegetation has limited effects against major disturbances like cyclones.[64] 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.[65]

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.[66] 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. Conventional engineering solutions, on the other hand, may generate adverse environmental impacts, such as altering sedimentation patterns, and may provide a false sense of security.[67]

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.[68] Other studies have demonstrated how deforested slopes are more susceptible to erosion and landslides[69], 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.[70] 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.[71] 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.[72] There are clear knowledge gaps in assessing ecosystem capacity to maintain services over time, especially in the context of changing environmental conditions and disturbances.[73] 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.

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.[74] 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.

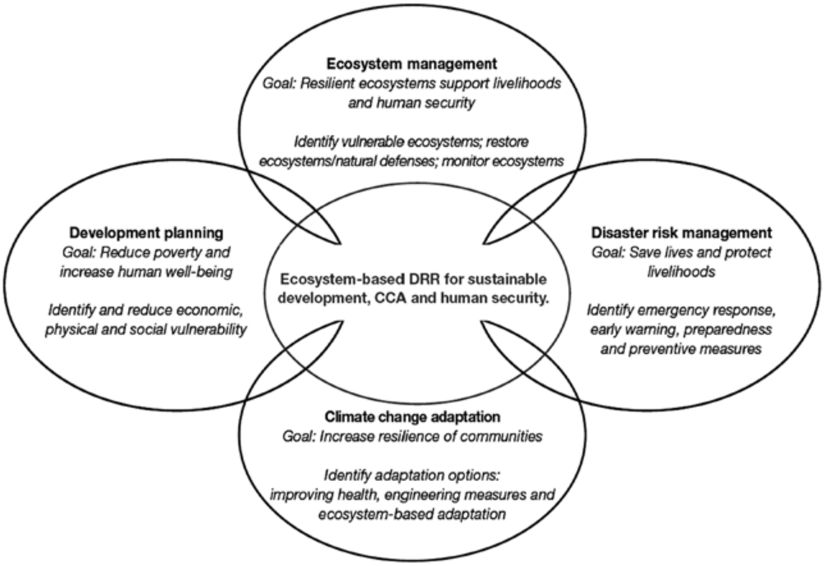

Figure 2.2. Ecosystem-based disaster risk reduction, a more sustainable approach to DRR and climate change adaptation (CCA).[75]

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.

Integrating Disaster Risk Reduction in Environmental Assessments

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.[76] 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.

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:[77]

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.[78]
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).[79] Together they have produced a sourcebook for integrating natural hazard concerns, including potential climate change impacts, into the application of EIAs at country level.[80] 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.[81]

Strategic environmental assessments (SEAs)

In contrast to EIAs, SEAs generally have a broader focus.[82] It is a tool for integrating environmental considerations into policies, plans or programmes at the earliest stages of strategic decision-making.[83]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.[84]

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.[85] 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.[86] 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 (Government of Sri Lanka/UNDP/UNEP 2011).

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.[87]

Integrated Risk and Vulnerability Assessments

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.[88] 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.

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.

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 (2010a) pilot tested a methodology that quantified through spatial and statistical modelling the role of coral reefs and seagrass in minimizing beach erosion. 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, Chatenoux and Peduzzi (2007) 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. 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.[89] 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.

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. 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.

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.[90] Over 120,000 designated protected areas now cover approximately 13.9 percent of the Earth's land area.[91] 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.[92]

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.[93]

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.[94] Protected areas not only safeguard biodiversity but also economic and social well-being.[95]

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.[96] 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.[97] In Switzerland, protected forests have been recognized over the last century for their role in mitigating impacts from avalanches, rock falls and landslides.[98] In eastern Madagascar, the Mantadia National Park protects upland forests and watersheds which reduces flooding damage to lowland agrarian communities.[99]

Table 3.1 Risk reduction benefits provided by protected areas[100]

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.[101] 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.[102] 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.[103]

However, it is also important to recognize how protected areas contribute towards social and economic well-being.104 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.105 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.106 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.107

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.108 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.109 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.110 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.111 Nonetheless, efforts to valuate in monetary terms protection benefits are continuously being applied and improved.112

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).

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.[113] 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).[114]

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[115], and the watershed border area of Mexico and Guatemala (Box 3.1).

Box 3.1. International transboundary watershed management for DRR in Mexico and Guatemala[116]

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.

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.[117] 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.118 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.119 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.120

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 2005.121 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.122 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[123]

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.

Integrated fire management

Integrated fire management addresses wildfire hazards together with other social, economic and ecological sustainability concerns in a given area.[124] In Lebanon, land restoration and traditional and modern fire management practices are combined to build the social and ecological resilience of local communities.[125] 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.[126]

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.[127] 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.[128] cultural 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.[129]

Community-based sustainable natural resource management

Previous sections have underlined the importance of involving local communities in ecosystem-based disaster risk reduction as 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.[130] 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.[131] 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.[132] 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.

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).[133] 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.[134]

Box 3.3 Fish as tsunami early warning[135]

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 (Box 3.4). 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.[136]

Box 3.4 Resilience to Drought through Agro-ecological Restoration of Drylands, Burkina Faso and Niger[137]

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 capacities of local populations, the initiatives have significantly reduced risks and vulnerabilities associated with frequent droughts in the region.

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.[138] 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 Lebanon, where traditional land management and new approaches are combined to create fire-resilient landscapes and include specific activities for sustaining local forest-based livelihoods.[139] In northern Australia, aboriginals have revived traditional fire management practices, successfully controlling large-scale fires and generating income for disadvantaged communities (Box 3.5).

Box 3.5 Aboriginal fire management in Northern Australia[140]

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 km2 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 CO2-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. such as using satellite data on fire locations, over an area of 28,000 km2 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 CO2-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.

Recognizing the value of 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.[141] 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.[142]

However, several 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, where top-down, prescriptive approaches failed to address livelihood concerns of local communities and resulted in local abandonment of sites.[143] Another example shows how exotic trees, mainly Casuariana equisetifolia[144], 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.[145]

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.

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[146]** 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.[147] 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 or management.

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. 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.[148]

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.[149] 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.

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. 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.[150]

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.[151] 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).[152] 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 encompass work on climate change adaptation.

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. Such innovative policies are still, however, more exceptions than common practice. Integrated policies can both minimize implementation costs and improve flow of services.[153] 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.

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 to build consensus.

6. Involve local stakeholders in decision-making.

Local stakeholders clearly have a role to play in promoting risk reduction through sustainable ecosystems management. What successful examples demonstrate is the need to take into account local livelihoods needs and priorities, utilize local or indigenous knowledge, and involve local stakeholders in decision-making.[154] 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. It is equally important to recognize that communities are not homogenous and pressure groups exist with competing interests.

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.

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.[155] 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 DRR.[156] 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.[157] In order to support national and local level decision-making, more efforts are needed to effectively value ecosystem services specifically for DRR and compare costs-benefits *vis a vis* hard engineering measures, and PEDRR partners have prioritized this work over the next two years.

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, which utilize scientific and stakeholder-based analyses to 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.[158] 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).

Aside from improving technical guidelines, there is also a need for more practical decision-making support tools that enable policymakers and planners to weigh different alternatives, including "soft" and "hard" solutions, "natural" and "engineered" options.

(iii) Develop and enhance institutional capacities

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, 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.[159] 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.

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 (see www.pedrr.net).

(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. 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.

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References

1. ADPC. *(2009). Regional training manual on disaster risk reduction for coastal zone managers.* UNEP, UNISDR and EuropeAid: Bangkok.
2. Badola,R. and Hussain, S. A. (2005). Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation* 32: 85-92.
3. Barbier, E. B. (2006). Natural barriers to natural disasters: replanting mangroves after the tsunami. *Frontiers in Ecology and the Environment* 4, 124-131.
4. Barbier, E. B. (2007). Valuing ecosystem services as productive inputs. *Economic Policy* 22(49): 178-229.
5. Batker, D.P., de la Torre, I., Costanza, R., Swedeen, P., Day, J.W., Boumans, R., Bagstad, K. (2010). Gaining ground—wetlands, hurricanes and the economy: the value of restoring the Mississippi River Delta. Earth Economics.
6. Bebi, P., Kulakowski, D. and Christian, R. (2009) Snow avalanche disturbances in forest ecosystems – State of research and implications for management. *Forest Ecology and Management* 257, 1883–1892.
7. Benson, C., Twigg, J., and Rosetto, T. (2007). "Environmental assessments" in *Tools for mainstreaming disaster risk reduction:* Guidance notes for development organizations. ProVention Consortium: Switzerland. pp. 79-90.
8. Bohle, H.G. (2001). "Vulnerability and criticality: Perspectives from social geography", IHDP Update 2/2001, Newsletter of the International Human Dimensions Programme on Global Environmental Change: pp. 1-7.
9. Birkmann, J. (2006). "Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions", in Measuring vulnerability to natural hazards – Towards disaster resilient societies. Jörn Birkmann (ed.) United Nations University Press: Tokyo. pp. 9-54.
10. Birkmann, J. and Fernando, N. (2008). "Measuring revealed and emergent vulnerabilities of coastal communities to tsunami in Sri Lanka". Disasters 32 (1): pp. 82-104.
11. Bradshaw, C.J.A., Sodhi, N.S., Peh, K., Brook, B.W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. Global Change Biology 13, 2379–2395.
12. Brang, P., Schönenberger, W., Frehner, M., Schwitter, R., Thormann, J.-J., Wasser, B. (2006). Management of protection forests in the European Alps: an overview. Forest Snow and Landscape Research 80, 23–44.
13. Brenner, J., Jiménez, J.A., Sardá, R. and Garola, A. (2010). An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain. Ocean & Coastal Management 53, 27-38.
14. Campbell, A., Kapos, V., Scharlemann, J. P.W., Bubb, P., Chenery, A., Coad, L., Dickson, B., Doswald, N., Khan, M. S. I., Kershaw, F. and Rashid, M. (2009). Review of the literature on the links between biodiversity and climate change: impacts, adaptation and mitigation. Secretariat of the Convention on Biological Diversity. Technical series 42.
15. CARE.(2009). Climate vulnerability and capacity analysis handbook. First edition. CARE International.
16. CDB and CARICOM Secretariat. (2004). Sourcebook on the integration of natural hazards into environmental impact assessment (EIA): NHIA-EIA Sourcebook. Caribbean Development Bank: Bridgetown, Barbados.
17. http://www.caribank.org/Projects.nsf/NHIA/$File/NHIA-EIA_Newsletter.pdf
18. Cesar, H., van Beukering,P., Pintz, S., Dierking, J. (2002). Economic Valuation of the Coral Reefs of Hawaii, Hawaii Coral Reefs Initiative, University of Hawaii, Hawaii, US.
19. Chan, H.T. and Baba, S. (2009). Manual on guidelines for rehabilitation of coastal forests damaged by natural hazards in the Asia-Pacific region. International Society for Mangrove Ecosystems and International Tropical Timber Organization.
20. Chatenoux, B., Peduzzi, P. (2007). Impacts from the 2004 Indian Ocean tsunami: analysing the potential protecting role of environmental features. Natural Hazards 40:289–304.
21. Colls, A., Ash, N. and Ikkala, N. (2009). Ecosystem-based Adaptation: a natural response to climate change. IUCN.
22. Conservation International (2008). Economic values of coral reefs, mangroves, and seagrasses: a global compilation.
23. Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

24. Costanza, R., Mitsch, W. J. and Day, J. W. Jr. (2006). Creating a sustainable and desirable New Orleans. Ecological Economics 26:317-320.

25. Costanza, R., Pérez-Maqueo, O.M., Martínez, M.L., Sutton, P., Anderson, S.J., Mulder, K. (2008). The value of coastal wetlands for hurricane protection. Ambio 37, 241-248.

26. Dahm, J., Jenks, G. and Bergin, D. (2005). Community-based dune management for the mitigation of coastal hazards and climate change effects: A guide for local authorities. Whakatane, Coast Care. http://www.envbop.govt.nz/Reports/Report-050400-CommunityBasedDuneManagementMitigationCoastalHazardsClimateChangeEffects.pdf

27. DANIDA (2007). Community-based natural resource management. Technical note 2007.

28. Département du territoire (2009). Renaturation des cours d'eau du canton de Genève. Bilan de 10 ans d'actions. http://etat.geneve.ch/dt/eau/a_votre_service-publications_bilan_ans_renaturation_cours_eau_1998_2008_disponible_ligne-1868.html

29. Day, J. W. Jr., Boesch, D. F. et al. (2007). Restoration of the Mississippi delta: lessons from hurricanes Katrina and Rita. Science 315 (5819): 1679-1684.

30. DEFRA (2005). Making space for water: taking forward a new government strategy for flood and coastal erosion risk management in England.

31. Deltacommissie (2008). Working together with water. A living land builds for its future. Findings of the Delatcomissie. Summary and conclusions. http://www.deltacommissie.com/en/advies

32. DFID. (2003). Environment guide. A guide to environmental screening. DFID: London.

33. Disasters and Environment Working Group (DEWGA). (2008). "Linking disaster risk reduction, environment management and development practices and practitioners in Asia-Pacific region: A review of opportunities for integration." Working paper.

34. Dolcemascolo, G. (2004). "Environmental degradation and disaster risk." Issue paper prepared by the Asian Disaster Preparedness Center(ADPC) for the Embassy of Sweden/SIDA Bangkok. February 2004. ADPC: Bangkok. 39 pp.

35. Dolidon, N., Hofer, T., Jansky, L. and Sidle, R. (2009). Watershed and forest management for landslide risk reduction. 633-646. In: Sassa, K. and Canuti, P. Landslides. Disaster risk reduction.

36. Dorren, L., Berger, F., Imeson, A., Meier, B. and Rey, F. (2004). Integrity, stability and management of protection forests in the European Alps. Forest Ecology and Management 195, 165-176.

37. Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran (Eds). (2010). Natural Solutions: Protected areas helping people cope with climate change. IUCN-WCPA, TNC, UNDP, WCS, The World Bank and WWF: Gland, Switzerland, Washington DC and New York, USA.

38. Dudley, N. (ed). (2008). "Guidelines for Applying Protected Area Management Categories". IUCN: Gland.

39. Elias, D., Rungmanee, S. And Cruz, I. (2005). The knowledge that saved the sea gypsies. A World of Science, 3(2): 20–23.

40. Emerton, L. and Kekulandala, L. D. C. B. (2003). Assessment of the economic value of Muthurajawela wetland. Occasional Papers of IUCN Sri Lanka No. 4.

41. Emerton, L. and Bos, E. (2004). Value: counting ecosystems as an economic part of water infrastructure. Water and Nature Initiative. IUCN.

42. FAO and CIFOR. (2005). Forests and floods: drowning in fiction or thriving on facts?

43. FAO (2007a). Coastal protection in the aftermath of the Indian Ocean tsunami: What role for forests and trees? Proceedings of the Regional Technical Workshop, Khao Lak, Thailand, 28–31 August 2006. RAP publication 2007/7. http://www.fao.org/docrep/010/ag127e/ag127e00.htm

44. FAO (2007b). The role of coastal forests in the mitigation of tsunami impacts. RAP publication 2007/1.

45. Feagin, R.A., Mukherjee, N., Shanker, K. et al. (2010). Shelter from the storm? Use and misuse of coastal vegetation bioshields for managing natural disasters. Conservation Letters. 3:1-11.

46. FLOODsite Consortium. (2008). "Integrated flood risk analysis and management methodologies. German Bight Coast pilot study: Executive summary". Report numbers T27-07-12. http://www.floodsite.net

47. Galloway McLean, K. (2009). Advance guard: Climate change impacts, adaptation, mitigation and indigenous peoples – a compendium of case studies. United Nations University – Traditional Knowledge Initiative, Darwin, Australia.

48. Global Water Partnership. (2000). Integrated Water Resource Management. TAC background papers No. 4.

49. Global Water Partnership. (2009). Lessons from Integrated Water Resources Management in practice. Policy Brief 9. http://www.gwpforum.org/gwp/library/GWP_Policy_brief9_English.pdf

50. Goldammer, J.G. and de Ronde, C. (eds.) (2004). Wildland Fire Management Handbook for Sub-Sahara Africa. Global Fire Management Center and Oneworldbooks, Freiburg – Cape Town.

51. Goldammer, J.G. 2010. “Use of prescribed fire in land management, nature conservation and forestry in temperate-boreal Eurasia”. Results and recommendations of the Symposium on Fire Management in Cultural and Natural Landscapes, Nature Conservation and Forestry in Temperate-Boreal Eurasia and members of the Eurasian Fire in Nature Conservation Network (EFNCN), Freiburg, Germany, 25-27 January 2008. Fire Ecology Research Group/ Global Fire Monitoring Center, 28 p. http://www.fire.uni-freiburg.de/programmes/natcon/EFNCN-White-Paper-2010.pdf

52. Gonzalez, P. and Marques, A. (2008). “Forest Carbon Sequestration from Avoided Deforestation and Reforestation in Mata Atlântica (Atlantic Forest), Sul da Bahia, Brazil”. The Nature Conservancy, Arlington, VA. USA.

53. Granek, E.F., Ruttenberg, B.I. (2007). Protective capacity of mangroves during tropical storms: a case study from ‘Wilma’ and ‘Gamma’ in Belize. Marine Ecology Progress Series 343:101-105.

54. Government of Sri Lanka, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP). (2011). Integrated strategic environmental assessment in the Northern Province. UNDP Sri Lanka: Colombo.

55. Government of Sri Lanka, Disaster Management Centre. (2005). “Towards a safer Sri Lanka: Road map for disaster risk management”. http://www.adrc.asia/documents/dm_information/srilanka_plan02.pdf (Retrieved 5 July 2010).

56. Hanley, N. and Barbier, E. B. (2009). Pricing nature: cost-benefit analysis and environmental policy.

57. Harakunarak, A. and Aksornkoae, S. (2005). Life-saving belts: post-tsunami reassessment of mangrove ecosystem values and management in Thailand. Tropical Coasts 12(1): 48-55.

58. Hussain Shah, B. (2008). Field manual on slope stabilization. UNDP Pakistan and ERRA. http://preventionweb.net/english/professional/publications/v.php?id=13232

59. ICEM. (2003). Lessons Learned From Global Experience. “Review of Protected Areas and Development in the Lower Mekong River Region”. Indooroopilly, Queensland, Australia.

60. Iftekhar, M.S. and Islam, M.R. (2004). Managing mangroves in Bangladesh: a strategy analysis. Journal of Coastal Conservation 10: 139-146.

61. Intergovernmental Panel on Climate Change (IPCC). (2011). Special report: Managing the risks of extreme events and disasters to advance climate change adaptation (SREX). Summary for Policymakers. Available at: http://www.ipcc-wg2.gov/SREX/

62. Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change 2007: The physical science basis. Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC. Cambridge University Press: Cambridge.

63. Intergovernmental Oceanographic Commission (IOC) (2009) Tsunami risk assessment and mitigation for the Indian Ocean. Knowing your tsunami risk – and what to do about it. UNESCO Manuals and Guides 52.

64. ISDR (2009). Global assessment report on disaster risk reduction. United Nations: Geneva, Switzerland.

65. IUCN (2007). Technical guidelines for the establishment of a coastal greenbelt. IUCN Sri Lanka Country Office.

66. Iverson, L.R. and Prasad, A.M. (2008). Modeling tsunami damage in Aceh: a reply. Landscape Ecology 23:7–10.

67. Kaiser, B. and Roumasset, J. (2002) Valuing indirect ecosystem services: the case of tropical watersheds. Environment and Development Economics (7): pp. 701-714.

68. Kerr, A.M., Baird, A.H., Bhalla, R.S. and Srinivas, V (2009). Reply to ‘Using remote sensing to assess the protective role of coastal woody vegetation against tsunami waves’. International Journal of Remote Sensing 30(14): 3817-3820.

69. Kramer, R. A., D. D. Richter, S. Pattanayak, and N. P. Sharma. (1997). “Ecological and economic analysis of watershed protection in eastern Madagascar”. Journal of Environmental Management 49(3): pp. 277-295.

70. Krysanova, V., Buiteveld, H., Haase, D., Hattermann, F. F., van Niekerk, K., Roest, K., Martinez-Santos, P. and Schlüter, M. (2008). Practices and lessons learned in coping with climatic hazards at the river-basin scale: floods and drought. Ecology and Society 13, 32.

71. Louisiana-Mississippi Gulf Coast Ecosystem Restoration Working Group (2010). Roadmap for restoring ecosystem resiliency and sustainability. March 2010. Council on Environmental Quality. http://www.whitehouse.gov/administration/eop/ceq/initiatives/gulfcoast/roadmap

72. Mazda, Y., Magi, M., Kogo, M., Hong, P.N. (1997). Mangroves as a coastal protection from waves in the Tong Kong delta, Vietnam. Mangroves Salt Marshes 1:127–135.

73. Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: current state and trends: findings of the Condition and Trends Working Group.

74. Ming J, Lu X, Xu L, Chu L, Tong S. (2007). "Flood mitigation benefit of wetland soil — A case study in Momoge National Nature Reserve in China". Ecological Economics 61(2-3): pp. 217-223.

75. Mortimore, M. with Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Morton, J., Nyangena, W., Skinner, J. and Wolfangel, C. (2009). Dryland opportunities: a new paradigm for people, ecosystems and development. IUCN, IIED and UNDP/DDC.

76. Möller, I. (2006). Quantifying saltmarsh vegetation and its effect on wave height dissipation: results from a UK East coast saltmarsh. Journal of Estuarine, Coastal and Shelf Sciences 69(3-4), 337-351

77. Norris, J. E., Stokes, A., Mickovski, S. B., Cammeraat, E., van Beek, R., Nicoll, B. C. and Achim, A. (eds). (2008). Slope stability and erosion control: ecotechnological solutions.

78. OECD. (2008). Strategic environmental assessment (SEA) and disaster risk reduction (DRR). DAC Network on Environment and Development Co-operation (ENVIRONET). 25 pp.

79. Okori, W., Obua, J. and. Baryamureeb, V. (2009). Famine disaster causes and management based on local community's perception in Northern Uganda. Research Journal of Social Sciences, 4: 21-32.

80. Olwig, M. F., Sørensen, M. K., Rasmussen, M. S., Danielsen, F., Selvam, V., Hansen, L. B., Nyborg, L., Vestergaard, K. B., Parish, F., Karunagaran, V. M., Singh, R. (2007). Using remote sensing to assess the protective role of coastal woody vegetation against tsunami waves. International Journal of Remote Sensing 28 (13/14): 3153-3169.

81. Osti, R., Tanaka, S., Tokioka, T. (2009). The importance of mangrove forest in tsunami disaster mitigation. Disasters 33 (2): 203-213.

82. Parliamentary Office for Science and Technology (2009). Coastal management. Postnote 342, October 2009.

83. http://www.parliament.uk/business/publications/research/post/publications-by-year/pubs2009/

84. Peduzzi, P. (2010). Landslides and vegetation cover in the 2005 North Pakistan earthquake: a GIS and statistical quantitative approach. Natural Hazards and Earth System Sciences 10, 623-640.

85. Perotto-Baldiviezo, H.L., Thurow, T.L., Smith, C.T., Fisher, R.F., Wu, X.B. (2003). "GIS-based spatial analysis and modelling for landslide hazard assessment in steeplands, southern Honduras". Agriculture, Ecosystems and Environment. 103: pp. 165-176.

86. Phillips, A. (ed.). (1998). "Economic Values of Protected Areas: Guidelines for protected area managers". Task Force on Economic Benefits of Protected Areas of the World Commission on Protected Areas (WCPA) of IUCN, in collaboration with the Economics Unit of IUCN, Gland, Switzerland and Cambridge, UK.

87. Pimbert, M.P. & Pretty, J.N. (1995). "Parks, people and professionals: putting "participation" into protected area management". Discussion Paper n° 57.

88. ProAct Network (2008). The role of environmental management and eco-engineering in disaster risk reduction and climate change adaptation.

89. Quarto, A. (2003). " China's Mangrove Forests of the Leizhou Peninsula". Mangrove Action Project. Retrieved July 13, 2010 from: http://www.wrm.org.uy/deforestation/mangroves/China.html

90. Ramsar Convention on Wetlands (2010a). Flood control. Wetland ecosystem services. Factsheet 1. http://www.ramsar.org/pdf/info/services_01_e.pdf

91. Ramsar Convention on Wetlands (2010b). Shoreline stabilisation & storm protection. Wetland ecosystem services. Factsheet 3.

92. http://www.ramsar.org/pdf/info/services_03_e.pdf

93. Regato, P. (2008). Adapting to global change – Mediterranean forests. IUCN. http://cmsdata.iucn.org/downloads/adapting_to_global_change.pdf

94. Reij, C., Tappan, G. and Smale, M. (2009a). Agroenvironmental transformation in the Sahel, another kind of “green revolution”. IFPRI Discussion Paper 00914. International Food Policy Research Institute (IFPRI), Washington, D.C.

95. Reij, C., Tappan, G. and Smale, M. (2009b). Re-greening the Sahel, farmer-led innovation in Burkina Faso and Niger. In D. J. Spielman & R. Pandya-Lorch (eds). MillionsFed: Proven successes in agricultural development. International Food Policy Research Institute (IFPRI), Washington, D.C. pp. 53-58.

96. Reij, C. and D. Steeds. (2003). “Success stories in Africa’s drylands: Supporting advocates and answering sceptics”. Paper commissioned by the Global Mechanism of the Convention to Combat Desertification, 18 March 2003. Centre for International Cooperation, Vrije Universiteit Amsterdam.

97. Rego, F., Rigolot, E., Fernandes, P., Montiel, C. and Sande Silva, J. (2010). Towards Integrated Fire Management. EFI Policy Brief 4. European Forest Institute.

98. Robledo, C., Fischler, M. and Patiño, A. (2004) Increasing the resilience of hillside communities in Bolivia - Has vulnerability to climate change been reduced as a result of previous sustainable development cooperation? Mountain Research and Development 24(1): 14-18.

99. Sathirathai, S. and Barbier, E. (2001). “Valuing Mangrove Conservation in Southern Thailand”. Contemporary Economic Policy, Vol.19 (2): pp. 109-122.

100. Shepherd, G. (2004). The ecosystem approach. Five steps to implementation. IUCN: Gland.

101. Sida. (2002). Guidelines for the review of environmental impact assessments: Sustainable development? SIDA, Environmental policy division: Stockholm.

102. Smith, D.M. and Barchiesi, S. (2009). Environment as infrastructure - resilience to climate change impacts on water through investments in nature. Perspectives on water and climate change adaptation, series no. 2. IUCN.

103. Stolton, S., Dudley, N. & Randall, J. (2008). Natural security: protected areas and hazard mitigation. WWF and Equilibrium: Gland, Switzerland.

104. Sudmeier-Rieux, K. and Ash, N. (2009). Environmental guidance note for disaster risk reduction. IUCN: Gland.

105. Sudmeier-Rieux, K., Masundire, H., Rizvi, A. and Rietbergen, S. (eds) (2006). Ecosystems, livelihoods and disasters – an integrated approach to disaster risk management. Ecosystem Management Series No. 4. IUCN.

106. Tanaka, N. (2009) Vegetation bioshields for tsunami mitigation: review of effectiveness, limitations, construction, and sustainable management. Landscape and Ecological Engineering 5, 71-79.

107. Turner, B.L., Kasperson, P.A., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A. (2003). “A framework for vulnerability analysis in sustainability science”, Proceedings of the National Academy of Sciences, 100 (14): 8074-8079.

108. TEEB – The economics of ecosystems and biodiversity for national and international policy makers (2009).

109. UNEP / UNISDR. (2008). Environment and disaster risk. Emerging perspectives. 2nd edition. UNISDR Secretariat: Geneva.

110. UNEP (2008). Indigenous knowledge in disaster management in Africa.

111. UNEP (2009a). Learning from Cyclone Nargis. Investing in the environment for livelihoods and disaster risk reduction. A case study.

112. UNEP (2009b). The role of ecosystems management in climate change adaptation and disaster risk reduction. Copenhagen Discussion Series, June 2009. p. 4.

113. UNEP (2010a). Linking ecosystems to risk and vulnerability reduction. The case of Jamaica. UNEP/Post-Conflict and Disaster Management Branch and GRID Europe: Geneva.

114. UNEP (2010b). Dead planet, living planet – biodiversity and ecosystem restoration for sustainable development. A rapid response assessment. UNEP, GRID-Arendal.

115. UNEP/IISD/UNITAR. (2009). Vulnerability and impact assessments for adaptation to climate change (VIA Module). IEA Training Manual, volume 2. UNEP: Nairobi.

116. UNEP/MAP/PAP. (2008) Protocol on Integrated Coastal Zone Management in the Mediterranean. Priority Actions Programme. http://www.pap-thecoastcentre.org

117. UNEP/OCHA. (2009). Environmental emergencies. Learning from multilateral response to disasters. Joint UNEP/OCHA Environmental Unit: Geneva.

118. UNEP/PEDRR. (2009). "Opportunities in environmental management for disaster risk reduction: Recent progress". Background document for the 2009 Global Assessment Report on Disaster Reduction. Geneva.

119. UNEP-WCMC. (2006). In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs.

120. van Dijk, A.I., van Noordwijk, M., Calder, I.R., Bruijnzeel, S.L., Schellekens, J. and Chappell, N.A. (2009). Forest–flood relation still tenuous – comment on 'Global evidence that deforestation amplifies flood risk and severity in the developing world'. Global Change Biology. 15, 110–115.

121. Van Eijk, P. and Kumar, R. (2009). Bio-rights in theory and practice. A financing mechanism for linking poverty alleviation and environmental conservation. Wetlands International.

122. Van Halsema, G.E. and Zingstra, H. 2008. "Revitalizing regulating services. The Netherlands floodplain policy." in Scoping wetland-agriculture functions. FAO: Rome. pp. 73-80.

123. Vo-Luong, P., Massel, S. (2008). Energy dissipation in non-uniform mangrove forests of arbitrary depth. Journal of Marine Systems 74, 603–622.

124. Wetlands International. (2009). Wetlands and climate change adaptation. Sustaining and restoring wetlands: an effective climate change response. http://www.wetlands.org/WatchRead/tabid/56/mod/1570/articleType/ArticleView/articleId/1953/Default.aspx

125. Wibisono, I.T.C. and Sualia, I. (2008). Final Report: An Assessment of Lessons Learnt from the "Green Coast Project" in Nanggroe Aceh Darussalam Province and Nias Island, Indonesia. 2005-2008. Wetlands International - Indonesia Programme.

126. Wisner, B., Blaikie, P., Cannon, T, Davis, I. (2004). At risk: Natural hazards, people's vulnerability and disasters. 2nd edition. Routledge: London.

127. World Bank. (2010). Convenient solutions to an inconvenient truth: ecosystem-based approaches to climate change.

128. World Bank. (28 October 2010). "World Bank launches new global parternship to green national accounts". Press release No: 2011/155/ISDN.

129. WWF (2006). Tsunami green reconstruction policy guidelines. WWF-Indonesia.

130. WWF (2008). Water for life: lessons for climate change adaptation from better management of rivers for people and nature.

131. WWF and American Red Cross (forthcoming). Green Recovery and Reconstruction Toolkit. WWF-USA: Washington, DC.

132. Xu, J. and Melick, D.R. (2007). "Rethinking the effectiveness of public protected areas in southwestern China" Conservation Biology 21 (2): pp. 318–328.

133. Yin, H. and Li, C. (2001). Human impact on floods and flood disasters on the Yangtze River. Geomorphology 41, 105-109.

134. Zhao, B. et al. (2005). Estimation of ecological service values of wetlands in Shanghai, China. Chinese Geographical Science 15: 151-156.

Endnotes

1. SDR/Global Assessment Report (2009).
2. IPCC (2007).
3. (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.).
4. 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.
5. The IPCC SREX summary report for policymakers can be downloaded from http://www.ipcc-wg2.gov/SREX/. The full report will be available in February 2012.
6. World Bank (2010).

7. Millennium Ecosystem Assessment (2005).
8. UNEP/UNISDR (2008).
9. Millennium Ecosystem Assessment (2005).
10. Sudmeier-Rieux and Ash (2009).
11. Millennium Ecosystem Assessment (2005).
12. TEEB (2009).
13. TEEB (2009).
14. 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.
15. TEEB (2009).
16. Conservation International (2008)
17. Costanza et al (2008).
18. Costanza et al (2008).
19. ProAct Network (2008).
20. Emerton and Bos (2004), see also Emerton and Kekulandala (2003).
21. Brenner et al (2010).
22. ProAct Network (2008).
23. Sudmeier-Rieux and Ash (2009); UNEP /UNISDR (2008).
24. Adapted from UNEP / UNISDR (2008): p. 13.
25. UNEP / UNISDR (2008).
26. Sudmeier-Rieux et al (2006).
27. Day et al (2007), Batker et al (2010), see also World Bank (2010).
28. ISDR (2009).
29. UNEP (2009a)
30. Sudmeier-Rieux and Ash (2009: pp. 1-2).
31. TEEB (2009 : p. 23).
32. ISDR (2009).
33. Millennium Ecosystem Assessment (2005).
34. 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.
35. ProAct Network (2008),Sudmeier-Rieux and Ash (2009),World Bank (2010).
36. See, for example, the Alpine Convention protocol on mountain forests, http://www.alpconv.org/theconvention/conv02_en.htm
37. Brang et al (2006), ProAct Network (2008).
38. DEFRA (2005), Deltacomissie (2008), Parliamentary Office for Science and Technology (2009). See also http://www.deltacommissie.com/en/advies
39. Département du Territoire (2009), see also http://etat.geneve.ch/dt/eau/renaturation-80-645.html
40. World Bank (2010).
41. DEFRA (2005).
42. WWF (2008).
43. 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.
44. Robledo et al (2004).
45. Intergovernmental Oceanographic Commission (2009).

46. Dolidon et al (2009), Peduzzi (2010), Norris et al (2008).
47. Bebi et al (2009), Dorren et al (2004).
48. Bradshaw et al (2007), Krysanova et al (2008).
49. See World Bank 2010.
50. Campbell et al (2009).
51. Batker et al (2010), Costanza et al (2008), Ramsar (2010a), Zhao (2005).
52. See, for example Badola et al (2005), Batker et al (2010), Granek and Ruttenberg (2007).
53. Campbell et al (2009), Ramsar (2010b), UNEP-WCMC (2006), World Bank (2010).
54. Mazda et al (1997), Möller (2006), Vo-Luong and Massel (2008).
55. Campbell et al (2009).
56. Intergovernmental Oceanographic Commission (2009), UNEP-WCMC (2006).
57. Campbell et al (2009), Krysanova et al (2008).
58. Campbell et al (2009).
59. World Bank (2010).
60. WWF 2008.
61. World Bank (2010) ; Sudmeier-Rieux and Ash (2009).
62. Campbell et al (2009), Sudmeier-Rieux and Ash (2009).
63. FAO and CIFOR (2005), van Dijk et al (2009).
64. See, for example, FAO (2007a), Feagin et al (2010), Campbell (2009).
65. 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).
66. See Sudmeier-Rieux and Ash (2009), TEEB (2009), UNEP (2010b), World Bank (2010).
67. Batker et al (2010), Campbell (2009), Ramsar (2010), World Bank (2010).
68. Campbell et al (2009).
69. For review of the scientific literature on deforestation and flooding events in Asia, see Dolcemascolo (2004). See also Peduzzi (2010)
70. World Bank (2010).
71. UNEP (2010b).
72. Dolcemascolo (2004).
73. TEEB (2009).
74. Sudmeier-Rieux and Ash (2009).
75. Sudmeier-Rieux and Ash (2009) : p. 11.
76. ProVention Consortium (2007).
77. This set of actions has been adapted from ProVention Consortium (2007) while drawing on other resources such as the TEEB, Ch.4 (2009), CDB and CARICOM (2004), OECD (2008); DFID (2003); Sida (2002).
78. TEEB, Ch. 4 (2009): p. 26.
79. CARICOM is an intergovernmental entity comprised of 15 Caribbean countries.
80. See CDB and CARICOM (2004).
81. UNEP/PEDRR (2009).
82. TEEB, Ch. 4 (2009) : p. 17.
83. Benson et al. (2007).
84. OECD (2008). The OECD has also developed a guidance note on linking SEAs with adaptation to climate change, with clear linkages to DRR.
85. ADB (2004) cited in Benson et al. (2007).

86. ADB (2004) cited in Benson et al. (2007).
87. UNEP/OCHA (2009) ; Sudmeier-Rieux and Ash (2009).
88. UNEP and UNISDR (2008).
89. Perotto-Baldiviezo et al. (2003).
90. Stolton et al. (2008); IUCN (1994).
91. TEEB, Ch.8 (2009): p. 2.
92. Coad et al. 2009 cited in TEEB, Ch.8 (2009):p. 2.
93. Stolton et al. (2008).
94. Stolton et al. (2008).
95. TEEB, Ch.8 (2009); Mulongoy and Gidda (2008); Stolton, Dudlely and Randall (2008).
96. Stolton et al. (2008).
97. Ming J, Lu X, Xu L, Chu L, Tong S. (2007): pp.217-223.
98. Stolton et al. (2008).
99. Kramer, R. A., D. D. Richter, S. Pattanayak, and N. P. Sharma. 1997) : pp. 277-295.
100. Adapted from Stolton et al. (2008); see also Brang et al. (2006).
101. Cesar, H., van Beukering,P., Pintz, S., Dierking, J. (2002): pp 34.
102. Dudley, N. (2008).
103. Quarto, A. (2003).
104. TEEB, Ch.8 (2009): pp. 10-13.
105. UN Millennium Project (2005) cited in TEEB Ch. 8 (2009): p.4.
106. Gonzalez, P. and Marques, A. (2008); Stolton, Dudlely and Randall (2008); Kulshreshtha S.N., Lac S., Johnston M., Kinar C. (2000).
107. Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran [editors] (2010): pp.36
108. TEEB, Ch. 8 (2009); Kaiser, B. and Roumasset, J. (2002).
109. TEEB, Ch.8 (2009).
110. Badola, R. and Hussain, S.A., 2005.
111. Barbier, E.B. (1993).
112. Kaiser and Roumasset (2002). Sathirathai and Barbier (2001); Phillips, A. (ed.). (1998): p. 22. Kramer, R. A., D. D. Richter, S. Pattanayak, and N. P. Sharma. (1997): pp: 277-295.
113. Global Water Partnership (2000).
114. Global Water Partnership (2009).
115. http://www.alpenrhein.net/
116. R. Cordoba, IUCN Mesoamerica (pers. comm..)
117. UNEP/MAP/PAP (2008).
118. Campbell (2009), UNEP-WCMC (2006).
119. DEFRA (2005), Deltacomissie (2008).
120. See also ADPC (2009).
121. Louisiana-Mississippi Gulf Coast Ecosystem Restoration Working Group (2010). See also http://www.clear.lsu.edu/needs_in_louisiana
122. Costanza et al (2006), Day et al (2007).
123. Iftehkar and Islam (2004).
124. See also http://www.fireparadox.org/
125. Regato (2008).

126. Goldammer (2010), Rego et al (2010).
127. Okori et al (2009).
128. Reij et al (2009a and 2009b).
129. See for example Campbell et al (2009).
130. Community-Based Natural Resource Management Network, http://www.cbnrm.net/resources/terminology/terms_processual.html
131. Danida (2007).
132. UNESCO. Local and indigenous knowledge systems LINKS. http://portal.unesco.org/science/en/ev.php-URL_ID=2034&URL_DO=DO_TOPIC&URL_SECTION=201.html
133. Galloway McLean (2009) - case study 18 & 83; UNEP (2008).
134. Galloway McLean (2009).
135. Elias et al (2005); see also Galloway McLean (2009) - case study no. 190.
136. Reij and Steeds (2003).
137. Reij et al (2009a, 2009b).
138. Robledo (2004).
139. Regato (2008).
140. ProAct Network (2008); see also http://ourworld.unu.edu/en/fighting-carbon-with-fire/ , http://savanna.cdu.edu.au/information/arnhem_fire_project.html
141. See, for example, Badola and Hussain (2005).
142. Dahm et al (2005).
143. See, for example, Tanaka (2009), van Ejik and Kumar (2009), Wibisono and Sualia (2008).
144. Casuarina is a pine-like tree.
145. Feagin et al (2010).
146. See Shepherd (2004).
147. Sudmeier-Rieux and Ash (2009: p. 9).
148. Sudmeier-Rieux and Ash (2009).
149. Hussain Shah (2008) , see also Norris et al (2008).
150. UNEP (2009b).
151. Smith and Barchesi (2009: p. 5-6).
152. See Campbell et al (2009), Colls et al (2009), World Bank (2010). Colls, A., Ash, N. and Ikkala, N. (2009).
153. World Bank (2010); TEEB (2009).
154. Pimbert and Pretty (1995).
155. IUCN is spearheading efforts involving 21 scientists from nine countries to develop a "Red List of Ecosystems" that establishes thresholds and risk criteria applicable to terrestrial, marine and freshwater ecosystems, at multiple scales ranging from local to global. The proposed risk assessment system for ecosystems is currently being tested globally with final results expected in 2012. (Rodriguez et al. no date. "Establishing Red List Criteria for Threatened Ecosystems") For further information, contact: jonpaul.rodriguez@gmail.com
156. TEEB (2009).
157. For further information, see http://climate-l.org/news/world-bank-launches-partnership-for-ecosystem-services-valuation/?referrer=climate-change-daily-feed (accessed on 03 November 2010).
158. Stolton et al. (2008).
159. ADPC has developed a regional training manual on DRR for coastal zone managers. UNEP together with local partners developed and delivered integrated DRR-coastal zone management trainings in Sri Lanka, India and Indonesia. IUCN has undertaken extensive work and capacity-building on integrated watershed management. GFMC has developed ecosystem-based wildfire management trainings. WWF-US/American Red Cross is launching its Green Recovery and Reconstruction Toolkit in November 2010, which has a specific module on "greening" DRR.

2

Natural Resource Management Strategies for Disaster Risk Reduction

Vinod K. Sharma and A.D. Kaushik

The relentless and unwanted human activities i.e. extensive blasting operations and deforestation carried out for constructing roads, buildings and dams & degradation of the Himalayas have led to the loss of natural resources & massive soil erosion, landslides and forest fire in Himalayas. In due course, landslides, ground subsidence and avalanches occurred and a good deal of silt and other materials are carried down, causing flood disaster in the rivers and causes environmental damage, which leads to loss of agriculture, land building and even large human life in the plains. Annually one million houses damaged including human social & other losses due to natural disasters. A natural hazard pertains, "to a natural phenomenon which occurs in proximity and poses a threat to people structure and economic assets caused by biological, geological, seismic, hydrological and meteorological conditions or processes in the natural environment". The inter-dependencies and interrelationships among natural resources viz. water; land, animal, human beings and vegetation resources determine the nature and kind of livelihood supporting systems particularly in rural areas. The depletion of natural resource base and increasing biomass demand of rising human and livestock population are attracting attention of all concerned: farmers, technicians, scientists, administrators, and policy makers. Management of natural resources means the rational utilization of a sustainable environment to provide the highest quality of living for mankind. Management of natural resources is essential for the survival of man because life depends on air, water, soil, rocks, forests and water bodies; the ultimate purpose of management is to maintain all these in a healthy operating condition. Management of natural resources has, therefore, economic, aesthetic, and scientific value leading for reduction of risk of disasters for mankind.

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

Introduction

The complex geological systems have contributed to the aggravating of the earth's dynamic processes of weathering, erosion, wastage, and seismicity, etc, which affect and modify the environment. The melting snows and about 1500 glaciers feed several rivers, which sustain life of the plain. They are the natural sources of our economic development. As a matter of fact, Himalayas directly or indirectly influence the climatic conditions of India. During last two decades, the unwanted human activities i.e. extensive blasting operations and deforestation carried out for constructing roads, buildings and dams, etc. have led to increased soil erosion and landslides in Himalayas. In due course, landslides, ground subsidence and avalanches occurred and a good deal of silt and other materials are carried down, causing flood disaster in the rivers and causes environmental damage in the plains.

The high man-land ratio, lack of employment opportunities, poverty and food shortages combined with natural disasters like flood & drought, etc., contribute to the migration of people particularly from the Himalayas for getting job and increasing their economic status. Even out migration also creates implications on fragile environment and leads to decline of natural resources and rural productivity because women, children and old people left behind and they cannot maintain their agriculture and natural resources properly.

Relentless degradation of the Himalayas leads to the loss of fuel wood and fodder supplies, massive soil erosion, landslides, debris deposition, sedimentation of rivers, dams and reservoirs. The consequences have increased flood frequency, which leads to loss of agriculture, land building and even large human life. In India, the cost of increasing flood damage and destruction of reservoirs and irrigation systems by sediment from misused slopes have averaged US $ 250 million a year in compensation and damage prevention measures (WRI, 1999) 1.

Disaster Profile

Being a vast country with unique geo-climatic vicissitudes as well as a large population, the Indian sub-continent is exposed to major natural hazards, which often turn into disasters causing significant disruption of socio-economic life of communities leading to loss of life and property to mount year after year.

Disaster is defined as "the occurrence of sudden and major misfortunes which disrupts the basic fabric and normal functioning of a society". (The United Nations definition). Among all the disasters affecting the country, floods are the most frequent and often the most devastating. Floods are most frequent in the Ganga-Brahmaputra- Meghna basin, which carry 60% of the nation's total river flow. Almost 85% of the somewhat copious annual average rainfall of 1200 mm is concentrated over a short monsoon season in four months. In the country, the pattern of rainfall in 35 meteorological sub-divisions varies considerably from a high of 10,000 mm in Cherrapunji to 200-300 mm in Jaisalmer. This factor combined with the inflow of water in the northern rivers from Nepal, results in some areas invariably getting flooded each year, while others found under the impact of creeping droughts (NCDM, 2001)2.

The decade 1990-2010, has been one of very high disaster losses within the country, e.g. Orissa Cyclone '1999' and later the Gujarat Earthquake (2001) alone estimate to several thousand crore of Rupees (Mishra, 2004)3. The total damage caused to property by natural disasters in 2001 was still amounted maximum as Rs. 12,000 crore in India. The earthquake of South East Asia (2005) has been caused the losses of human life (1309), injured (6622) and damaged building/Houses (37,607) in Jammu & Kashmir.

During the last three decades, 218 countries of the world faced as many as 8393 disaster events, each killing a minimum of 10 and/ or injuring 100 or more people (Table-1).

Table 1: Disasters events in five continents during 1974-2008

Continents	1974-78	1979-83	1984-88	1989-93	1994-98	1999-2003	2004-2008	Total
Africa	88	113	128	107	149	333	480	1398
Americas	99	199	255	319	320	475	429	2096
Asia	220	336	353	482	449	726	780	3346
Europe	43	108	136	144	134	288	272	1125
Oceania	47	56	57	64	64	75	65	428
Total	497	812	929	1116	1116	1897	2026	8393

Source: South Asia disaster Report 2008

The Indian subcontinent is highly vulnerable to cyclones, droughts, earthquakes and floods. Avalanches, forest fire and landslides occur frequently in the Himalayan region of northern India. Among the 35 total states/ Union Territories in the country, 25 are disaster prone. On an average, more than 50 million people in the country are affected by one or the other disaster every year, besides loss of property worth several million (Table 2).

Table 2: Total number of people reported killed and affected by disasters in India.

Year	Total number of People reported killed	Total number of People reported affected
1986-1995	42,026	561,472,995
1996-2005	85,001	686,724,143
2005	5,405	28,262,805
2006	2071	7384760
2007	2236	38143000
2008	1808	13989018

Source: World Disasters Report 2006 & 2007- Disaster data
South Asia disaster Report 2008

In the 1970s and the 80s, droughts and famines were the biggest killers in India, the situation stands altered today. It is probably a combination of factors like better resources management and food security measures that has greatly reduced the deaths caused by droughts and famines. Floods, high winds and earthquakes dominate (98%) the reported injuries, with ever increasing numbers in the last ten years. The period from 1973 to 2010 has been associated with a large number of earthquakes in Asia that have a relatively high injury- to death ratio. Floods, droughts, cyclones, earthquakes, landslides and avalanches are some of the major natural disasters that repeatedly and increasingly affect India.

Vulnerability

As stated above that India is the most vulnerable to natural disasters in the world. Over 8000 major disasters have been registered worldwide since 1960. The disaster is the product of hazards like floods, cyclones, landslides, earthquakes, etc. and these are not rare, while the vulnerability varies from region to region. Indian sub-continent is amongst the world's most disaster prone areas with –

- 57% area is vulnerable to Earthquake
- 28% area is vulnerable to Droughts
- 8% area is vulnerable to Cyclones and
- 12% area is vulnerable to Floods (while 37% area was affected in 1998)
- 50 % forest cover area is vulnerable to forest fire
- 18% area is vulnerable to landslides

One million houses damaged annually including human social & other losses. A natural hazard pertains, "to a natural phenomenon which occurs in proximity and poses a threat to people structure and economic assets caused by biological, geological, seismic, hydrological and meteorological conditions or processes in the natural environment".

Types of Disasters

Due to the increasing frequency of natural & man-made disasters and their severe impact on the individuals, society, economy, natural resources and environment, Government of India constituted a High Powered Committee (HPC) on Disaster Management in August 1999 to prepare comprehensive plans for National, State and District levels. The HPC has rightly stressed on the need for a comprehensive and holistic approach towards dealing with all kinds of disasters. From a compartmentalized response oriented approach, a coordinated, holistic and participatory approach has been recommended. HPC identified thirty-one disasters in the country4. These disasters have been categorized into five sub-groups depending on generic considerations and various departments/ ministries dealing with various aspects. These five sub-groups are as follows:

1. **Sub-Group I – Water and Climate Related Disasters**
   This sub-group includes Floods & Drainage Management, Cyclones, Tornadoes and Hurricanes, Hailstorm, Cloud Burst, Heat Wave and Cold Wave, Snow Avalanches, Droughts, Sea Erosion and Thunder & Lightning.
2. **Sub-Group II - Geologically related disasters**
   It includes Landslides and Mudflows, Earthquakes, Dam Failures/ Dam Bursts Mine Fires
3. **Sub-Group III- Chemical, Industrial & Nuclear related disasters**
   In this category, the chemical and industrial & nuclear disasters have been included.
4. **Sub-Group IV- Accident related disasters**
   Forest Fires, Urban Fires, Mines Flooding Oil Spill, Major Building Collapse, Serial Bomb Blasts, Festival related disasters, Electrical disasters and Fires, Air, Road and Rail Accidents, Boat Capsizing and Village Fire have been included by HPC.
5. **Sub-Group V – Biologically related disasters**
   This sub-group includes Biological disasters and Epidemics, Pest Attacks, Cattle epidemics and Food poisoning

Natural Resource Management and Natural Disaster Risk Reduction Linkages

The natural resources like sunlight, water and land constitute the primary life supporting systems of all forms of life-micro-organisms, vegetation, animals and human being. The inter-dependencies and interrelationships among water, land, animal and vegetation resources determine the nature and kind of livelihood supporting systems particularly in rural areas. The depletion of natural resource base and increasing biomass demand of rising human and livestock population are attracting attention of all concerned: farmers, technicians, scientists, administrators, and policy makers. The degeneration of natural resources in rain fed areas is not only assuming alarming proportion but also exercise a tremendous influence on the ecosystem as well as on their sustainable development5. The proper management of natural resources reduces disaster risk in all ecosystems. The statement will be strengthened further in the ensuing pages.

Natural resources may be classified in several ways. They may be classified on the basis of their sources of origin. For example, most of the minerals are obtained from the land. Salt and fish are the resources available from the oceans.

The resources may also be classified on the basis of their continued availability to serve the needs of man. Some resources, like those obtained from agriculture, may be obtained continuously year after year. These are called replenishable resources. Such resources do not get exhausted. Mineral resources may get exhausted after some years. Oil wells and coalfields are abandoned after a few years. These resources are non-replenish able resources. There is a limit to the availability of such resources in the year.

The resources available may also be grouped according to the stage of their development. For example, Africa has vast potential resources of waterpower out of which only a small percentage is developed at present. The extent of development of a potential resource depends on the stage of economic development as this indicated the demand for various resources. In the developed countries of the world, a greater percentage of the potential resources have been developed. As a result the distribution of potential as well as developed resources on the surface of the earth is highly uneven.

Management Strategies

Management or Conservation of natural resources means the rational utilisation of environment to provide the highest sustainable quality of living for mankind. Management of resources is essential for the survival of man. Because life depends on air, water, soil, rocks, forests and water bodies, the ultimate purpose of conservation is to maintain all these in a healthy operating condition. Management of natural resources has, therefore, economic, aesthetic, and scientific value particularly leading to reduction of disasters for mankind.

Certain management practices have been developed and adopted from the earliest times of human civilization. Some species of animals were protected by religious taboos. Religious sanctions prevented the destruction of forests, groves, sacred rocks, and mountains. Early civilizations developed good techniques of terracing to prevent soil erosion on hillsides and to make more effective use of water for irrigation. As civilizations progressed and developed, human experiences led to increasingly sound land use practices and protection of wild animals and forests. The agricultural landscapes in India, Japan and China- especially in the hilly areas,- reflect the great skill in management of soil resources. Irrigated land in the Nile Valley, Alluvial soils in the Great Plains of India and the lava soils in Maharashtra have been kept fertile and productive over thousands of years by the sustained and skilled efforts of men.

The recent history of management of natural resources has been marked by a great expansion of government role in protecting the environment and by a growth of public interest in conservation. For the management or conservation of resources and for a much more integrated approach to environmental problems, many countries have established ministries. The principal resources that need conservation and suitable management are soil, water, forest, wildlife (birds, fish, and animals), power resources, metallic and non-metallic minerals, recreational resources, and the life of the people.

Management of Soil

Soils are the basis of support for most life, and a source of nutrients for marine life and fresh water. Soils vary from place to place, depending upon the rocks and minerals from which they are derived; the local climate and the animals and plants live in or on them. Soils are essential for man for growing crops, fodder, and timber. It is, therefore, important that they should not be allowed to wash or blow-away more rapidly than they can be regenerated, their fertility should not be exhausted, and their physical structures should remain suited to continued production of desired plant materials. The objective of soil management is, therefore, to keep soil in place and in a state favourable to its highest productive capacity.

There are a number of physical and cultural factors responsible for the depletion and erosion of soil, slopes, rainfall, weather, temperature, wind snowfall, and man's action like deforestation, overgrazing, and unscientific cultivation, etc. Once the fertile portion of the earth surfaces lost, it is very difficult to replace it. In extreme cases, soil erosion leads to the formation of deep gullies that cut into the soil and then spread and grow until all the soil is removed from the sloping ground. To check soil erosion and to improve soil fertility, various methods have been practiced in different parts of the world. Some of the important methods of soil conservation are to control excessive grazing, rotations of crops, cultivation of short duration cover crops, control of shifting cultivations, and to restore gully plugging. Soil erosion on sloping ground and landslides can be prevented by terracing on steep slopes or by contour cultivation on gentle slopes. To prevent wind erosion, shelterbelts of trees are to be planted to break the force of the wind. Ploughing of land at right angles to the direction of wind further serves to prevent wind erosion.

Although measures to stop landslides/ soil erosion are now widely used in the developed countries, the problem remains a major one in the developing and the underdeveloped countries of the world. Landslides/ soil erosion is particularly severe in the tropics, where heavy rainfall and steep sloping ground favour the rapid loss of any soil exposed by agriculture, and around the edges of the world deserts. Planned programme for soil management is undertaken by a government, can help a long way in this direction.

Management of Water and Air

Man requires water for a variety of purposes. There is a steadily growing need of water supply for drinking, for domestic animals, plants, irrigation, industries, transportation, cleaning, sewage disposal, and for the generation of electricity. The management of water is, therefore, essential for the survival of the human race, plants, and animal life. The requisites of a good water supply are that it should be free from mud, smell, chemical impurities, and infectious bacteria. Most of the governments and local governments in India are trying to provide good quality of water to their people6, but there is still much left to be done in the rural areas of Afro-Asian and Latin American countries.

The scientists' concern about the quality of air is a relatively recent development. Air pollution results from a variety of causes, not all of which are man's responsibility. Dust storms in the desert areas and smoke from forests and grasslands contribute to chemical and particulate pollution of the air. Air pollution on urban atmosphere is noticeable and causes great public reaction. The task of removing air pollution, although difficult, is not insurmountable. Apart from government it is the duty of each of us to minimize air pollution.

Management of Forests

With the rapid increase in the demand for timbers, fuel-wood, paper, pulp in construction industry, and synthetic fibres in the world, forests have been exploited rapidly. Besides, the misuse of forests by man there are other factors like forest fire, insects, disease, and windstorm, which are also responsible for forest depletion of a great extent.

Recently, the importance of forests has been realized and different scientific policies have been adopted in different countries to stop the exploitation and destruction of forests, and to attain the maximum possible satisfaction from the forests by making their use rational and by conserving them. One of the greatest enemies of forests is forest fire, which is a natural disaster and has been occurring rapidly since 1990 in India. Each year forest-fires sweep over large areas. This great waste can be, almost wholly prevented if adequate attention is given to safeguarding the forests from fire. Many fires are due to sparks from locomotive, lumber mills, carelessness of hunters, and picnickers. Most of these can be prevented if proper care is exercised. In dry seasons hunters and idle visitors should be forbidden to enter the forests. The burning of forest waste should be done after a heavy rain or snowfall when the danger of conflagration is much less.

Another way of conserving forests is the prevention waste in lumbering and in preparing the lumber for use. Still at many places much of the waste material is burned which can be used for fuel and some in making small articles like toys, laths, and handles for tools. More attention is to be given to the treatment of lumber with chemicals to prevent decay and destruction by insects. Afforestation on large scale is also necessary for the conservation of forests to provide the benefits to future generation of the National Forest Policy (1988) 7. The recommendations on Joint Forest Management may be implemented for the management of forests.

In India as in many parts of the world, misuse of vegetal cover lead to disastrous results. Rajasthan is largely a man-made desert. Most of our Sahadris are now poor and dry. Much of the Central Maharashtra has been transformed from natural grassland to scrub land due to overgrazing, extensive tilling of land during good years and abandoning it during bad years. According to experts, every country should have at least one-third of its total land under forests, as there is a well-known saying “After man the desert”.

Management of Wildlife and Fisheries

Wildlife and fisheries have contributed appreciably to the human progress and civilization. At present in the Age of “Machines we cannot do without cattle. Many species of animals have been extinguished from the earth and many have been reduced in number only because the ecological system and locate have been changed by man. In tropical and subtropical semi-arid areas, Mediterranean countries and West Asia, there has been overgrazing. In the developed countries of Europe, America, Australia, and New Zealand, cattle are well taken care of and the quality of the grassland or pasture is not allowed to deteriorate. Our country needs better and well-nourished breeds in place of the present thin, undernourished stocks. Wild animals like deer, lion, tiger, elephant, and various types of birds also need protection and conservation. This can be done by closed seasons when they cannot be hunted.

Fisheries include catching of fish and gathering of shells and mammals like the whale and the seal. Fisheries at present are contributing to the food resources of the world and their management is, therefore, very important for our use and for the future. Moreover, increased productivity in fisheries may contribute to the commercial harvest, raising the income and standard of the people dependent on them. The problems of fisheries management are, however, numerous. It is essential first to locate the fish and to derive some estimate of their abundance. It is also necessary to determine the maximum sustained yield of fish population. Moreover, there should be supervision control over fisheries, and the ecological requirements of the fishing grounds should not be disturbed and polluted.

Management of Bio-diversity

It is well known fact that Biological diversity with different kinds of plants and animals ensures food supply and maintenance of ecological balance in nature. However, Biological diversity is being threatened by the disturbances caused either by the natural hazards or by the encroachment on the natural ecosystems by the human activities.

In this scenario there is urgent need to collect and preserve indigenous germ plasm in-situ and ex-situ in the long term and sustainable interest of rain fed farming systems. The bio-diversity could be managed and utilized in topo-sequence in watersheds under different agro-ecological situation. Bio-diversity, which is essential for sustainable natural resource management in rain fed areas, is under threat from modern trends in agriculture, animal husbandry and forestry development. Fortunately, many individuals and institutions are rising up to preserve bio-diversity. The Natural Bureau of Plant Genetic Resources (NBPGR), under the Indian Council of Agricultural Research (ICAR) has a well-designed massive plant genetic resources conservation and maintenance programme. Besides, it has also taken up the conservation and utilization of animal, fish microbes and insect genetic resources.

Management of Mineral Resources

Minerals, more than forests need to be carefully managed. Forests are renewable and can grow again but minerals once dissipated can never be replaced except over long periods of geological time-which extends over millions of years. The exploitation and management of mineral resources depend on the stage of culture and technological advances, price of mineral, the location of mineral ore with reference to transportation and market, the case of exploitation, the policies of the government, the richness of the ore, the depth of the ore-body, climate, and labour cost.

Management of Coal

The utilisation and exploitation of coal has been going on for a long time. Coal supply is, however, limited and there is no way of replacing it. Coal can be saved by more careful and scientific methods of mining. Now more electricity used for light and power is being generated by waterpower. The use of hydro-electricity should be increased to save coal and therefore many more rivers should be harnessed.

Management of Petroleum

It is not easy to say how long the world's petroleum supplies will last. All the experts of petroleum are of the opinion that with the rapid increase in consumption it is not going to last as long as coal. The length of time it will last is probably a matter of decades rather than centuries. What then can be done to save as much petroleum as possible for future use? A great deal of waste of petroleum takes place in the oil fields. More oil is taken from the earth than is really needed. Each owner is probably, eager to turn his oil into cash. Owners perhaps fear that if they do not drain the oil from their own wells, it may flow into the wells of the other owners nearby.

In the early days of the petroleum industry the hits or miss method was used. A well was drilled and, if oil was found, the owner was lucky. Now geologists study regions with great care and give close attention to the kind of rock through which the drill passes. With the help of experts oil deposits are much more readily located. Oil is also saved if the owners of a well in a region agree to draw the oil slowly and maintain the pressure in all the wells. If this is not done much oil remains in the earth and is lost. Methods of refining also offer opportunities for saving oil supplies. Petrol is the one product of petroleum for which there is a great demand. Refiners are seeking methods of obtaining more Petrol from a given amount of crude oil. As oil reserves are limited we should be obliged to look elsewhere for sources of liquid fuel. Rocks known as oil shale, of which the world has large resources, contain much oil. These rocks when subjected to varying degrees of heat yield the various products now derived from liquid petroleum. Such products, however, are not so cheap as when obtained directly from crude oil. Leading experts of petroleum believe that all the oil we need for 2000 years can be obtained from our reserves of coal at a cost not much greater than we are now paying.

Management of Iron Ore

Ours is an Iron Age in which we cannot live without using vast quantities of iron. This metal differs from coal and petroleum because it can be used more than once. Old bridges, locomotives, steel ships, automobiles and many other iron products yield large quantities of iron, which can be used again. The junkman by gathering up iron waste helps to make our supply of iron last longer. Japan, Italy and some other countries, which are poor in, iron ore, import scrap iron for their heavy machine industries. Rust is the great enemy of iron. The prevention of rust seems to be the best means of conserving our supplies of iron and steel. Similarly all the minerals, metallic or non-metallic are to be conserved.

Management of Human Resources

The greatest resource of a country is its people. The health and education of citizens is of far more importance than land, soil, forests, and water, mineral and power resources. Ill health brings sufferings, loss of employment poor efficiency and expenses. In cases of severe epidemic a whole region may be affected adversely. People with poor health cannot perform ordinary duties. One of the best methods to conserve it is by a proper and balance diet. It has been found that cleanliness brings health. Sewage and other waste must be properly disposed of.

Water, food, and air must be kept pure. A sustained growth rate of population8 can increase the standard of living of the people, which will ultimately increase man's health and efficiency.

Management of Global Climate Drift by managing natural resources/ ecosystems

Generally, global climate drift is due to over-use of fossil fuels and wrong exploitation of natural resources. The process, however, containable if vigorous action is taken right away. Grantham (1989) proposed the following ten steps to control the global climate drift:

- Increasing natural photosynthesis
- Starting engineered photosynthesis
- Augmenting $CaCO_3$ sedimentation
- Managing wetlands
- Sequestering water
- Reclaiming deserts
- Limiting animal husbandry
- Burning hydrogenated fuels
- Developing renewable energies and
- Creating an evolutionary population plan

Tropical countries can avoid the excessive CO_2 emissions and may adopt the remedial measures, which are needed anyhow to improve the biosphere, that is, those favourable to its long-term stability and vigor.

Some immediate steps to take i.e. All CFCs must be phased out and all substitutes should be given rigorous scientific scrutiny for possible contribution to the greenhouse drift as well as to ozone destruction10. Coal and petroleum can be replaced by natural gas, and hydrogen can be added to natural gas.

Subsidizing the petroleum and nuclear energy enterprises should stop; instead eolian, hydrogen and solar energies should be developed. These energies have been disadvantaged so far through lack of research and developing funding. Forest destruction must be halted and reforestation started. Mangroves, reef corals and deep-sea corals should be surveyed for extent, productivity, and state of health and possibilities for improvement.

The Earth is overpopulated in the sense that renewable resource cannot underwrite present human numbers and life-styles. We have overshot with technological development so that the resources of other peoples and future generations can only maintain the industrialised part of the world. Therefore, we need to research technological solutions for possible use to avert a massive population crash within the next century. The biosphere is sick and requires aerotherapeutics measures in order to survive.

The global heating process is already engaged and we cannot stop it in the near future11. Indeed, thermal inertia is protecting us now by retarding the effects of trace gas build-up, but this same inertia will insure continued perturbations for centuries, even after correction becomes efficient.

References

1 World Disasters Report-1999, International Federation of Red Cross and Red Crescent Societies.

2 Manual on Natural Disaster Management in India, 2001. NCDM, IIPA Publication.

3 Mishra, P.K. 2004, The Kutch Earthquake 2001, Recollections, Lessons & Insights. NIDM Publication.

4 High Powered Committee Report, 2001, NCDM, IIPA Publication.

5. Government of India-Planning Commission (September 2001): Report of the Working Group on Watershed Development, Rain fed Farming & Natural Resource Management for the Tenth Five Year Plan (2002-2007).

6. Satendra & A.D. Kaushik, 2003, Water Resource Management for Disaster Mitigation. Indian Journal of Public Administration, Vol. XLIX, No.3, July-September 2003.

7. National Forest Policy, 1988. Resolution No. 3-1/86-FP, dated 7th December, 1998, Ministry of Environment and Forests, Department of Environment & Forest & Wild Life, Government of India, New Delhi.

8. Human Development Report, 1999 & 2000 UNDP.

9. Grantham, R., 1989. Approaches to correcting the global greenhouse drift by managing tropical ecosystems. Tropical Ecology, 30 (2) : 157-174.

10. UNEP (United Nations Environment Programme), 1987.The Ozone Layer. UNEP, Nairobi.

11. Schneider, S.H. 1989, The Greenhouse effect: Science and Policy Science 243: 771-781.

3

Traditional Environmental Wisdom and Disaster Risk Reduction

Experiences from Terai of Eastern Uttar Pradesh

Shiraz A. Wajih

Background

Eastern Uttar Pradesh is among the most naturally bountiful regions in the country, with a plentiful availability of underground and surface water. Rivers and streams issuing from the mountains have, over time, carried and deposited precious silt in these plains, which has made the land here extremely fertile. Consequently, the region is inhabited with a high population density.

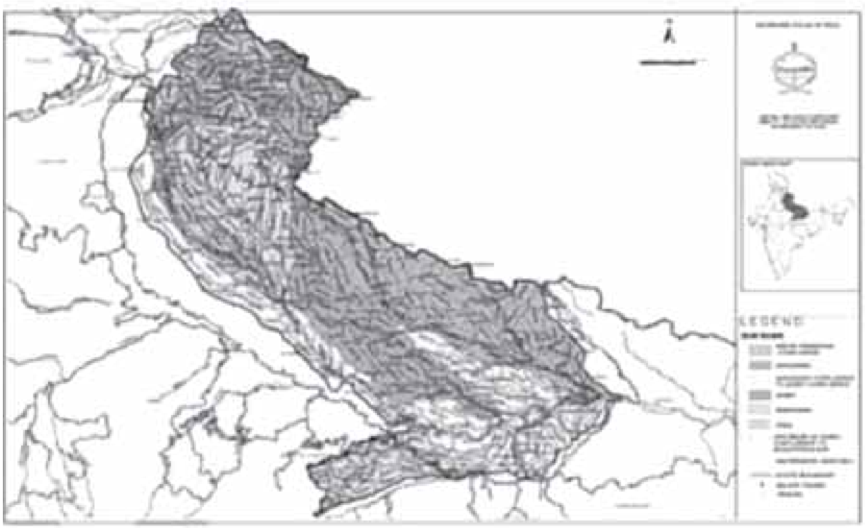


Figure 1: Map of Upper Ganga Region

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

But large parts of eastern Uttar Pradesh are also poverty-stricken and flood-affected. In a region where agriculture on small holdings is predominant, floods have caused extreme devastation. However, floods have been a natural phenomenon here. With the gradient of the land being very gentle and the current of the river water not so swift, seasonal water retention over land for short periods has always been there. It is only that, over the last several decades, changes in the pattern, character, duration and extent of floods have brought untold misery to the people, had an adverse effect on agriculture, health and livelihood of the people, caused loss of life and property, decreased the productivity of the land and worsened the state of water retention into a problem of water-logging.

Effectively, the flood related changes observed in the region are :

- Change in time, volume, pattern, etc. of rain.
- Increasing frequency of flash floods resulting in fissures in or collapsing of embankments.
- Smaller rivers and streams becoming a major cause for floods.
- Decreasing lakes and reservoirs and their decreasing capacity to hold large volumes of water.
- Increasing duration of water-logging.

Government and development organizations have tried to deal with the situation, but their initiatives have been more relief oriented and short period targeted. As a result, there have been no long-term solutions to the people's problems nor have such initiatives had a positive impact on the people's coping mechanisms and capacities.

On the other hand, over centuries, local people have developed their own ways and means to deal with floods. These measures and techniques are local specific, require no external help or support and are inherently scientific. These ways and means have shaped the people's lifestyles in these regions and strengthened their adaptive capabilities.

Today, such adaptive capabilities of the local communities are being seen as extremely important in dealing with problems of flood, water-logging and climate change. However, it must also be realized that the people's local adaptive ways and means have by and large remained confined to the respective local areas, and have not been documented for wider dissemination, use and benefit.

There are range of activities undertaken by the communities with the help of available traditional wisdom. The small holding farmers and women farmers are particularly rich in such traditional wisdom with which they are able to coop with the environmental changes and disaster impacts. It is needed that such practices based on local knowledge are documented and shared for the benefit of farmers struggling with such problems in the flood affected areas. The sharing of these various local and traditional flood responsive ways and measures, with people over a larger area in will help to build and strengthen their adaptive capabilities and capacities in tackling disasters like floods and thereby mitigating their impacts.

Environmental change, adaptation and local wisdom

Every year, floods affect a large part of the country. But whereas earlier, floods came and receded as a natural phenomenon, today these are becoming more unpredictable and damaging. There is increasing loss of life and property as also an increasing extent of water-logged and submergences areas. In the region that is agriculture predominant, it is the farmers whose livelihood and very survival is dependent on land and hundreds of related work that are the most affected. Crops and houses get submerged in flood, health problems become acute and water-logging seriously delays and affects the next crop. Options and opportunities for work and labour decrease and the multi-pronged problems make the community extremely vulnerable.

It has been seen that a community's adaptive capacities are affected mainly by

- The state of natural resources in the area.
- The livelihood system and opportunities at the local level.
- Income generating opportunities outside, in the nearby areas.
- Basic physical infrastructures, services and facilities like roads, housing, drinking water, etc. at the local level.
- The area's socio-economic and gender sensitivities.
- People's accessibility to information and know-how.
- Social capital in the community, such as the existence of social infrastructures as well as networking with government and formal sector organizations like bank, government departments, voluntary organizations, etc.

As such, in order for people to deal better with floods and their changing character, one of the ways is to build people's adaptive capabilities through raising their awareness, knowledge base and capacities to earn a living through a selection of appropriate crops and techniques. This is essential, but as much a challenge. The traditional wisdom is effective in developing capacities of the community particularly by improving various aspects of resilience, like:

- Redundancy
- Responsiveness
- Flexibility and Diversity
- Enhancing the capacity to learn

The practices based on local knowledge broadly address all these parameters.

However, one needs to differentiate between local wisdom and myths. Hence, it is important that the local knowledge is integrated on scientific base. This integration of science and local knowledge (Fig. 2) builds up knowledge which help people to adapt to local flooding situations

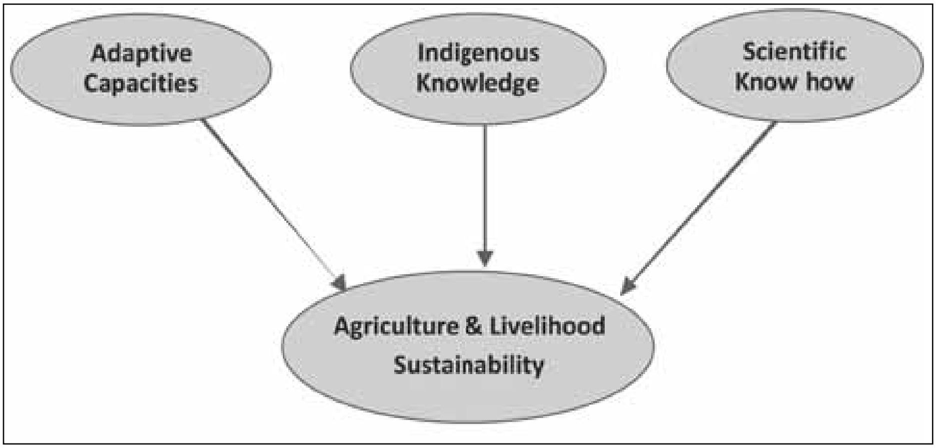


Fig 2 : The synergy of local knowledge and Science helps in developing adaptive capacities

Environmental Change And Floods In Uttar Pradesh

The geography of eastern Uttar Pradesh makes the region naturally sensitive to floods. Spread along the terai region, there is a wide network of rivers, which originate in the mountains of Nepal and are known for their inordinate temperament. Heavy rains in Nepal result in a sudden rise in water level in rivers here. The rushing waters from the mountains slow down and spread out on reaching comparatively gentle gradient of the slopes and the low lying land in purvanchal and induce water retention which becomes a menace as flood. Changes in the climatic conditions have only worsened the problem. In the last several decades, the ferocity and frequency of floods in purvanchal has considerably increased, recurring every 3-4 years. At places, it has even become a regular, annual feature, which greatly affects the livelihood of the people. The people inhabiting the flood-affected regions attribute this to climate change.

Indeed, the climate of eastern Uttar Pradesh has undergone a definite change in the last few years. For example, it has now become normal for the temperature to cross 45 degree C and remain so for long periods during the summers. Such temperature rise causes rapid melting of glaciers which is increasing the water level in the rivers.

On the other hand, there has been a significant change in the monsoon period. The timings of rain have become very unpredictable. While earlier, August-September was the usual period of flood, today it is not. In 2007, there were heavy rains in July itself causing sudden floods here, for which the people were ill prepared, had very little time to respond and there was considerable loss of life and property.

The principles of livelihood resilience in flood-affected regions

Today, the effects of increased frequency and ferocity of floods are being felt at some level or the other every month during the monsoon period (July-September). At such time, everyone from the government to organizations and the public tries to help the affected people, and every other work comes to a virtual standstill.

But with the receding of floods, individuals and agencies that were hitherto working for the flood-affected people soon return to their respective routine jobs, and the extensive destruction of the people's basic resources and infrastructures in floods are left unattended or the intensity and pace of attention gets slow. The people themselves too, bearing their losses, seek to return to their normal lives as soon as possible with whatever resources they are left with. Remarkably, there is no wide scale migration and people continue to inhabit these regions and learn to live with floods.

In order to understand why and how it is so, we sought to analyze the practices people have adopted, and found how these practices underline the people's livelihood resilience in flood affected regions. In these collected practices, we find that there is a strong element of people's indigenous knowledge. Neither the government nor non-government nor private organizations have been able to develop and provide technical know-how for people to survive in disaster prone areas. In fact, at times, external, alien knowledge or know-how tends to even mislead the people. People solely survive on the strength of their traditional knowledge and their ingenuity. From these collected practices, it is apparent that people ingenuously use a mix of their local and externally gathered knowledge, as required.

People's indigenous technical knowledge is very rich, as can be seen in their practices of treatment of sick cattle, seed preservation and storage, seed improvement, grain storage, house construction, water purification, etc. This knowledge together with their generational experience and memories enables many people to anticipate events, make accurate forecasts and prepare themselves accordingly.

It has been observed that the following factors have helped the people's resilience capacities and in all such factors local knowledge plays a crucial role:

Adaptation

The effects of environmental changes - irregular flow in rivers, irregular rain and impractical external measures to prevent floods (embankments, canals, drainage, etc.) have exacerbated the havoc from floods. Yet, by accepting natural disasters as inevitable, the people living in disaster-prone areas have integrated these into their lifestyles, and always evolved rapidly and imbibed indigenous ways and means to get over their flood problems. This has not only helped reduced the impact of disasters but also considerably helped secure people's livelihood.

Certainly, people's livelihood resilience depends a great deal on how well the community uses the available resources through its adaptive strategies. It has been seen that the community that is rapidly able to adapt itself to the changing character of disasters, faces must less erosion of its livelihood. It may not be an exaggeration then to say that people's livelihood resilience and their adaptive capacities are dependent on each other.

Intensification

The more intensively people in flood-affected regions practice adaptive strategies and activities or the more conducive the situations are to the adaptation of these strategies, the more easy it becomes for the people to return to their normal lives once the floods recede. Though floods have a drastic effect on the people's activities, they are still able to recover some harvest or income. Take sugarcane for example. Despite the occurrence of floods and the sorry state of the sugar-mills in the region, people use their knowledge and skills to produce and sell jaggery and find a way out by growing hemp and vegetables like okra.

By way of adaptive strategies for livelihood, people have adopted both agricultural and non-agricultural practices, which can be classified as pre-flood, during flood and post-flood, and are as follows:

- Fuel collection and storage
- Fodder collection and storage
- Grain and seeds collection and storage
- Selection and storage of seeds of quick growing crop varieties
- Vegetable growing
- Agricultural work and labour
- Animal husbandry
- Afforestation
- Employment generating small business/industry, organization development and community initiatives and seeking government facilities and services
- Fish catch and sale
- Short-term migration, sand dredging and sale.

Diversification

Looking at the various activities compiled, it appears that the flood-affected region is richly biodiverse. There is a tremendous diversity of crop varieties, trees, plants, grass and animals, besides people's knowledge, experience, skills and enterprises. The landless are able to make a living on small and useful animals and plants or temporarily migrate in search of employment. When silt and sand spreads over paddy fields, people learn to grow watermelons, gourds and other appropriate vegetables and fruit. Indeed, this diversity forms the basis of people's livelihood as well. So, be it in agriculture, labour work, animal husbandry or other employment, during the floods and post-flood scenario, people adopt different measures and activities that they can afford and which suit their skills.

These various activities can be classified as:

- Agriculture Mixed farming, subsidiary farming vegetables, fruit, spices, etc.
- Animal husbandry Milch cattle, poulty, duckery, sheep, goatary, fishery.
- Employment Farm labour, brick kiln, short-term migration, construction labour, door-to-door product selling, and sale-purchase of grains.
- Fuel Wood, crop residue (mustard, pigeon pea stalks), dung fuel, hay, dry leaves, sugarcane residue, etc.
- Fodder Hay, green fodder, nitrogenous plants, coarse grains like millet, maize, sorghum, etc.

The farmers have made their farms floods resilient through integration of various farm sub systems. The traditional agricultural practices comprised of this integration amongst farmers households, the live stock, farm and kitchen garden. The flows amongst various farm sub systems on one hand enriches the recycling of inputs within farm system and hence reducing the demand of external input costs, at the same time the robustness of farm systems provides greater resilience capacity to the farm in the event of floods. Fig. 3 shows the example of flows in one small landholding farm. The adopted approach is based on the science of recycling of resources and energy and the increase of diversity and complexity.

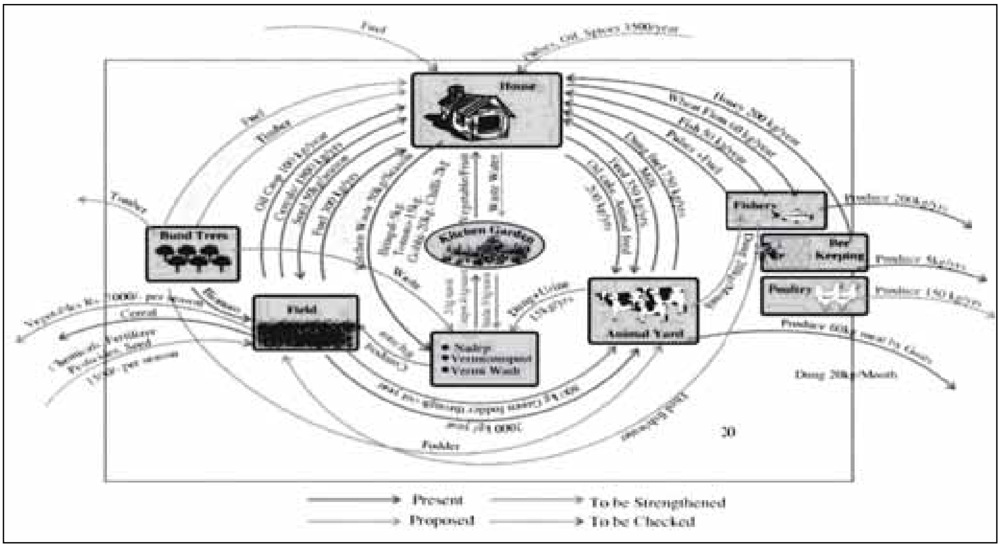


Figure 3 : The resource flows amongst various farm sub systems in the farm of a small farmer of Gorakhpur

Value Addition

Value addition enhances the use and price of a product. The people of the flood affected region are aware of this, but lack marketing facilities. For instance, the local women groups are engaged in giving value addition to various products from paddy, milk, vegetables, etc. People in the area also prepare jaggery and other by-products from sugarcane or even manufacture sugar. The possibilities are immense, but due to lack of resources and information, the initiatives by farmers remain improperly or incompletely harnessed.

Marketing

Market is emerging as an important factor in people's livelihood accretion and resilience. People in flood-affected regions have poor access to market, and though they are able to sell products like jaggery from sugarcane, khoya from milk, vegetables, fish, brooms, etc., they do not get appropriate price for their products, while middlemen corner most of the profits. Because of market distances, lack of transport, meagre production, the people's own, immediate monetary needs for their basic requirements and the fact that they are unorganized, forces the people to sell their products in the villages itself.

Collective Action

It is obvious that people realize the strength of unity and collective action, particularly for livelihood sustenance in the face of grave problems in the flood-affected regions. People have collectively repaired embankments, constructed bridges and culverts, removed silt and sand from the fields, organized themselves into a "Livelihood Rights Association" to rally, demonstrate and even sit-in on protests for their demands of livelihood. repaired embankments, constructed bridges and culverts, removed silt and sand from the fields, organized themselves into a "Livelihood Rights Association" to rally, demonstrate and even sit-in on protests for their demands of livelihood.

The paper is based on the documentation of community practices helping them to coop with the floods in eastern Uttar Pradesh, conducted by Gorakhpur Environmental Action Group and local NGOs

4

Environmental Management for Coastal Hazard Mitigation

Shailaja Ravindran

Introduction

"Around the world, a growing share of the devastation triggered by 'natural' disasters arises from ecologically destructive practices. Many ecosystems have been frayed to the point where they are no longer resilient and able to withstand natural disturbances, setting the stage for 'unnatural disasters' – those made more frequent or more severe due to human actions. By degrading forests, engineering rivers, filling in wetlands and destabilizing the climate, we are unraveling the strands of a complex ecological safety net" - Abramovitz (1).

This statement reflects on our limited knowledge of the environment that we are living in , the ecological processes and services that they deliver in reducing the hazard risks. A study, conducted by the scientists at the University of Delhi, India and Duke University has shown that coastal villages in Orissa with the widest mangrove belts suffered fewer deaths, compared to those with narrower belts or no mangroves in the devastating super cyclone of 1999. Their statistical models suggest that without mangroves, villages within ten kilometers of the coast would have suffered an additional deaths. "Statistical evidence of this life-saving effect is robust" and remains "highly significant" even after taking into account other environmental and socioeconomic factors, the report says. (2)

It is important therefore to understand the coastal environment and the unique ecosystem services they deliver to perceive the impact in reducing the risks of coastal communities to the coastal hazards and development at large.

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

Coastal Environments (4)

Near-shore :	Dunes, cliffs, rocky and sandy shores, coastal xeromorphic habitats,
Terrestrial :	Urban, industrial and Agricultural landscapes
Intertidal :	Estuaries, deltas, lagoons, mangrove forests, mudflats, salt marshes, salt pans, other coastal wetlands, ports and marinas, aquaculture beds
Benthic :	Kelp forests, sea grass beds, coral reefs, and soft bottom environments above the continental shelf, artificial reefs and structures
Pelagic :	Open waters above continental shelf, freestanding fish farms: e.g. plankton blooms, neuston zone, sea ice herring schools

Figure 1 : Orissa Super Cyclone 1999

Understanding the coastal environment

There is no precise definition for coastal ecosystem. Millennium Ecosystem Assessment has considered areas falling under less than 50 meter depth on the seaward side to the coastline and to a maximum of 100 kilometer or 50 meter elevation landwards from the coastline (whichever is closer to the sea) . The line which separates the water and the land is a coastline. However, it is difficult to draw a precise line that can be called a coastline due to the constant tidal action.

The term "coastal zone" is a spatial zone where the processes of interaction between the sea and the land occur. The Millennium Ecosystem Assessment (MEA) report defines the coastal zone as a narrower band of terrestrial area dominated by ocean influences of tides and marine aerosols. However, the term coastal zone is used more in the context of coastal management and therefore its definition differs from country to country.(3)

Coastal ecosystems are unique because land and water meet here to create an environment with a distinct structure, diversity and flow of energy. They encompass a diverse array of habitats than any other ecosystems .Coral reefs, mangroves, tidal wetlands, sea grass beds, barrier islands, estuaries, peat swamps, and a variety of other habitats - each provides its own distinct bundle of goods and services . Due to the array of habitats coastal ecosystem is home to many different species of plants and animals. Habitats also interact within themselves and are dependent on one another (4).

About 18% of the surface of the globe is said to be the coastal zone with 1.6 million kilometers Coastline. Around the world 123 countries are endowed with coastline. Many of the coasts are becoming increasingly urban. Two thirds of the world cities are coastal cities with 14 of the world's 17 largest cities located along coasts. Eleven of these cities, including Mumbai, Bangkok, Jakarta, Shanghai are in Asia. According to an estimate nearly 40% of the global population lives in the coastal zone, and that 20% population lives within 25 km; 29% within 50 km and 39% within 100 km (5).

Coastal hazards and vulnerability

Coastal hazards are generally natural and hydro meteorological in nature (atmospheric, hydrological or oceanographic). They include floods, flash floods, debris and mud floods; tropical cyclones, storm surges, torrential rains and wind storms, tsunami; coastal erosion; harmful algal blooms; submarine mudslides; hazards due to global climate change such as sea level rise, surface sea temperature rise, frequent storms. Coasts are also subjected to human induced hazards like pollution due to industrial and domestic effluents, oil spills.

Figure 2 : Flash floods

The magnitude of the impact of each hazard are different in terms of the duration of an event and its impact on life and property . While some hazards like tsunami and storm surges are short-lived, each event has a high impact per unit time. They cause considerable damage in the shortest time. However, the frequency of occurrence of an event like tsunami is low along the Indian ocean. Other hazards like coastal erosion, pollution occur over a long duration. Hence they are not events but processes. The impact per unit time is low. Any damage they cause occurs gradually and in an incremental fashion. Short-duration, high-impact events are easily recognized and registered . Persistent cumulative effect of processes like pollution usually have greater impact over a longer period of time than that of the high-impact events.

Figure 3 : Storm surge impact

Some hazards like harmful algal blooms may not cause fatalities, but affect health thereby affecting normal life and the economy. Some hazards like sea level rise may not cause loss of life, but have the potential for disrupting life . Coastal erosion will not cause loss of life but has a serious impact on settlements, livelihood and the infrastructure along the coastline.

It is necessary to identify the type of hazard to determine the type of threat. Information on the frequency of their occurrence, spatial distribution and magnitude of impacts associated with them will help in analyzing these hazards. Hazards may turn into disasters disrupting life , causing widespread damage/losses to life , livelihood and property like the recent Asian tsunami (2004), the super cyclone of Orissa in the eastern coast of India (1999). Most of the coastal communities, particularly in the developing countries do not possess adequate capacity to cope up with such extreme events due to various factors and so are vulnerable to hazards. These factors may be geographic (slope, elevation, shoreline features);climatic (temperature increase); demographic (population, gender, age, density); social (literacy and education, insurance, health); economic (livelihood, property);physical (houses , road, bridges , cyclone shelters, transport and communication systems); environmental (availability and quality of natural resources, quality of ecosystem services); developmental (Type of developmental activity , location , process followed) in nature and contribute to the vulnerability of the coastal communities to hazards. In the recent years there is immense interest to understand the relationship between the environmental factors and coastal hazards because numerous studies have shown that a sound environmental management will strategically improve and strengthen the coastal hazard mitigation plan.

Contribution of ecosystem services to coastal hazard mitigation

Ecosystems as we all know is the complex interaction between the organisms including the humans and their physical environment such as water, soil. As mentioned earlier , coastal ecology is distinct and offer multiple services that benefit people, other living organisms and the physical environment as well. These services can be grouped into five categories;

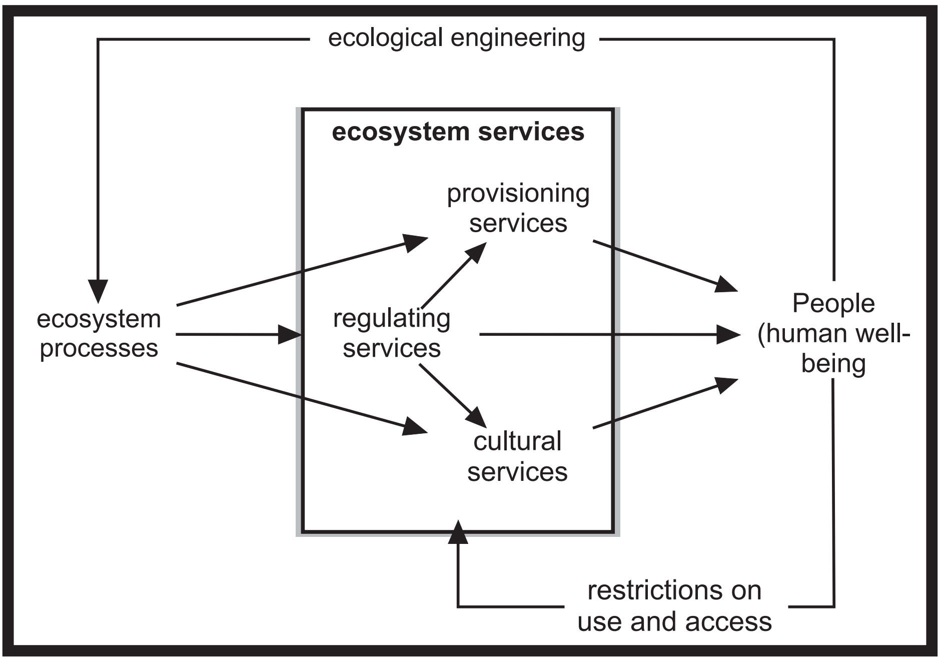


Figure 4 : Diagram representing ecosystem services (3)

provisioning such as the production of food, fuel fodder, medicine, fuel; regulating, such as the control of climate ,floods , storm surges, disease; supporting, such as nutrient cycles and crop pollination; cultural, such as spiritual and recreational benefits; and preserving, which includes guarding against uncertainty through the maintenance of diversity (3).

A preliminary estimate of the total economic value of ecosystem services showed that covering only 8% of the world's surface, coastal zone provides goods and services of approximately 43% of the estimated total value of global ecosystem services which in economic terms amounts to more than 12.6 trillion USD (3). However, the value of the ecosystem services cannot be fully quantified. Most people perceive ecosystem services as free and do not value them.

Ecological services (5)

Productivity	:	A quarter of global primary productivity and around 14% of global ocean production comes from coasts
Fish catch	:	Approximately 90% of world fish catch
Other services	:	Up to 50% of global oceanic denitrification ; 80% of the global organic matter burial ; 90% of the global sedimentary mineralization ; 75-90% of the global sink of suspended river load and associated elements/pollutants ; > 50% of present day global carbonate deposition

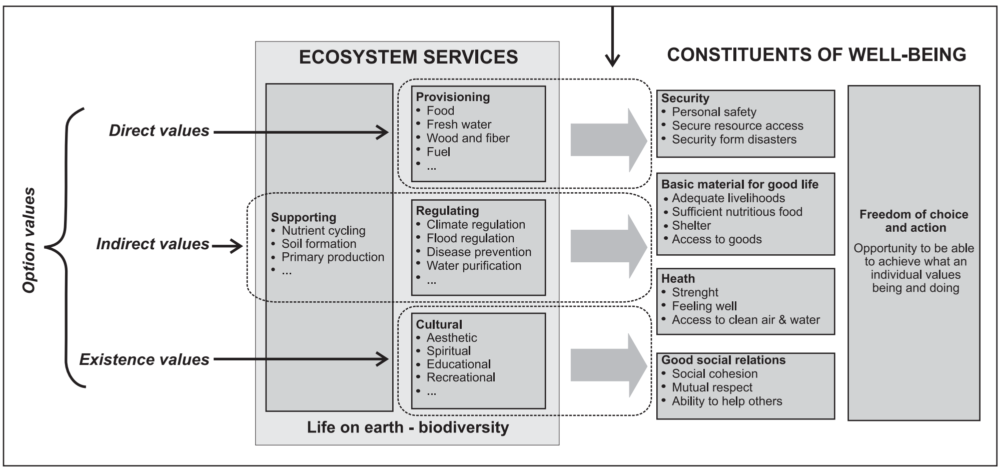
Important coastal habitats such as coral reefs, estuaries, marshes, lagoons provide direct benefits like food (fish, crustaceans, mollusks, seaweeds), clean water (shallow aquifers, surface fresh water), fuel and timber (mangroves and other coastal vegetation). They open up a wide variety of livelihood opportunities like fishing, tourism, aquaculture for the coastal communities, improving their socio- economic conditions thereby. They also provide services like pollinating the crops, maintaining nutrient balance in the soil, supplying clean water and so on thus help indirectly in the improvement of socio economic conditions. Improved socio economic conditions decrease vulnerability to disasters.

Figure 5 : Sea grass

However, regulating services play a direct role in reducing the vulnerability . For instance, climate regulation is one of the most important services to combat climate change. The major greenhouse gas (CO2) is absorbed by water and vegetation, leading to storage in biomass, soil and water. Other greenhouse gases, methane (CH4) and nitrous oxide (N2O) in particular, are also regulated by soil microbes. They regulate the hydrological cycle and control soil erosion. Photosynthesis process by the coastal vegetation and by the sea weeds gives out oxygen and help balancing the atmospheric gas concentration thereby. Wetlands hold flood waters and reduce damage by flooding. Coastal vegetation, notably mangroves and coral reefs act like speed breakers and lessen the effect of coastal storms and extreme tides. Mangrove forests also play a key role in stabilizing land by trapping sediments, cycling nutrients, processing pollutants, supporting nursery habitats for marine organisms besides providing fuel wood, timber, fisheries resources for coastal communities. Sand dune systems act as sediment reserves, stabilize coastlines and reduce the wind speed to some extent. Seagrass that usually colonize soft-bottom areas of the oceans from the tropics to the temperate zones play a notable role in stabilizing shorelines and sand dunes (Appendix A).

Changes in the coastal ecosystem

In the past 50 years the coastal ecosystem have been significantly transformed by both natural and anthropogenic factors. These factors have brought in one change or series of changes directly or indirectly in one habitat or several habitats in the coastal ecosystem and have even had cascading effects. For instance, natural factors like wind, wave action have induced coastal erosion but this process has happened over several years and it has been slow. The global trend shows that the anthropogenic factors seem to have contributed to the rapid changes towards degradation in the coastal ecosystems that have been observed in the recent years.



Source: Ecosystems and Disaster Risk Reduction working paper to the global Assessment Report – Prepared by ited Nations Environment Programme and Stockholm Resilience Center; 28 September 2008

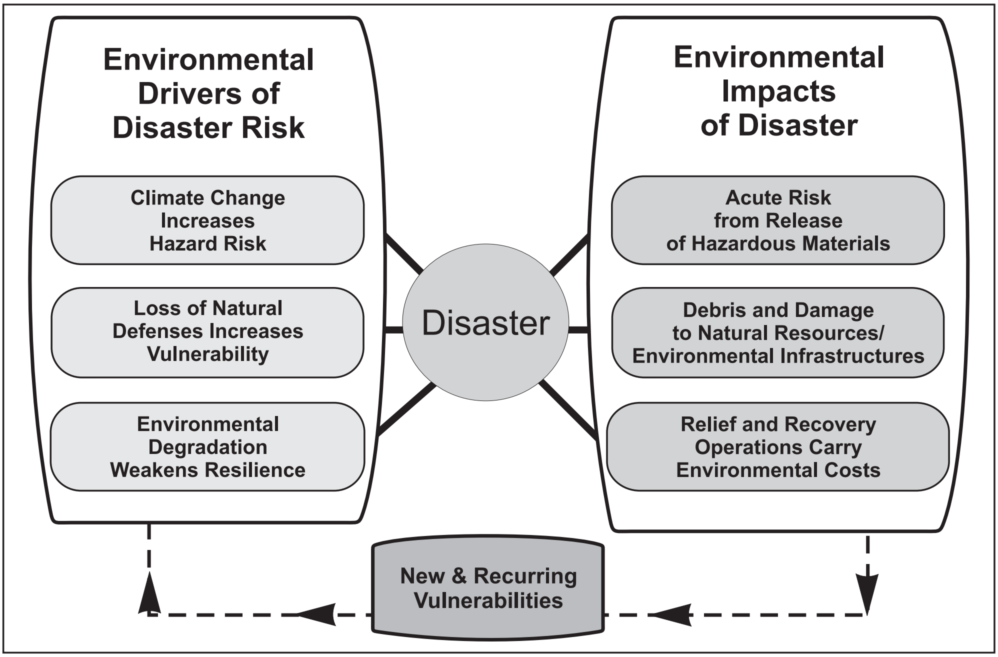
> **Natural coast guards**
>
> Chinnoorpettai is a hamlet (Nagapattinum in Tamil Nadu) barely 150 meters from the high tide line. Situated on a large sand dune it has a wall of high sand banks on the shore side. Loss was less and deaths were fewer (11 for 260) in the recent tsunami (2004) despite being so close to the sea and high waves of tsunami. Most houses on the elevated location (4.5 – 5 meters) were undamaged and relatively safe. Communities believe that elevated location and sand dunes are the main reason for this low damage. Studies in Tamil Nadu and Pondicherry area have shown that areas with sand dunes had less inundation compared to areas with vegetation cover.
>
> **Source :** Naveen Namboothri et al.,Policy Brief : Sand dunes, UNDP /UNTRS and ATREE, Bangalore, India 2008

Coasts are the hub of multiple economic activities and hence there is a major commercial interest in the coastal development. As a result ports, tourism, industries, destructive fisheries (dynamite and cyanide use, bottom trawling), destruction of mangrove and coastal vegetation, mining (sand, coal, minerals), aquaculture, infrastructure (buildings, roads , transportation) , urbanization are booming, contributing to the habitat shrinking, loss and conversion to support commercial activities. As a consequence, there is an increase in the levels of eutrophication, pollution, salinization of estuaries; sea level is rising due to climate change; exotic species are invading threatening the coastal biodiversity. With the overexploitation of coastal resources like fish, coastal vegetation, minerals including sand, the pressure on the resources are swelling. With the habitat loss, degradation and overexploitation of coastal resources, the coasts are fast degrading reducing the capacity of the ecosystem to render the ecological services . This has increased the vulnerability of the coastline making the coastal communities more vulnerable to hazards, besides impacting their livelihood . PIC 4

Environmental management for the hazard mitigation

The relation between environment, development and disasters is hardly disputed. Environmental management actually functions as risk management. However, understanding of the multi-dimensional role of environment, the inherent relationship between coastal environmental management and hazard mitigation that

- Hazards / Natural hazards are physical processes that can be directly affected by social processes. For instance, pollution, global warming due to increase in anthropogenic green house gases;
- Healthy ecosystems often provide natural defenses;
- Degraded ecosystems reduce community resilience;
- Environmental degradation is a hazard in itself;
- Environmental impacts can result in serious risk to life and livelihoods if not addressed; is still a key challenge. Hence there is confusion and a lack of clarity with regards to approaches and mechanisms for mainstreaming disaster risk reduction in coastal management . This being the case, focus on research and policy measure is limited. While it is often recognized that ecosystems are affected by disasters, it is forgotten that protecting ecosystem services can both save lives and protect livelihoods Hence the intriguing concept of using environmental tools for disaster reduction has not yet been widely applied by many practitioners (6).



Ecosystem approach to the coastal hazard mitigation

In recognition of the value of coastal ecosystem services in providing protection against coastal hazards including that of climate change impacts, the ‘ecosystem approach’ to manage the coasts is emerging globally. With its diverse habitats posing variety of management challenges, it is believed that the protection of coastal ecosystems and sound environmental management today are the major and the most cost-effective disaster risk reduction measures, and is a positive way of looking at development. The appreciation of ‘the ecosystem approach’ for the coastal management comes from the fact that it views ecosystem as ‘central’ to decision making and planning. It integrates environmental concerns in to developmental planning. It takes into account the factors that drive change and their impacts on the ecosystem. Several experts are of the view that ecosystem approach is effective in sustaining the ecosystem services and maintaining safe coasts, and therefore of great relevance to coastal managers.

Ecosystem Approach evolved during United Nations Conference on Environment and Development (UNCED, 1992) in the UN Convention on Biological Diversity (CBD). There are 12 principles to the ecosystem approach (Appendix B) which have been organized into five steps, each step involving a range of actions (7).

The five steps to the implementation of the ecosystem approach are as follows:

i. Determining the main stakeholders, defining the ecosystem area, and developing the relationship between them;

ii. Characterizing the structure and function of the ecosystem, and setting in place mechanisms to manage and monitor it;
iii. Identifying the important economic issues that will affect the ecosystem and its inhabitants;
iv. Determining the likely impact of the ecosystem on adjacent ecosystems;
v. Deciding on long-term goals, and flexible ways of reaching them.

Ecosystem approach to hazard risk addresses all the three measures viz., prevention, mitigation, preparedness. They promote both structural and non structural activities. For instance, structural measure in coastal areas can be any physical construction including engineering techniques to achieve hazard-resistance or reduce / avoid possible impacts of extreme events involve disaster resistant housing, cyclone shelters, dykes, sea-walls, tidal barriers, detached breakwaters .

Non-structural measures are those which do not involve physical -construction related activities. These measures may include soft structures like dune or wetland restoration or creation, beach nourishment, greenbelts, biodiversity conservation. Development of legislation for coastal protection, research and monitoring of coast and coastal ecosystems, economic incentives for habitat protection and benefit sharing, awareness and education, use of traditional knowledge are also some of the non structural measures. Thus there is a wide range of coastal protection measures. Each of these measures perform a number of different functions. However, they should take into account the social, economic and environmental considerations, thereby promoting sustainable development. Depending on the situation, a combination of hard and soft measures can be adopted. Ecosystem approach also helps to reduce the climate risks and reduce the vulnerability. For instance, coastal green belt is a measure to reduce the coastal vulnerability . While it reduces the impact of the storm surges, it will also reduce long-term soil degradation, help control local temperature and rainfall, and is a sink to CO2. (Appendix C)

Disaster Risk Reduction aims at building safe societies through disaster prevention, mitigation, preparedness.

Prevention measures promote ‘activities to provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological and biological disasters’. For instance, land use planning, canal desilting, safe structures.

Mitigation measures promote activities to prevent or reduce impacts of a catastrophic event prior to its occurrence such as land use planning, changes in cropping pattern , sand dune conservation, building codes and public education.

Preparedness measures promote activities to improve the effectiveness of response and recovery such as establishing warning systems, connectivity structures, cyclone shelters, developing risk assessment plans and storing emergency supplies. (8)

Integrated Coastal Zone Management (ICZM) which evolved in 1992 during the Earth Summit of Rio de Janeiro (UNCED), gives adequate focus to the issues of environment . According to UNEP (1995) ICZM is “An adaptative process of resource management for environmentally sustainable development in coastal areas….” . IPCC (1994) believes that ICZM is “the most appropriate process to address current and long-term coastal management issues, including habitat loss, degradation of water quality, changes in hydrological cycles, depletion of coastal resources, and adaptation to sea level rise and other impacts of global climate change”(9). In order to pursue the sustainable development of the coastal zone, ICZM integrates at least five different dimensions – the sectors, the levels of government, the land-water interface, various disciplines and the nations. Several coastal countries such as Srilanka, China, Bangladesh, Indonesia, Thailand, Philippines, USA are therefore trying employ ICZM plans for their costal management. With fair amount of success in the ICZM implementation, the national parliament of Indonesia is now considering this law.

Knowing bio-shields better

There are considerable debates on the effectiveness of bio-shields in protecting the coast , particularly habitations. The concept of coastal plantations to protect the coasts probably started in the late 1960s In India. Dominated by casuarina, the raising of bio-shileds or the coastal shelterbelts started in Tamil Nadu. Several scientific studies have reported that the coastal vegetation like mangroves and others did provide protection from tsunami. However, several other studies criticized these findings. These studies reported that the impact of tsunami was topography dependent and that other features contributed to the protection.

Despite the inconclusive arguments, there is a huge drive to initiate the large scale plantations along the coast in India, especially after tsunami. Communities want a clear view of the coast as it is crucial for fishing activity like understanding the weather, sighting of shoals, fish landing , drying, auctioning and so on. To help these fishing communities, bio-sheilds in many places are planted either behind or on the either side of the hamlet. Experts are of the view that plantations on the either side of the hamlet will make the village more vulnerable due to the funnel effect (wind blocked by the plantations and channelized to the hamlet).

However plantation also have co benefits . For instance , according to forest department in Andhra Pradesh, the economic returns from one acre of casuarina plantation was INR 60,000 (around 1500 USD). Besides, community also gets benefits like fuel wood and small timber. Plantations are also carbon-dioxide sinks and contribute to climate change mitigation in the long run.

Coastal vegetation may in combination with other factors act like coastal defence. However, their role as carbon sinks, soil binding, nitrogen fixing and socio-economic benefits define their important role in the coastal ecosystem. Promotion of mixed species plantations with indigenous species; with better defined community role along with a proper understanding of benefit sharing may help in socio-ecological resilience. It is a "no regret" option.

Source: Nibedita Mukherjee et.al , Policy Brief : Bioshields, UNDP /UNTRS and ATREE, Bangalore , India , 2008

Environmental Management for Coastal Hazard Mitigation : The Case of India

The rich Indian coasts

India's 8118 km coast line is endowed with variety of habitats such as mangroves, lagoons, marshes, beaches ,deltas ,mangrove , coral reefs, mudflats. The western coastline has a wide continental shelf and is marked by backwaters and mud flats. The Murmagao bay in Goa is one of the largest estuarine system on west coast. Cochin-Vembanad in Kerala is the largest estuarine systems in the country. East coast is low-lying with lagoons, marshes, beaches and deltas rich in mangrove forests . Coral reefs are predominant on small islands in the Gulf of Kutch in Gujarat, Gulf of Mannar in Tamil Nadu and on Lakshadweeep, and Andaman and Nicobar groups of islands. The area of reef is 2375 km.

There are 31 marine protected areas in India. Gulf of Mannar is the marine Biosphere reserve. Lakshwadeep has extensive lagoons and has the largest coastal backwaters in India. 350 islands in Andaman and Nicobar islands out of which 38 are inhabited; Lakshadweep archipelago has 36 tiny islands of which 10 are inhabited . The islands are volcanic in origin. There are 97 major estuaries and 34 major lagoons in the coastal zone . About 2,305,413 km2 area marked as the Exclusive Economic Zone enjoys the special rights over the exploration and use of marine resources.

Figure 6 : Waste disposal - Mumbai Coast

More than 5% of the world's mangrove vegetation is reported from India, the extent of which is 4500 km2. The mangroves of Sundarbans are the largest single block of tidal halophytic mangroves of the world. Coasts harbor rich and diverse life forms belonging to both land and water. In India are three major mass-nesting sites of the olive ridley sea turtle (Lepidochelys olivacea), all on the east coast, in Orissa; Gahirmata (a part of Bhitarkanika sanctuary) at the mouth of the river Maipura near Dhamra is the largest sea turtle rockery in the world with 100,000 to 500,000 turtles nesting there each year. Such is the richness of Indian coasts. (10)

The changing coasts

Significant changes in the coastal zone recorded in the recent years have only taken the coasts towards degradation. Closely following the global trend, human induced factors have taken the upper hand in plundering the coastal resources, accelerating the disturbance of the ecosystem services more rapidly than ever. The major anthropogenic factors are

Population pressure: Roughly around 25% population lives within 50 km of the coast line (2011 census). (11). This has resulted in uncontrolled development along the coastline with multiple competing economic sectors, like tourism, aquaculture, commercial fishing, expansion of salt pan areas, agriculture, oil and gas extraction, marine transportation, and real estate development.

Urbanization: Virtually all the mega-cities of India are located on the coast and are fast expanding

Boom in tourism: Coastal tourism is on the rise in India putting pressure on the coastal resources including space. It is a major threat in several coasts in India especially in urban coasts and beaches.

Paradise lost

Goa, on the Western Coast of India is indeed a place of tranquillity and a great tourist destination for the visitors from all over the world. Tourism is the most important component of state economy. From 2 lakh tourists in 1970's the tourist traffic in 2003 increased to 20 lakhs, which was more than Goan population of about 13.5 lakhs in 2001. Prior to 1970's, before tourism became a source of revenue, large plains behind the dune belts were used for paddy cultivation. Today construction of resorts, residential dwellings, commercial establishments, beach side entertainment centres – all these have changed the coastal strip drastically. Coastal areas are overcrowded resulting in over-urbanization. Increase in tourism and related activities have enhanced employment opportunities though, they have induced environmental and social problems.

Loss of Biodiversity, adverse effect on beaches and sand dunes, mangroves, water bodies and khazan lands have degraded the coastal environment and ecological services, deteriorating the quality of life and increasing the vulnerability of the Goan coasts to disasters. Realizing the environmental consequences along the coast, Goa is now shifting the developmental activities towards hinterlands, along rivers, backwaters and forest land as well as in the name of eco-tourism.

Source : goaenvis.nic.in/tourism.htm

Commercial harvesting : Coastal ecosystems will continue to be used both for commercial and artisanal fisheries. Experts feel that the current trend of harvesting is highly unsustainable. If it continues many of the fish stocks will be depleted . The fear is also that some marine species may even face the danger of ecological extinction. For instance, overfishing and destructive fishing methods, such as some forms of bottom trawling (use of heavy gear on sensitive substrates), dredging, use of explosives and fish poisons (like cyanide) , impact marine ecosystems by physically altering or destroying the systems or changing community structure and altering trophic and other interactions between ecosystem components. Environmental Science department of Andhra university has reported the vanishing of 70 species of fish by dredging in Gangavarm port in Vishaka Pattanam in Andhra Pradesh.

Aquaculture : Aquaculture also has serious implications on the environment. Degradation and removal of mangroves, salinization of adjacent lands, release of effluents into the surrounding waters, use of high quality fishmeal impacting the genetic diversity of wild fish populations , spread infectious diseases to wild fish populations are all the problems that India is facing today due to aquaculture. In view of the environmental and socio-economic impacts, the Supreme Court in 1996 ordered the closure of shrimp farms in coastal areas that were not permissible under the Coastal Regulation Zone (CRZ) 1991 Notification. (12)

Developmental projects : Mega projects such as ports, airports, oil refineries, major roads claim huge coastal space. This has added to the woe leading to habitat loss. Some of the coastal developmental programmes related to risk reduction like sea wall construction also have had serious environmental impacts. The effectiveness of such engineering structures is highly debated across the world. For instance, to overcome the growing problem of the beach erosion, the Government of Kerala has constructed sea wall along the coast. As a result, over the years, the sea waves impounding on the seawall has destroyed it, thereby littering these already strained beaches.

The sinking Sunderbans

Lohachara and Suparibhanga, islands in the Sunderbans have gone under waters - in to the history- before any one even knew of these islands. These are the first inhabited islands to sink into the swelling seas, say reports. So remote are these places that their disappearance was noticed only from the satellite pictures.The islands form part of the UN world heritage site of the mangrove forests, famous for the Bengal tiger, the endangered big cat species. Ganges and the Brahmaputra rivers emptied their waters here into the Bay of Bengal.

Source:1. Islands sinking in Sunderbans; Subhra Priyadarshini ; The Telegraph ; Calcutta , India - Monday , October 30, 2006 2.Disappearing world: Global warming claims tropical island; Geoffrey Lean; The Independent ; Sunday, December 24, 2006

Climate change : Indian coasts are fast responding to this global phenomenon. They are seen as one of the dominant drivers in the coming years. Climate change induced sea level rise has already devouring islands in the coasts of West Bengal and Orissa washing then off the map. Warming of seas has already affected temperature-sensitive organisms such as corals and causing their death. Climate change, as mentioned is expected to magnify the hazards particularly increase in extreme events like cyclones, storm surges. Sinking of islands is attributed to sea level rise.

Education and Awareness : There is limited understanding of ecosystem services. We do not have sufficient information on several environmental processes and consequences. The efforts to transfer the existing knowledge to coastal mangers is inadequate . There is need to strengthen this knowledge to help develop capacity to respond to the environmental issues of the coasts.

Lack of proper use of technology, strict regulations, policies, governance, institutional and legal systems are also contributing to the coastal changes. Socio economic, political and technological pressures which are the root cause of these ecosystem changes are not necessarily coastal in origin. The State, National , International interests or priorities can also influence coastal habitats and services.

All these have resulted in the destruction of almost every coastal habitat such as mangroves, coral reefs, sea grass, turtle nesting grounds , estuaries, deltaic areas, salt marshes, mudflats, wetlands, lagoons, beaches. Habitat loss has already disturbed the coastal biodiversity. Activities like sand mining, coastal dredging/mining projects have accelerated the erosional processes like clogging of river flow, construction on shoreline. Poorly designed coastal engineering works are altering the long shore currents / wave forces leading to undesirable erosion and deposition patterns. The pressure on coastal resources like space, food, timber, fuel, water are increasing. Increase in the pollution load in the coastal areas have increased the rate of eutrophication and prevalence of hypoxic or dead zones as levels of nutrient inputs and wastes rise and as ocean waters warm. Some 77% of the pollutant load reaching the coastal ecosystems currently originates on land from municipal and industrial waste, and 44% of this comes from improperly treated wastes and runoff. Pollutants affect water quality, and with it many provisioning services. They also cause large-scale failures of fish farming operations that are extremely costly (white spot syndrome in shrimp costed India 200 million USD . Several incidences of harmful algal bloom have been reported in recent years, particularly in Arabian sea .(10)

Figure 7 : Sea wall erosion

Various human activities have either augmented the impact of natural drivers or induced changes which resulting in exploitative utilization of natural resources and rapid environmental degradation. Stemming out of this are various issues like livelihood security; food security; inequity ; multiple vulnerabilities and safety. In recent years, coastal areas are increasingly being subjected to such abuses which have amplified the vulnerability of coastal communities to hazards .

Coastal Management in India and the Ecosystem approach

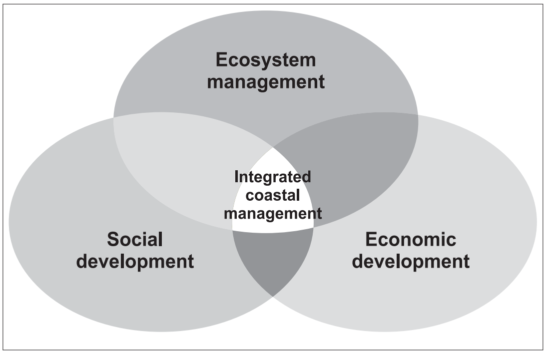
In India, more than 200 laws and acts regulate the developmental activities to conserve environment and sustain a healthy environment . Environmental Impact Assessment (EIA) is much a part of many developmental projects in India today. The new coastal regulation zone notification (CRZ, 2011) put forth by the Ministry of Environment and Forests to protect the coastal zones from the commercial activities by regulating these activities (14) ; emergence of the Disaster Management Act in 2005 (15), setting up of the legislative and institutional framework for these acts, all show the political commitment besides providing the formal basis for action and necessary reforms. The recent national action plan for climate change has included ‘ecosystem services enhancement’ as one of the eight missions, recognizing the vital role of healthy ecosystems in building socio-ecological resilience in the coast.

All these have empowered stakeholders for improving the effectiveness of coastal and disaster management in India. These acts are now a part of India’s development planning. There are also programmes initiated by the National Government on coastal development and disaster management like capacity building at all levels including schools and universities, mapping of the coasts etc., in conjunction with the state governments and with the participation of local governments, technical institutions and NGOs. It all seem adequate and so perfect. Yet, millions of people across the country are losing lives and livelihoods from disasters like storm surges, floods year after year.

Are our policies, practices adequate to cope with the new demands?

Do we need to develop new strategies to meet these complex challenges?

Where is the problem? Issues and challenges



Improving environmental conditions and ecosystems services are never the priority in the developmental sector, particularly in coastal development in India . To add to the problem, the acts are not found very effective on the ground. In fact they have triggered many debates across the country. Integration of the ecological perspective in Disaster Management Act and integration of Disaster Risk Reduction (DRR) in coastal regulation are not adequate to address the scale of the need. Net result, people , the poor in particular suffer the most.

Some of the issues in using environmental tools for hazard mitigation are

- Lack of sensitiveness to the issues be it social , economic or environment;
- DRR and environmental management still remain as separate domains;
- Total lack of environmental perspective in DRR plans and programmes;
- Inadequate knowledge of natural systems especially when it comes to coastal ecosystems;
- Insufficient institutional capacity to link DRR and environmental management and use of tools like EIA and hence absence of assessing environmental changes in the coastal areas as a parameter of risk;
- Lack of greater attention to environmentally sound designs and the maintenance of ecosystem services to help protect communities better from disasters and resource degradation as well;
- Lopsided planning which do not address sufficiently the socio economic, scientific environmental feasibility;
- Need more political will and commitment at the implementation stage;
- Peoples' participation is more or less absent except in few pockets.

Figure 8 : Coastal hazard impact

Ecosystem approach to hazard mitigation is a recent initiative in India. It needs more time to establish, strategise and percolate down to various sectors, levels and departments. Considering ecological services as an integral component of hazard mitigation is an important planning aspect.

The entire basis of coastal planning in India is conservation of the coastal environment and ecosystem; and natural hazard is a important concern. Questions like - How are the decisions influencing coastal ecosystems? How to arrive at an opinion or a decision, especially when it has an implication on the coastal ecosystem and the services ? What are the best processes that can be followed to arrive at a decision ? How to evaluate the 'appropriateness' of the decision? What are the strategies to translate the decision in to action? Who should be involved in such processes? should help in the better management of the coastal environment to reduce the risk of disasters.

Walling the sea?

Engineering structures such as sea walls, dykes , groynes and breakwaters are one of the key DRR measures for the coastal protection. However, their social and environmental implications are under scanner. The sea walls often affect littoral and estuarine dynamics which results in shoreline changes. For instance, on the east coast where the littoral drift is very significant, these structures obstruct the drift and cause erosion on the northern side and accretion on the southern side of the structure . As a result the problem of erosion is only transferred to further north. There is a fear that the wall may create unnatural water currents. When high tide waves hit against the walls they reflect back towards the ocean with much more energy. This doubles the erosion problem than in beaches without a sea wall. Reflected waves and the diminished sand supply may also degrade the sand bars and destroy the surf. With the habitat degradation the flora and fauna may undergo drastic changes. Many experts feel that these structures often are built with inadequate understanding of the coasts. For instance seawall of 386 km constructed in Kerala has only shifted the problem of erosion to Karnataka. Karnataka already suffers from high rate of sea erosion, the annual rate of which has gone to 40 tonnes per hectare from 5 tonnes. Sea wall in Kerala is magnifying the problem on the contrary. According to expert opinion, hard engineering structures should be the last options when other measures are not going to be effective. The view now is that hard measures like dykes and dam can no longer be regarded as protection against the sea. Soft solution such as dunes with a minimum of hard elements such as jetties, dykes , dam provides better and cost effective measures

Source : Rodriguez ,S. et al.,Policy Brief : Seawalls , UNDP /UNTRS and ATREE, Bangalore, India 2008

With increasing coastal environmental degradation and lack of control over exploitative developmental patterns in the coastal area, an integration of the planning and actions amongst the various institutions / departments can only save our coasts.

1. *The terms Disaster Risk Reduction and Hazard Mitigation used in this paper are interchangeable*
2. *This paper has drawn contents largely from the Hand Book ' Towards safe coasts : Integrating Disaster Risk Reduction into Coastal Development in India', developed by the author for the coastal managers of Indiawith the financial support of UNEP*

Appendices

Appendix A : Habitat -Wise coastal and marine ecosystem services

ECOSYSTEM SERVICES	Coastal									Marine		
	Estuaries and marshes	Mangroves	Lagoon and salt ponds	Intertidal	Kelp	Rock and shell reefs	Seagrass	Coral reefs	Inner shelf	Outer shelves edges slopes	Seamounts & mid-ocean ridges	Deep sea and central gyres
Biodiversity	X	X	X	X	X	X	X	X	X	X	X	X
Provisioning services												
Food	X	X	X	X	X	X	X	X		X	X	X
Fibre, timber, fuel	X	X	X						X	X		X
Medicines, other resources	X	X	X		X			X	X			
Regulating services												
Biological regulation	X	X	X	X		X		X				
Freshwater storage and retention	X		X									
Hydrological balance	X		X									
Atmospheric and climate regulation	X	X	X	X		X	X	X	X	X		X
Human disease control	X	X	X	X		X	X	X				
Waste processing	X	X	X				X	X				
Flood/storm protection	X	X	X	X	X	X	X	X				
Erosion control	X	X	X				X	X				
Cultural services												
Cultural and amenity	X	X	X	X	X	X	X	X	X			
Recreational	X	X	X	X	X			X				
Aesthetics	X		X	X				X				
Education and research	X	X	X	X	X	X	X	X	X	X	X	X
Supporting services												
Biochemical	X	X			X			X				
Nutrient cycling and fertility	X	X	X	X	X	X		X	X	X	X	X

Source : Millennium Assessment Report , 2008

Appendix B

The 12 principles of the ecosystem approach

1. The objectives of management of land, water and living resources are a matter of societal choice.
2. Management should be decentralized to the lowest appropriate level.
3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
4. Recognizing potential gains from management, there is usually a need to understand nd manage the ecosystem in an economic context. Any such ecosystem-management programme should:

(i) reduce those market distortions that adversely affect biological diversity;

(ii) align incentives to promote biodiversity conservation and sustainable use; and

(iii) internalize costs and benefits in the given ecosystem to the extent feasible.

5. Conservation of ecosystem structure and functioning, to maintain ecosystem services, should be a priority target of the ecosystem approach.
6. Ecosystems must be managed within the limits of their functioning.
7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
9. Management must recognize that change is inevitable.
10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Source : www.cbd.int/ecosystem/sourcebook

Appendix C : Fact sheet

Structural measures for disaster risk reduction

Structural measures which include human made hard (engineering) and soft measures have different purposes and functions such as

- Protection of a receding coastline endangering land and other assets;
- Protection of low lying areas under natural protection of a beach barrier or dune system;
- Control of undesired fluctuations of the coastal profile around tidal inlets and river estuaries;
- Maintenance of coastal areas of recreational value, in particular, related to tourism;
- Specific protection around and in the vicinity of coastal installations such as harbours, cooling water intakes and marine highways.

Some of the commonly used hard structures are:

A groyne is a rigid hydraulic structure built from an ocean shore (or from a bank of a river) that interrupts water flow and limits the movement of sediments. In the coastal areas they create and maintain a wide area of beach or sediment on its up drift side, and reduce erosion on the other

Artificial headlands are very similar to groyne but they are more massive structure designed to eliminate problems of down drift erosion and promote the formation of beaches.

Offshore breakwaters are placed generally parallel to the shore and at a certain distance from the shore. These structures can be used to change the transport capacities, both alongshore and onshore/offshore to the coast, resulting in the accumulation in the lee of the breakwater.

A seawall is a form of hard and strong coastal defense constructed on the inland part of a coast to reduce the effects of strong waves. In the past these have been the most widely used option for coast and flood defense ranging from massive vertical retaining walls to sloping revetment. However, it is observed that concrete seawalls and revetments are rigid and steep and **therefore can have a substantial impact on the shoreline and on the coastal processes**

Some of the commonly used soft structures are :

Artificial nourishment or **beach nourishment** where an external supply of sand is used to replenish an eroding stretch of a coast. This method seems to be expensive and does not attract coastal engineers.

Dune building/reconstruction wherein sand fences and mesh matting in combination with vegetation planting have successfully regenerated dunes via sediment entrapment and vegetation colonization.

Coastal revegetation requires a good planning based on site suitability and species selection.

A combination of hard and soft solutions is sometimes necessary to improve the efficiency of the options and provide an environmentally and economically acceptable coastal protection system.

Source : Coastal protection in the aftermath of the Indian Ocean tsunami: What role for forests and trees? , Proceedings of the Regional Technical Workshop, Thailand, 28–31 August 2006

References

1. Asian Disaster preparedness Centre (2004) : Environmental Degradation and Disaster Risk, Issue Paper ; prepared by ADPC for Embassy of Sweden / Sida Bangkok
2. Saudamini Das and Jeffrey R. Vincent (2009) : Mangroves protected villages and reduced death toll during Indian super cyclone ; Proceedings of National Academy of Science of the USA June 2
3. Millennium Ecosystem Assessment Report (2005)
4. World Resource Institute (2001) : Coastal Ecosystems, Pilot Analysis of Global Ecosystems (PAGE)
5. Liz Creel (2003) : Ripple effects : Populations and coastal regions; Population Reference Bureau
   (Also see UNEP, Global Environment Outlook 3; WRI, World Resources 2001 - 2001)
6. Centre for Environment Education (2009) : Towards safe coasts : Integrating Disaster risk reduction into coastal development in India
7. www.cbd.int/ecosystem/sourcebook
8. United Nations Strategy for disaster Reduction (2005) : Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters
9. Integrated Coastal Zone management (ICZM) - Marine Biodiversity
   http://www.marbef.org/wiki/Integrated_Coastl_Zone-Management_%28ICZM%29
10. Committee Report (2005) : Report of the committee chaired by M S Swaminathan to review the coastal regulation zone notification 1991
11. Ministry of Environment and Forests (2011): India: FAQ on Coastal Regulation Zone (CRZ) Notification 2011.
12. Centre for Environment Education (2004) : Understanding Environment ; Sage publication
13. Anand Patwardhan , K. Narayanan, D. parthasarathy and Upasna Sharma , (2003): Impacts of climate change on coastal zones, In climate change and India - Vulnerability assessment and Adaptation; Edited by P.R.Shukla, Subodh K Sharma, N.H. Ravindranath, Amit Garg, Sumana Bhattacharya, Universities Press (India)Pvt. Ltd. Hyderabad , 2003
14. Ministry of Environment and Forests (2011): Coastal Regulation Zone (CRZ) Notification 2011
15. National Disaster Management Authority(2005) : Disaster Management Act 2005 ; ndma.gov.in/

5

Environmental Concerns for DRR in Hindu-Kush Himalaya region

Hari Krishna Nibanupudi and
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"If a tree which protects a river bank collapses in a flood, the creeper, which live on it and the lives who need for survival will surely follow the suit".
-Raja Tarangini (An ancient Indian scripture)

The Hindu Kush Himalaya (HKH) region is environmentally stressed and economically underdeveloped. Consequently the region is highly vulnerable for climate change, natural disaster and their environmental and socio-economic risks. This paper based on secondary data shows that the HKH region is affected by increasing frequency of flash flood and river-line flood which are among the more devastating types of hazard as they occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. Disasters affect people, environment, livelihoods and infrastructure. It is increasingly evident development interacts with nature and therefore with natural hazards. When development pursuits ignore this reality, they contribute to turning natural hazards in to disasters. Environment can prevent or accelerate climate induced disasters depending on how the development policies and practices treat the environment.

People living in fragile eco system of HKH region have been subject to the increasing frequency and intensity of disasters in mountain areas. Data analysis suggesting that out of total annual disaster in HKH region 14% are earthquake and landslide disaster 48% are hydrological disasters (i.e.36% flood, 9% mass movement, 3% drought) whereas 38% are other types of disasters such as storm (23%), wild fire (1%), extreme temperature (6%), epidemic (8%). Results concluded that climate change accelerating the hazard events with the growth rate of 6% each year. Subsequently human casualties increasing with the rate of 9% each year whereas affected people and infrastructural loss increasing with that rate of respectively 6% and 4% each year. Because of the high growth rates of the existing risks level expected that the emerging risk has the potential to evolve into extreme events. Therefore, Disaster Risk Reduciton requires a comprehensive approach combining structural mitigation, socio-economic development, environmental sustainability and regional cooperation efforts.

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

Introduction

Hindu Kush Himalaya region lies between the latitude 15°42”–40°8”N and longitude 59°34”–112°5”E on the globe and encompasses a geographical area of 3,441,719 km2 including over all or part of eight Asian countries from west to east (Figure 1). These countries are Afghanistan Bangladesh Bhutan, China, India, Myanmar, Nepal, and Pakistan. Topographically it is mountainous part and source of ten large Asian river systems – the Amu Darya, Indus, Ganges, Brahmaputra (Yarlungtsanpo), Irrawaddy, Salween (Nu), Mekong (Lancang), Yangtse (Jinsha), Yellow River (Huanghe), and Tarim (Dayan), - and provides water, ecosystem services, and the basis for livelihoods to a population of around 210.53 million people in the region.

About 95% population of the total population in the HKH region depends on agriculture and forest resources but the forest cover is decreasing 0.36 km2 per year and the agricultural production decreasing due climate change and several natural disasters (Rawat et. al., 2011-a). Hindu Kush Himalaya is the youngest mountain system, which is still undergoing tectonic movement due its complex geological structures, dynamic geomorphology, and seasonality in hydro-meteorological conditions. The region experience natural disasters very frequently, especially earthquake and water induced hazards. Neo-tectonic activities in HKH region along the several active thrusts and faults responsible for earthquake disasters whereas climate change and land use degradation accelerating the water-induced disasters such as flash flood, river-line flood, erosion, wet mass movement during monsoon period and drought in non-monsoon period as drying up of natural water springs and streams (Rawat et. al., 2011-b).

Figure 1: Hindu Kush Himalaya Region:

Climate Change, Natural Hazards and Disasters in the HKH Region

The frequency and intensity of disasters is on the rise all over the world according to a report of reinsurance company, Munichre (Munich Re, 2011). The steady increase the loss of lives, properties and economies year after year is alarming. According to the report of Munichre, the first half of 2011 records the highest economic losses caused by disasters. The loss of over US$ 265 billions in the first half of 2011 is already higher than the total loss of $ US 220 billion in 2005 that was considered to be the worst year in terms of natural disasters. Most of the losses in 2011 were caused by the earthquake in Japan on 11 March (Munich Re, 2011). Countries in the HKH region have a history of devastating earthquakes, floods, landslides, droughts and cyclones that have caused economic and human losses. The physiographic settings and the climatic characteristics of the region is favorable towards the high incidence of both geological and hydro-metrological hazards (SAARC 2008).

The most common type of disaster in the region is flooding. The increasing frequency of floods in the HKH region cause greater and longer-lasting damage to infrastructure and livelihoods in the region. Although, early warning could save many lives, floods still cause great loss to livelihoods and public infrastructure, destroy crops, erode river banks and disrupt irrigation channels. As the Table 1 suggests, HKH region countries have particularly been affected by deadly disasters in the last couple of years. While, some of these countries have responded to local and global pressures for disaster mitigation, the actual efforts remained inadequate compared to the scale of disaster risk the region is faced with. The recent Indus floods in Pakistan that affected over two million people raise a serious question on the adequacy of resources, capacities and effectiveness of disaster management plans and policies in reducing disaster losses. It is expected that existing risk patterns in the region will continue to intensify, especially in the Hindu Kush and Himalayan region in view of climate change, urbanization, economic globalization, poverty and environmental degradation.

Table. 1: Disaster events and impacts by country in the HKH region- 1980-2009

Country	No. of Disaster Events	No. Of deaths	No. of people Affected (000)	Damages (US$ Millions)
China	574	148, 419	2,549,840	321,545
India	416	141,888	1,501,211	51,645
Pakistan	131	84,841	29,966	8,871
Afghanistan	125	19,304	6,774	497
Bangladesh	229	191,650	316,348	16,273

Nepal	74	10,881	4,507	1,621
Bhutan	9	303	66	5
Myanmar	25	139,095	3,315	2,726

Note: Damage data are at 2005 prices
Source: Derived from a ESCAP 2010: based on data from EM-DAT: the OFDA/CRED International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium

The flash flood and river-line flood occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. Flash floods and river-line floods affect thousands of people in the Himalayan region every year by affecting lives, homes, and livelihoods along with expensive infrastructure. There are several different causes of flash flood and river-line flood in HKH region such as intense rainfall (IRF); glacial lake outburst (GLO), landslide dam outburst (LDO), rapid snow melt (RSM) and failure of dams and other hydraulic structures (Jonkman, 2005, Rawat et. al., 2011-c). But intense rainfall (IRF) is very frequent cause for flash flood and river-line flood in the Himalaya which play a key role for flash flood and river-line flood.

There is an increased recognition of the link between climate change and disasters. The Intergovernmental Panel on Climate Change (IPCC, 2007) concluded that the frequency and severity of hot and cold extremes and heavy precipitation events is increasing and this trend will continue. Data from Center for research on the epidemiology of disasters shows that in the last century, hydro-meteorological disasters show rapid upward trend over geological disasters such as earth quakes (Figure 2). According to a number of studies and reports, the climate change seems to impact on the frequency and intensity of hydro meteorological disasters.

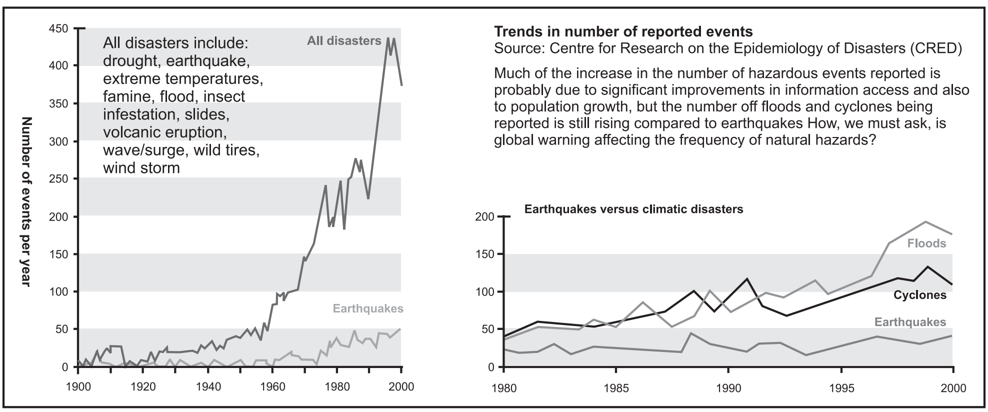


Figure 2: Trends in hydro-meteorological and geological disasters

Due limited data available covering the past three decades, it is statistically difficult to quantify and isolate the exact impact of climate change. However, there is some evidence of linkages between physical changes, atmospheric, terrestrial and oceanic, and the weather processes that lead to disaster caused by natural hazards. According to the IPCC report of 2007, In the Indian sub-continent over the last 100 years, the air temperature has increased by an estimated 0.3ºC to 0.6ºC – and by 2100 the temperature may increase further by 3.5 ºC to 5.5ºC (IPCC, 2007). This will affect high-altitude glacial environments, which are very sensitive to temperature changes.

A number of disaster events were reported in 2010 alone that reflect the impacts of climate change in high altitudes. A cloud burst incident destroyed an entire village in Almora district of India in 2010, while a similar incident killed hundreds and displaced thousands in the Ladakh district of India. There were more than ten major incidences of similar nature were recorded in the Himalayan regions of Uttarakhand, Himachal Pradesh and Jammu & Kashmir states of India in 2010. In the same year, a national television news channel India TV aired the visuals of Glacial Lake Outburst Flood in Garhwali region of Uttarakhand sending shivers down the spine of local people. This incident was followed by massive monsoon rains that posed major threat to the big dams like Bhakhara Nangal and Tehri. Flood waters in Tehri dam in particular Crossed the danger level and forced the media and people to take note of the dangers ahead (Alka Singh, 2010). Studies by ICIMOD (2007), SAARC (2008) and others have shown that in recent decades the Himalayan glaciers have been melting at unprecedented rates.

Climate Change, Natural Hazards and Environmental Degradation:

Climate Change not only triggering glacial lake outburst floods but also accelerating several monsoon and non-monsoon hydrological hazards through excessive land use degradation in HKH region. Monsoon hydrological hazard comprises of deforestation, high monsoon runoff, flash floods, river-line floods, soil erosion and landslide etc. whereas non-monsoon hydrological hazards comprises of decreasing under ground water table, drying up of natural water springs and decreasing trends of streams discharge due to deforestation during monsoon period. Rawat et al, (2011d) suggested that during last two decades the climate change and land use degradation reduced the protective vegetal cover as a result the significant proportion of rainfall goes waste as flood water without replenishing the groundwater reserve.

Consequentially 24% natural springs have gone dry, and 28% springs have become seasonal during last two decades period (1990-2010) in HKH. In order to that all the perennial rivers and their streams are drying up and caused for drought hazard in non-monsoon period which poses a serious threat to rural socio-economy and livelihood because these rain fed springs and streams are major sources for dirking water and agricultural irrigation in HKH region.

On the other hand during monsoon period climate change and land use degradation accelerating flash flood, river line flood, soil erosion and landslide. These hydrological hazards cause great loss to life and property and poses serious threat to the process of development with have far-reaching economic and social consequences. It also experienced that these accelerated hydrological hazard not only effecting HKH but also triggering trans-boundary disasters and their risks in its adjoining plain ecosystem (Ives, 1989 and Rawat, 2011). The indisputable fact that climate change is increasing risks to disasters that affect most of the HKH communities highlights the obvious relation between the two areas of work. The DRR approaches should recognize and seeks to exploit specific programmatic synergies with sustainable livelihoods, ecological sustainability, climate change adaptation, integrated water resource management (Figure 3).

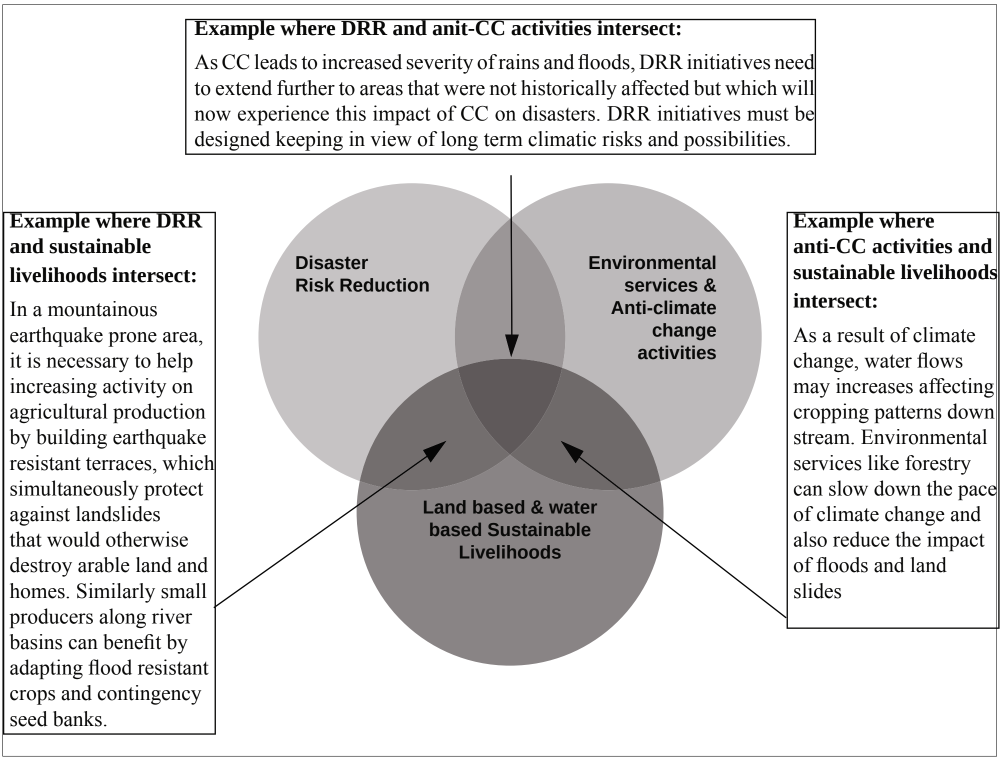


Figure 3.

[3]Adopted from DEWGA (2008): Linking Disaster Risk Reduction, environment management and development practice in Asia Pacific region, Disasters Environment Working Group for Asia http://www.preventionweb.net/files/13199_DEWGAIntegratingenvironmentandDRRSt.pdf

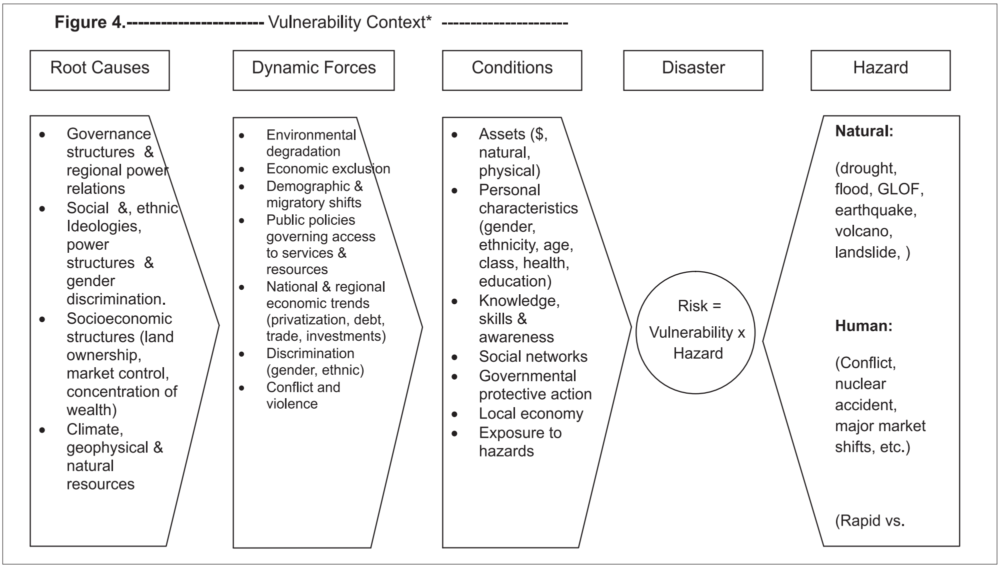
Socio- economic vulnerabilities and adapting to climate induced disasters

Disaster vulnerability is popularly defined as “the lack of capacity to anticipate, cope with, resist and recover from the impact of a natural disaster” (Blakie and others, 1994). Vulnerability, therefore, can be determined by factors such as access to information, assets, social protection and insurance (Figure 4). According to ESCAP small economies can experience huge falls in productive capacity even with low-impact disasters. Poor have limited choices and they are often forced to live in substandard housing in dangerous locations – on flood plains, riverbanks or steep slopes. Without secure land ownership rights they have less incentive to invest in structural risk reduction.

With environmental degradation resulting in limited livelihood opportunities the communities may be forced to further over-exploit the local environment, making it even more vulnerable. In mountain areas with little access to financial services, communities often have savings in the form of livestock, which may be killed in the event of a disaster. Reducing the risks of disasters require widespread and sustained commitment across a wide range of fields. And since many of the hazards will intensify because of climate change, it is also vital to be approach these issues on a broad front, integrating disasters and climate change policies and socioeconomic policies aimed at reducing poverty and inequities (ESCAP, 2010). Therefore, as illustrated in the following pressure model, sustainable livelihood, water management and environmental services can significantly reduce the negative effects of natural disasters by focusing on the root causes of vulnerability and taking steps to reduce it.

The value of this model rests on the acknowledgement that there are different contexts in which vulnerability occurs and that the reduction of risk to disasters must be considered at all levels. This model also helps in focus increasing attention on addressing the root causes and dynamic pressures contributing to vulnerability, not only the immediate conditions that characterize vulnerability. Some particular vulnerability factors, for instance gender, can be considered across the different levels of the vulnerability context. This can be seen as a root cause, a dynamic force, and a condition of vulnerability. In trying to address these concurrent causes though development initiatives, one may find carrying out a single activity with a double objective. This double impact will be the merging point for DRR and environmentally sound development.

This is especially relevant in the case of sustainable livelihoods in contexts of extreme poverty. Further, the increasing interest regional and global attention to the issues of Climate Change leads us to map this area of work in relation with DRR.



Source: Adopted from Pérez de Armiño (1999), B. Wisner et. al. (2004)

***Note:** The elements listed within the dimensions of vulnerability (root causes, dynamic forces, and conditions) provide some examples, but these lists are by no means exhaustive. Other elements may be at play in various contexts, and such elements should be taken into account when using this model.

Conclusion and Way Forward

Most of the natural hazards in Asia are regional in nature. Environmental degradation, geological, hydro-meteorological, climatic or anthropogenic factors in one country cause hazards transcend the political boundaries and affect communities in the neighboring countries too. Indian Ocean Tsunami for example, affected as many as eight countries in South and South East Asia. The South Asian earthquake of October 2005 damaged life and property over large areas of Pakistan and India. The typhoons of Pacific Island affect a number of island countries at the same time. Koshi floods devastate parts of Nepal and India every monsoon, while Ganges floods maroon hundreds of villages in India Bangladesh. Similarly, Indus river floods affect Afghanistan and Pakistan and Brahmaputra floods affect China and India. Therefore regional cooperation among countries of the region is very crucial for disaster risk reduction.

Specific and focused regional cooperation in Asia has been taking place on a more compact sub-regional basis that have common geo-physical, geo-climatic and geo-political features in Asia, namely in East Asia, South East Asia, South Asia, Central Asia & West Asia. The South East Asian Nations (ASEAN) adopted the ASEAN Agreement on Disaster Management and Emergency Response, while East Asia Summit has identified disaster risk reduction as one of the activities of cooperation among the member countries. Similarly, The South Asian Association of Regional Cooperation (SAARC) has adopted a Comprehensive Framework of Disaster Management and set up a SAARC Disaster Management Centre in New Delhi. Similar cooperative efforts for regional disaster risk reduction has been pursued by International Center for Integrated Mountain Development (ICIMOD) in the Himalaya Hindu-Kush (HKH) region (ASEAN, 2007). A notable initiative in this regard by ICIMOD has been a regional cooperation for flood information system along five rivers shared by six countries in the region.

The Hyogo Framework for Action has also emphasized the importance of regional cooperation for disaster risk reduction. Paragraph 31 of the HFA which deals with regional organizations calls up on regional organizations with a role related to disaster risk reduction to Promote regional programmes, including programmes for technical cooperation, capacity development, the development of methodologies and standards for hazard and vulnerability monitoring and assessment, the sharing of information and effective mobilization of resources, Establish or strengthen existing specialized regional collaborative centers, as appropriate, to undertake research, training, education and capacity building in the field of disaster risk reduction (ASEAN, 2007). Further a HKH regional treaty is the need of the hour for sustaining and ensuring consistency in regional cooperation for environmental sustainability and disaster risk reduction.

References

ASEAN 2007. Background note for Promoting Regional Cooperation Mechanisms on Disaster Reduction, 2nd Asian Ministerial Conference on Disaster Risk Reduction, 7-8 November 2007.

Blaikie P, Cannon T, Davis I & Wisner B 1994. At Risk: Natural Hazards, People's vulnerability, and Disasters. London, Routledge. pp. 275.

DEWGA (2008): Linking Disaster Risk Reduction, environment management and development practice in Asia Pacific region, Disasters Environment Working Group for Asia, http://www.preventionweb.net/files/13199_DEWGAIntegratingenvironmentandDRRSt.pdf

ESCAP 2010. Interpreted from The Asia Pacific Disasters Report, ESCAP 2010: based on data from EM-DAT: the OFDA/CRED International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium.

ICIMOD 2007. Impact of Climate Change on Himalayan Glaciers and Glacial Lakes: Case Studies on GLOF and Associated Hazards in Nepal and Bhutan. Kathmandu. International Centre for Integrated Mountain Development. www.rrcap.unep.org/reports/file/Impact_Climate_Change.pdf

IPCC 2007. Climate Change 2007. The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M.and Miller, H.L. (eds.)]. Cambridge University Press: Cambridge, UK and New York, NY, USA,996pp

Ives JD. 1989. Deforestation in the Himalaya: The Cause of Increased Flooding in Bangladesh and Northern India. Land Use Policy 6:187-193.

Jonkman SN. 2005. Global Perspectives on Loss of Human Life Caused by Floods. Natural Hazards 34:151-175.

Muniche Re 2011. Accumulation of very severe natural catastrophes, makes 2011 a year of unprecedented, Muniche Re, Press release, 12 July 2011. http://www.munichre.com/en/media_relations/press_releases/2011/2011_07_12.

Rawat Pradeep K, Tiwari PC and Pant CC. 2011a. Modeling of Stream Runoff and Sediment output for erosion hazard assessment in Lesser Himalaya; Need for sustainable land use plane using Remote Sensing and GIS: A case study. Natural Hazards, Articles in Press, 10 May 20011. http://dx.doi.org/10.1016/j.natural hazards.2011.

Rawat Pradeep K, Tiwari PC, Pant CC, Sharama AK and Pant PD. 2011b. Spatial variability assessment of river-line floods and flash floods in Himalaya: A case study using GIS. International journal of Disaster Prevention and Management 12(2):

Rawat Pradeep K, Tiwari PC, Pant CC, Sharama AK and Pant PD. 2011c. Morphometric analysis of third order river basins using high resolution satellite imagery and GIS technology: special reference to natural hazard vulnerability assessment. International Scientific Research Journal 3 (2):70-87.

Rawat Pradeep K, Tiwari PC and Pant CC. 2011d. Climate Change accelerating Hydrological Hazards and Risks in Himalaya: A Case Study through Remote Sensing and GIS Modeling. International Journal of Geomatics and Geosciences 1(4): 678-699.

Rawat Pradeep K. 2011. Consultant Report. Understand and Analyze the Existing and Emerging Risks in the Hindu Kush Himalaya Region. ICIMOD.

SAARC 2008. SAARC Workshop on Climate Change and Disasters: Emerging Trends and Future Strategies. SAARC Disaster Management Center. Accessed from www.saarc-sdmc.nic.in

Singh, Alka, (2010), Climate Change and Disasters In the Hindu Kush Himalayan Region, AMRITA Agency For Multidimensional Research, Implementation, Training & Advocacy, Allahabad, India: http://amritapeoplesvoice.blogspot.com/

6

Ecological Approach to Landslide Risk Remediation

Ashish Rawat, H.B. Vasistha and Prafulla Soni

Landslides are important soil degradation processes and are excellent illustrations of the dynamic interplay of disturbance and succession. Landslide restoration using ecological tools is difficult on landslide surfaces because of the high degree of spatial and temporal heterogeneity in soil stability and fertility. Promotion of the recovery of self sustaining communities on landslides is feasible by stabilization with primary colonizing and native ground cover, applications of nutrient amendments, facilitation of dispersal to overcome establishment bottlenecks, emphasis on functionally redundant species and promotion of connectivity with the adjacent landscape. Arrested succession through resource dominance by a single species could be beneficial if that species also reduces persistent erosion, yet the tradeoff is often reduced biodiversity. Restoration efforts could be streamlined by using techniques that promote successional processes.

The paper emphasizes on landslides patterns, problems associated with them and their mitigation & management measures using the ecological techniques.

The landslide pattern

Landslides are one of the natural hazards that affect at least 15% of land area of our country exceeding 0.49 million km2 (Sharda, 1998).The term “landslide” as presented by Varnes (1978) and Cruden and Varnes (1996) includes all types of gravity-induced mass movements, ranging from rock falls through slides/slumps, avalanches, and flows, and it includes both subaerial and submarine mass movements triggered mainly by precipitation (including snowmelt), seismic activity, and volcanic eruptions. Landslides are a form of slope failure characterized by the rapid mass movement of soil and/or rock along a discrete shear surface (Varnes, 1978). Landslides occur when forces driving instability are greater than forces promoting slope stability (Conforth, 2005). They could be triggered by heavy rainfall events (Larsen and

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Simon, 1993; Stern, 1995), earthquakes (Garwood et al., 1979; Restrepo and Alvarez, 2006) or human landuse activities such as road construction, clear-cutting and urbanization (Walker et al., 1996; Sidle and Ochiai, 2006).

Landslides are an important component of the natural disturbance regime in most mountainous regions of the world (Veblen et al., 1992) and could strongly alter environmental gradients (Myster, 2001). The most common pattern found on the heterogeneous surface of many landslides is a division into several relatively distinct zones that results from the initial mass wasting (Martin et al., 2002). The slip face or initiation zone at the upper edge of a landslide is usually steep and infertile because of the loss of most surface soil (Dalling, 1994; Myster and Fernández, 1995). In addition, residual soils are likely to be unstable, subject to erosion and not readily colonized. The deposition zone at the lower edge of a landslide is relatively flat, stable and fertile because of the transfer of organic matter and debris from upper regions of the landslide (Mark et al., 1964; Miles and Swanson, 1986; Walker, et al., 1996). Finally, the chute or transport zone is an often steep-sided zone that connects the slip face and deposition zones and is intermediate in stability and fertility. These zones impact local surface stability, fertility and succession (Guariguata, 1990) and each requires a different restoration approach. Other patterns found on landslides include gradients of decreasing nutrients and organic matter (Fetcher et al., 1996) and increasing light availability (Myster and Fernández, 1995) from the landslide edge toward its center. Patches of original soil and vegetation that do not erode provide additional heterogeneity (Francescato et al., 2001; Velázquez and Gómez-Sal, 2008) and the presence of such "fertile islands" could dramatically impact landslide revegetation (Shiels et al., 2006).

Ecological Restoration of Landslides

Natural ecosystems have an inherent characteristic to recover after natural or man imposed damage. However, in view of frequent damage of natural ecosystems in various regions such as the fragile Himalayan region, technologies are required to hasten the process of recovery. Ecological restoration (Aronson et al. 1993) is undoubtedly the most important factor in ameliorating the effects of severe ecological disturbance such as landslides. Ecological restoration is essentially the manipulation of succession in order to achieve some predetermined goal such as a certain species composition, site fertility or site stability (Walker et al. 2007).

The success of ecological restoration on landslides or other degraded habitat depends on the stability of the selected site or more or less predictable series of transitions occurs with minimal human interference (Hobbs et al. 2007). Important additional results for restoration on landslides include reduced surface erosion and maximal connectivity with biotic variables in the surrounding landscape (e.g., fruit and seed dispersers, pollinators, decomposers, vegetative spread). Goals that specify a certain vegetative cover, species composition or level of fertility are less likely to lead to a self-sustaining ecosystem than broader goals that restore successional processes (Walker and del Moral, 2003). Narrow goals may be counter-productive, even if short-term reductions in surface erosion are achieved. For example, fast-growing grasses are often added to meet goals of a certain plant cover in the restoration of landslides and similarly severe disturbances including mine spoils or pipeline corridors. Yet these grasses could form monospecific swards that actually inhibit invasion by native species and arrest succession (Densmore 1992; Shiels and Walker 2003). Ultimately, successful restoration projects will be those that are careful to address the specific local conditions.

Bioengineering Approach for Landslide Risk Mitigation

Bioengineering is an advanced application that effectively deal with landslides, hill slopes failure, rock fall and other related problems. It is an integrated approach that assists stabilization of hill slopes/landslide sites and improves the site quality by improving soil nutrient status. Bioengineering entails the use of living plants and other auxiliary materials for stabilization of hill slopes, works as an integrated technique to protect slope against surface tension, to reduce the risk of planer sliding and to improve surface draining. Species having colonizing behaviour, fast growing nature and dense and deep root system with potential of adventitious root system and fast and simple propagation are needed to be selected for bioengineering application. The application of bioengineering is also vital for restoration of biodiversity in landslide damaged/degraded sites. Furthermore, this technique is a cost-effective solution, which uses locally available materials and allows the involvement of the local population in management and maintenance

One of the main advantages of bioengineering approach to slope protection, viz. plants and the mechanical structures could function together in mutually reinforcing or complementary roles. The field studies (White, 1978) have shown that in many instances combined structural-vegetative slope protection systems are more cost-effective than the use of either vegetation or structure alone. Vegetative treatments alone are usually much less expensive than earth retaining structures or other geological protection systems. On the other hand, their effectiveness in terms of preventing soil loss or arresting slope movement under severe conditions may also be much lower.

Bioengineering application blend into the landscape, hence this application is environmentally viable but the geological structures do not visually intrude upon the landscape as much as the conventional earth retaining structures. Thus, opportunities arise to incorporate vegetation into structure itself. This is done by planting either in between structural members or upon the benches purposely designed into a structure.

Role of Native Species in Ecological Restoration and Bioengineering

The traditional ecological restoration techniques and even the advanced bioengineering applications both works on a basic theory called “Choice of Species”. The “Choice of Species” should be such that the demand for inputs is the least and attention needed is negligible. The selected species should have deep and large root system and preferably be hardy, fast-growing and suckering (Sastry and Kavathekar, 1990).

The native vegetation could be more useful and efficient in the restoration and bioengineering prorammes as they have fewer competitors than other species and the disturbances permits the germination and development of non-seeded species (Munshower, 1993). The role of native vegetation is quite significant in prevention of landslides as well as for stabilizing the landslide. Plant cover not only protects the surface from weathering due to direct impact of rain and winds but its intricate root system works as a cohesive in binding the loose soil and preventing it from erosion.

When properly installed and maintained, vegetation could protect slopes by reducing erosion, strengthening soil, and inhibiting landslides which increase general slope stability. The use of vegetation to manage erosion and protect slopes is relatively inexpensive, does not require heavy machinery on the slope, establishes wildlife habitat, and could improve the aesthetic quality of the property.

The major effects of herbaceous and to a lesser extent woody vegetation (Gray and Leiser, 1982) in controlling landslide and mass movement include:

1. **Interception:** Foliage and plant residues absorb rainfall energy and prevent soil compaction from rain drops.
2. **Restraint:** Root system physically binds or restrains soil particles while above-ground residues filter sediment out of runoff.
3. **Retardation:** Above-ground residues increase surface roughness and slow velocity of runoff.
4. **Infiltration:** Roots and plant residues help to maintain soil porosity and permeability.
5. **Transpiration:** Depletion of soil moisture by plants delays onset of saturation and runoff.

Vegetation, primarily woody plants, also helps to prevent mass-movement, particularly shallow sliding in slope. The factors affecting slope stability were grouped by Varnes (1978) into those tending to increase shear stress and those tending to reduce shear resistance. It provides a basis for examining the likely influence of vegetation on landslide stability. Possible ways vegetation might affect the balance of forces in a slope include:

1. **Root reinforcement:** Roots mechanically reinforce a soil by transfer of shear stress in the soil to tensile resistance in the roots.
2. **Soil moisture modification:** Evapotranspiration and interception in the foliage limit build of soil moisture stress. Vegetation also affects rate of snowmelt, which in turn affects soil moisture regime.
3. **Buttressing and arching:** Anchored and embedded stems could act as buttress heap or arch abutments in a slope, counteracting shear stress.
4. **Surcharge:** Weight of vegetation on a slope exerts both a downslope (destabilizing) stress and a stress component perpendicular to the slope which tends to increase resistance to sliding.
5. **Root Wedging:** Alleged tendency of roots to invade cracks, fissures, and channels in a soil or rock mass and thereby cause local instability by a wedging or praying action.
6. **Wind Throwing:** Destabilizing influence from turning moments exerted on a slope as a result of strong winds blowing downslope through trees.

Bradshaw (1987) envisaged the importance of achieving a stable and self-sustaining vegetative cover. Vegetation is a regulatory factor towards the reconstruction of an ecosystem and landslide soils, as it improves the physical and biological diversity of disturbed sites. Revegetation is supposed to be the best tool for stabilization of degraded habitats (Singh et al., 2002), because vegetation not only provide long-term ecosystem stabilization and render potential ameliorative effects on soil quality, but also have potential value (Torbert et al., 1993; Fisher, 1990; Ashby, 1987).

Barriers to Ecological Restoration and Bioengineering

Persistent surface erosion is the first barrier to ecological restoration and bioengineering of landslides (Walker and Shiels 2008). Physical attempts to revamp slopes, including diverting streams or adding retaining walls such as gabions (Chou et al. 2007) are often necessary before ecological restoration and bioengineering could begin because the site has passed a threshold of irreversibility where unaided recovery is unlikely (Whisenant 1999). These efforts will succeed if the initial disturbance is adequately ameliorated. Additional drawbacks could be excessive compaction or decreased heterogeneity of the soil surface that may limit potential successional trajectories (Walker and del Moral 2003) or alter competitive balances among species (Walker and del Moral 2008). Many attempts at revamping slopes fail and seemingly permanent barriers are undercut or buried by renewed erosion. Physical covers such as mulches or nettings require less effort than revamping slopes and could reduce surface erosion (e.g., along road banks), but may deter plant colonization, especially when there is poor contact with the soil surface. Similarly, fertilizers could promote colonization and growth of stabilizing plants, particularly when the plants grow rapidly, have extensive lateral roots and evenly cover the surface. Rapid growth without adequate ground cover can have drawbacks by actually increasing erosion through channeling of drainage or soil removal by raindrops impacting bare soil under plants >0.3 m above the surface (Morgan 2007). Sowing or transplanting native species onto landslides can be cheaper (but more labor intensive) than physical efforts and the results can be more resilient to episodic disturbances because there is less disruption of any residual soil or seed banks. In addition, any acceleration of natural recovery processes will most likely promote long-term succession. However, the success of restoration and bioengineering efforts is always vulnerable to persistent erosion that can destroy nascent plant communities and reset successional processes (Walker and Shiels, 2008).

Conclusion

While applying the ecological approaches to mitigate landslide problems, overall goals for restoration of ecological communities on landslides must reflect. Successful restoration is achievable when goals are broadly focused on recovery of ecosystem function and biodiversity rather than on a particular species composition. Ongoing disturbances require continuous monitoring and adaptive management strategies. A proper investigation of landslides is essential, since it is not possible to design an effective mitigation system without proper understanding of the slope problems. Many development schemes implemented without carrying proper geological and geotechnical investigation due to shortage of money or time or due to other constraints. In order to avoid or minimize the landslide hazard, a proper geological and geotechnical investigation is essential prior to implementation of any development scheme. First of all, proper investigation method of landslide should be selected according to the need, which will save time and money too. A landslide calamity may be avoided or at least minimized by applying appropriate remedial measures or set or remedial measures at the initial stage of development scheme. Several aspects of the restoration of ecological communities on landslides would benefit from additional research. Generalizations about successional principles and subsequent predictability derived from individual studies of landslides will improve (Thompson et al. 2001). The relative contribution of nutrient limitations, dispersal bottlenecks and species interactions can be explored with both long-term observations and experimental manipulations (Shiels et al. 2006, 2008). Ultimately, the impetus to mitigate problems caused by landslides will come from the continued danger they pose to property and lives.

References

1. Aronson J, Florest C, LeFloc'h E, Ovalle C, Pontanier R (1993) Restoration and rehabilitation of degraded ecosystems in arid and semiarid regions. 1. A view from the South. Rest Ecol 1:8–17
2. Ashby,W. C. (1987). Forests. In W. R. Jordan, M. E. Gilpin, and J. D. Aber (eds.) Restoration ecology: A synthetic approach to ecological research. Cambridge, UK: Cambridge University Press
3. Bradshaw, A. D. (1987). The reclamation of derelict land and the ecology of ecosystem. In W. R. Jordan, M. E. Gilpin, and J. D. Aber (eds.), Restoratio ecology: A Synthetic Approach to Ecological Research. Cambridge, UK: Cambridge University Press.
4. Chou WC, Lin WT, Lin CY (2007) Application of fuzzy set theory and PROMETHEE technique to evaluate suitable ecotechnology method: A case study in Shihmen Reservoir Watershed, Taiwan. Ecol Eng 31:269–280
5. Conforth DH (2005) Landslides in practice: investigations, analysis and remedial/preventive options in soils. Wiley, Hoboken
6. Cruden DM, Varnes DJ (1996) Landslides types and processes. In: Turner AK, Shuster RL (eds) Landslides: Investigation and mitigation. National Academy of Sciences,Washington, DC, pp 36–71
7. Dalling JW (1994) Vegetation colonization of landslides in the Blue Mountains, Jamaica. Biotropica 26:392–399
8. Densmore RV (1992) Succession on an Alaskan tundra disturbance with and without assisted revegetation with grass. Arct Alp Res 26:354–363
9. Fetcher N, Haines BL, Cordero RA, Lodge DJ, Walker LR, Fernández DS, Lawrence WT (1996) Responses of tropical plants to nutrients and light on a landslide in Puerto Rico. J Ecol 84:331–341
10. Fisher, R. F. (1990). Amelioration of soils by trees. In: S. P. Gessel, D. S. Lacate, G. F. Weetman, & R. F. Powers (eds.), Sustained Productivity of Forest Soils. Proc. North American For. Soils Conf., 7th. Vancouver, B.C., 24–28 July, 1988, Univ. British Columbia, Faculty of For. Publ. Vancouver, B.C. 525 p.
11. Francescato V, Scotton M, Zarin DJ, Innes JC, Bryant DM (2001) Fifty years of natural revegetation on a landslide in Franconia Notch, New Hampshire, USA. Can J Bot 79:1477–1485
12. Garwood NC, Janos DP, Brokaw N (1979) Earthquake-caused landslides: a major disturbance to tropical forests. Science 205:997–999
13. Gray, D.H. and Leiser, A.T. (1982). Role of vegetation in the stability and protection of slopes. In: Gray, D.H. and Leiser, A.T. (eds.), Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Company Inc. New York. Pp 37-65 pp.
14. Guariguata MR (1990) Landslide disturbance and forest regeneration in the upper Luquillo Mountains of Puerto Rico. J Ecol 78:814–832
15. Hobbs RJ Walker LR, Walker J (2007) Integrating restoration and succession. In: Walker LR, Walker J, Hobbs RJ (eds) Linking Restoration and Ecological Succession. Springer, New York, pp 168–179
16. Larsen MC, Simon A (1993) A rainfall intensity-duration threshold for landslides in a humid-tropical environment, Puerto Rico. Geogr Ann 75A:13–23

17. Mark AF, Scott GAM, Sanderson FR, James PW (1964) Changes in the landslide vegetation at Lake Thomson, Fjordland. NZ J Bot 2:60–89
18. Martin Y, Rood K, Schwab JW, Church M (2002) Sediment transfer by shallow landsliding in the Queen Charlotte Islands, British Columbia. Can J Earth Sci 39:189–205
19. Miles DWR, Swanson FJ (1986) Vegetation composition on recent landslides in the Cascade Mountains of western Oregon. Can J For Res 16:739–744
20. Morgan RPC (2007) Vegetative-based technologies for erosion control. In: Stokes A, Spanos I, Norris JE (eds) Eco- and ground bio-engineering: The use of vegetation to improve slope stability. Springer, New York, pp 265–272
21. Munshower, F.F. 1993. In. Practical Handbook of Disturbed Land Revegetation. Lewis Publishers. London (UK).
22. Myster RW (2001) Mechanisms of plant response to gradients and after disturbances. Bot Rev 64:441–452
23. Myster RW, Fernández DS (1995) Spatial gradients and patch structure on two Puerto Rican landslides. Biotropica 27:149–159
24. Restrepo C, Álvarez N (2006) Landslides and their contribution to land cover in the mountain of Mexico and Central America. Biotropica 38:446–457
25. Sastry, T. C. S. and Kavathekar, K.Y. 1990. (Ed.). Plants for Reclamation of Wastelands. Publication and Information Directorate, Council of Scientific & Industrial Research, Hillside Road, New Delhi, India.
26. Sharda, Y.P. 1992. Landslide Studies in India. Glimpses of Geoscience Research in India. 98-100 pp.
27. Shiels AB, Walker LR (2003) Bird perches increase forest seeds on Puerto Rican landslides. Restor Ecol 11:457–465
28. Shiels AB, Walker LR, Thompson DB (2006) Organic matter inputs create variable resource patches on Puerto Rican landslides. Plant Ecol 184:223–236
29. Shiels AB, West CA, Weiss L, Klawinski PD, Walker LR (2008) Soil factors predict initial plant colonization on Puerto Rican landslides. Plant Ecol 195:165–178
30. Sidle RC, Ochiai H (2006) Landslide processes, predictions and land use, American Geographical Union. Water Resour Monogr 18:312
31. Singh, A. N., Raghubanshi, A. S. and J. S. Singh. (2002). Plantations as a tool for mine spoil restoration. Current Science, 82(12): 1436–1441.
32. Stern M (1995) Vegetative recovery on earthquake triggered landslide sites in the Ecuadorian Andes. In: Churchill SP, Balslev H, Forero E, Luteyn JL (eds) Biodiversity and Conservation of Neotropical Montane Forests. The New York Botanical Garden, Bronx, pp 207–220
33. Thompson JN, Reichman OJ, Morin PJ, Polis GA, Power ME, Sterner RW, Couch CA, Gough L, Holt R, Hooper DU, Keesing F, Lovell CR, Milne BT, Molles MC, Roberts DW, Strauss SY (2001) Frontiers of ecology. Bioscience 51:15–24
34. Torbert, J. L., Burger, J. A. and Daniels, W. L. (1993). Pine growth variation associated with overburden rock type on a reclaimed surface mine in Virginia. Journal of Environmental Quality, 19: 88–92.
35. Varnes DJ (1978) Slope movement, types and processes: Landslides, analysis and control. In: Schuser RL, Krizek RS (eds) Special Report 176. United States National Academy of Sciences Transportation Research Board, Washington D.C., pp 11–33
36. Veblen TT, Kitzberger T, Lara A (1992) Disturbance and forest dynamics along a transect from Andean rainforest to Patagonian shrubland. J Veg Sci 3:507–520
37. Velázquez E, Gómez-Sal A (2008) Landslide early succession in a Neotropical dry forest. Plant Ecol 199:295–308
38. Walker LR, del Moral R (2003) Primary Succession and Ecosystem Rehabilitation. Cambridge University Press, Cambridge, p 442
39. Walker LR, del Moral R (2008) Transition dynamics in succession: implications for rates, trajectories and restoration. In: Hobbs RJ, Suding K (eds) New Models for Ecosystem Dynamics And Restoration. Island, Washington, pp 38–49
40. Walker LR, Shiels AB (2008) Post-disturbance erosion impacts carbon fluxes and plant succession on recent tropical landslides. Plant Soil 313:205–216a
41. Walker LR, Walker J, del Moral R (2007) Forging a new alliance between succession and restoration. In: Walker LR, Walker J, Hobbs RJ (eds) Linking Restoration and Ecological Succession. Springer, New York, pp 1–18
42. Walker LR, Zarin DJ, Fetcher N, Myster RW, Johnson AH (1996) Ecosystem development and plant succession on landslides in the Caribbean. Biotropica 28:566–576
43. Whisenant SG (1999) Repairing Damaged Wildlands: A Process Orientated Landscape-Scale Approach. Cambridge University Press, Cambridge, p 324
44. White, C.A. (1979). Best management practices for the control of erosion and sedimentation due to urbanization of the Lake Tahoe Region of California, Proc., Intl. Symposium on Urban Runoff, Univ. of Ky., Lexington, Ky., pp. 233-245.

7

Ecological Approach for Mitigation of Urban Flood Risks

T.V. Ramachandra, Uttam Kumar and Bharath H. Aithal

Floods in an urbanised landscape refer to the partial or complete inundation from the rapid accumulation or run-off resulting in the damage to property and loss of biotic elements (including humans). Urban flooding is a consequence of increased impermeable catchments resulting in higher catchment yield in a shorter duration and flood peaks sometimes reach up to three times. Thus, flooding occurs quickly due to faster flow times (in a matter of minutes). Causal factors include combinations of loss of pervious area in urbanising landscapes, inadequate drainage systems, blockade due to indiscriminate disposal of solid waste and building debris, encroachment of storm water drains, housing in floodplains and natural drainage and loss of natural flood-storages sites. Flood mitigation in urban landscape entails integrated ecological approaches combining the watershed land-use planning with the regional development planning. This includes engineering measures and flood preparedness with the understanding of ecological and hydrological functions of the landscape.

Bangalore is experiencing unprecedented urbanisation and sprawl in recent times due to concentrated developmental activities with impetus on industrialisation for the economic development of the region. This concentrated growth has resulted in the increase in population and consequent pressure on infrastructure, natural resources and ultimately giving rise to a plethora of serious challenges such as climate change, enhanced green-house gases emissions, lack of appropriate infrastructure, traffic congestion, and lack of basic amenities (electricity, water, and sanitation) in many localities, etc. This study shows that there has been a growth of 632% in urban areas of Greater Bangalore across 38 years (1973 to 2010). Urban heat island phenomenon is evident from large number of localities with higher local temperatures. The study unravels the pattern of growth in Greater Bangalore and its implication on local climate (an increase of ~2 to 2.5 ºC during the last decade) and also on the natural resources (76% decline in vegetation cover and 79% decline in water bodies), necessitating appropriate strategies for the sustainable management.

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Introduction

Urbanisation is a form of metropolitan growth that is a response to often bewildering sets of economic, social, and political forces and to the physical geography of an area. It is the increase in the population of cities in proportion to the region's rural population. The 20th century is witnessing "the rapid urbanisation of the world's population", as the global proportion of urban population rose dramatically from 13% (220 million) in 1900, to 29% (732 million) in 1950, to 49% (3.2 billion) in 2005 and is projected to rise to 60% (4.9 billion) by 2030 (UN, 2005). Urban ecosystems are the consequence of the intrinsic nature of humans as social beings to live together (Sudhira et al., 2003; Ramachandra and Uttam Kumar, 2008). The process of urbanisation contributed by infrastructure initiatives, consequent population growth and migration results in the growth of villages into towns, towns into cities and cities into metros. Urbanisation and urban sprawl have posed serious challenges to the decision makers in the city planning and management process involving plethora of issues like infrastructure development, traffic congestion, and basic amenities (electricity, water, and sanitation), etc. (Kulkarni and Ramachandra, 2006). Apart from this, major implications of urbanisation are:

- Loss of wetlands and green spaces: Urbanisation has telling influences on the natural resources such as decline in green spaces including wetlands and / or depleting groundwater table.
- Floods: Common consequences of urban development are increased peak discharge and frequency of floods as land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Conversion of water bodies to residential layouts has compounded the problem by removing the interconnectivities in an undulating terrain. Encroachment of natural drains, alteration of topography involving the construction of high rise buildings, removal of vegetative cover, reclamation of wetlands are the prime reasons for frequent flooding even during normal rainfall post 2000.
- Decline in groundwater table: Studies reveal the removal of waterbodies has led to the decline in water table. Water table has declined to 300 m from 28 m over a period of 20 years after the reclamation of lake with its catchment for commercial activities. Also, groundwater table in intensely urbanized area such as whitefield, etc. has now dropped to 400 to 500m.
- Heat island: Surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration.
- Increased carbon footprint: Due to the adoption of inappropriate building architecture, the consumption of electricity has increased in certain corporation wards drastically. The building design conducive to tropical climate would have reduced the dependence on electricity. Higher energy consumption, enhanced pollution levels due to the increase of private vehicles, traffic bottlenecks have contributed to carbon emissions significantly. Apart from these, mismanagement of solid and liquid wastes has aggravated the situation.

Unplanned urbanisation has drastically altered the drainage characteristics of natural catchments, or drainage areas, by increasing the volume and rate of surface runoff. Drainage systems are unable to cope with the increased volume of water and are often encountered with the blockage due to indiscriminate disposal of solid wastes. Encroachment of wetlands, floodplains, etc. obstructs floodways causing loss of natural flood storage. Damages from urban flooding could be categorized as: direct damage – typically material damage caused by water or flowing water, and indirect damage – e.g. traffic disruptions, administrative and labour costs, production losses, spreading of diseases, etc.

Studies on the phenomenon of Urban Heat Island (UHI) using satellite derived land surface temperature (LST) measurements have been conducted using various satellite data products acquired in thermal region of the electromagnetic spectrum. Currently available satellite thermal infrared sensors provide different spatial resolution and temporal coverage data that can be used to estimate LST. The Geostationary Operational Environmental Satellite (GOES) has a 4-km resolution in the thermal infrared, while the NOAA-Advanced Very High Resolution Radiometer (AVHRR) and the Terra and Aqua-MODIS have 1-km spatial resolutions. Significantly high resolution data come from the Terra-Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) which has a 90-m pixel resolution, the Landsat-5 Thematic Mapper (TM) which has a 120-m resolution, and Landsat-7 Enhanced Thematic Mapper (ETM) which has a 60-m resolution. However, these instruments have a repeat cycle of 16 days (Li et. al., 2004; Ramachandra and Uttam Kumar, 2009). Weng (2001, 2003) examined LST pattern and its relationship with land cover (LC) in Guangzhou and in the urban clusters in the Zhujiang Delta, China. Nikolakopopulos et al., (2003) have used Landsat-5 TM and Landsat-7 ETM+ data for creating the temperature profile of Alfios River Basin. Stathopoulou and Cartalis (2007) have used Landsat ETM+ data to identify daytime urban heat island using Corine LC data for major cities in Greece. Using a Landsat ETM+ imagery of City of Indianapolis, IN, USA, Weng et al., (2004) examined the surface temperature UHI in the city. They derived LST and analysed their spatial variations using Landsat ETM+ thermal measurements with the urban vegetation abundance and investigated their relationship. UHI studies have traditionally been conducted for isolated locations and with in situ measurements of air temperatures. The advent of satellite remote sensing technology has made it possible to study UHI both remotely and on continental or global scales (Streutker, 2002). In this work, Landsat data of 1973 (of 79 m spatial resolution), 1992 and 2000 (30 m), IRS LISS-III data of 1999 and 2006 (23.5 m) and MODIS data of 2002 and 2007 (with 250 m to 500 m spatial resolution) are used with supervised pattern classifiers based on maximum likelihood (ML) estimation. Also, an attempt is made to map land surface temperatures across various LC types to understand heat island effect.

Study Area

Greater Bangalore (77°37'19.54" E and 12°59'09.76" N) is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka with an area of 741 sq. km. Bangalore city administrative jurisdiction was widened in 2006 by merging the existing area of Bangalore city spatial limits with 8 neighbouring Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District (Ramachandra and Uttam Kumar, 2008; Sudhira et al., 2007). Thus, Bangalore has grown spatially more than ten times since 1949 (69 square kilometers) and is a part of both the Bangalore urban and rural districts (figure 1). Now, Bangalore is the fifth largest metropolis in India currently with a population of about 7 million (figure 2). The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last ten years. The summer temperature ranges from 18° C – 38° C, while the winter temperature ranges from 12° C – 25° C. Thus, Bangalore enjoys a salubrious climate all round the year. Bangalore is located at an altitude of 920 meters above mean sea level, delineating four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds. The undulating terrain in the region has facilitated creation of a large number of tanks providing for the traditional uses of irrigation, drinking, fishing and washing. This led to Bangalore having hundreds of such water bodies through the centuries. Even in early second half of 20th century, in 1961, the number of lakes and tanks in the city stood at 262 (and spatial extent of Bangalore was 112 sq km). However, number of lakes and tanks in 1985 was 81 (and spatial extent of Bangalore was 161 sq km).

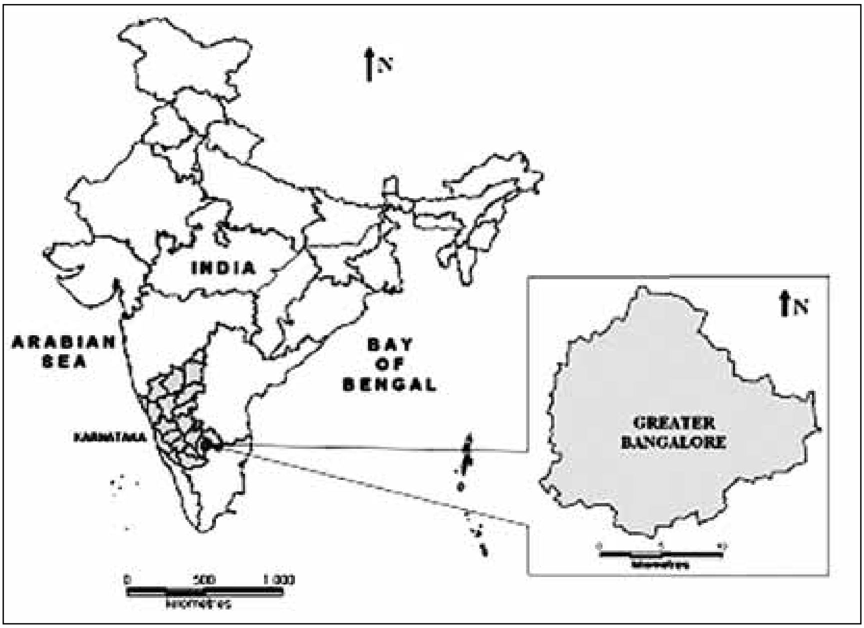


Figure 1: Study area – Greater Bangalore.

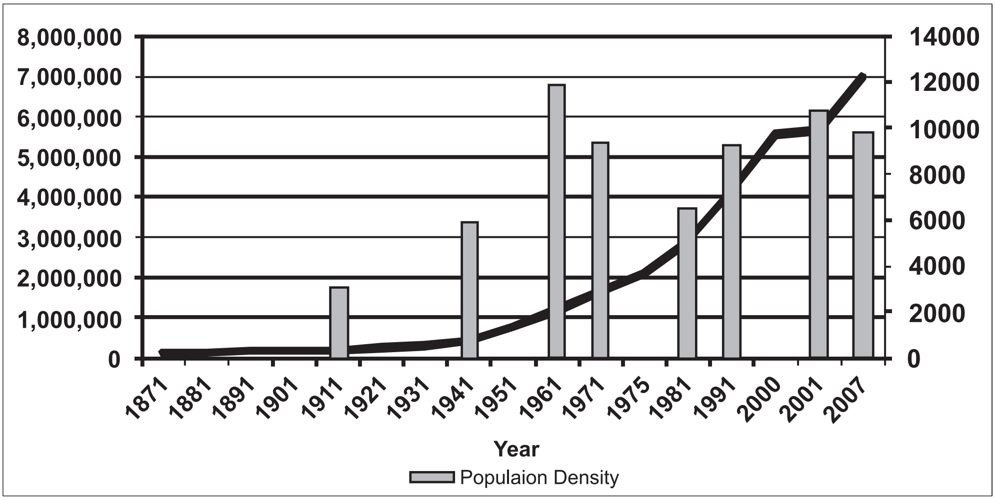


Figure 2: Population growth and population density.

Materials and Methods

Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales were used to generate base layers. Field data were collected with a handheld GPS. Remote sensing data used for the study are: Landsat MSS (1973), Landsat TM (1992), Landsat ETM+ (2000 and 2009) [Landsat data downloaded from http://glcf.umiacs.umd.edu/data/], IRS (Indian Remote Sensing) LISS (Linear Imaging Self Scanner)-III of (1999 and 2006), MODIS (Moderate Resolution Imaging Spectroradiometer) Surface Reflectance 7 bands product [downloaded from http://edcdaac.usgs.gov/main.asp] of 2002, MODIS Land Surface Temperature/Emissivity 8-Day L3 Global and Daily L3 Global (V004 product) [http://lpdaac.usgs.gov/modis/dataproducts.asp#mod11]. Google Earth data (http://earth.google.com) served in pre and post classification process and validation of the results. Latest data for 2010 (IRS – Indian remote Sensing) was procured from the National remote Sensing Centre (http://www.nrsc.gov.in), Hyderabad. The methods adopted in the analysis involved:

1. Georeferencing of acquired remote sensing data to latitude-longitude coordinate system with Evrst 56 datum: Landsat bands, IRS LISS-III MSS bands, MODIS bands 1 and 2 (spatial resolution 250 m) and bands 3 to 7 (spatial resolution 500 m) were geo-corrected with the known ground control points (GCP's) and projected to Polyconic with Evrst 1956 as the datum, followed by masking and cropping of the study area.
   - i) Band 1, 2, 3 and 4 of Landsat 1973 data to 79 m.
   - ii) Band 1, 2, 3 and 4 of Landsat TM of 1992 to 30 m.
   - iii) Band 1, 2, 3, 4, 5 and 7 of Lansat ETM+ to 30 m.
   - iv) MODIS bands 1 to 7 to 250 m.
   - v) IRS LISS-III band 1, 2 and 3 to 23.5 m.

vi) Thermal band of TM (resampled to 120m), ETM+ (to 60m) and MODIS (to 1 km) and Panchromatic bands of ETM+ (resampled to 15 m).

2. Supervised Classification using Bayesian Classifier: In supervised classification, the pixel categorisation process is done by specifying the numerical descriptors of the various LC types present in a scene. It involves (i) training, (ii) classification and (iii) output.
3. Accuracy assessment: Accuracy assessments were done with field knowledge, visual interpretation and also referring Google Earth (http://earth.google.com).
4. Computation of Normalised Difference Vegetation Index (NDVI): It separates green vegetation from its background soil brightness and retains the ability to minimize topographic effects while producing a measurement scale ranging from –1 to +1 with NDVI-values < 0 representing no vegetation.

Derivation of Land Surface Temperature (LST)

LST from Landsat TM: The TIR band 6 of Landsat-5 TM was used to calculate the surface temperature of the area. The digital number (DN) was first converted into radiance LTM using

$L_{TM} = 0.124 + 0.00563 * DN$ ….. (Equation 1)

The radiance was converted to equivalent blackbody temperature $T_{TMSurface}$ at the satellite using

$T_{TMSurface} = K_2/(K_1 - \ln LTM¬) - 273$ ….. (Equation 2)

The coefficients K_1 and K_2 depend on the range of blackbody temperatures. In the blackbody temperature range 260-300K the default values (Singh, S. M., 1988) for Landsat TM are K_1 = 4.127 and K_2 = 1274.7. Brightness temperature is the temperature that a blackbody would obtain in order to produce the same radiance at the same wavelength (λ = 11.5 µm). Therefore, additional correction for spectral emissivity (ε) is required to account for the non-uniform emissivity of the land surface. Spectral emissivity for all objects are very close to 1, yet for more accurate temperature derivation emissivity of each LC class is considered separately. Emissivity correction is carried out using surface emissivities for the specified LC (table 1) derived from the methodology described in Snyder *et al*., (1998) and Stathopoulou *et al*. (2006).

Table 1: Surface emissivity values by LC type

LC type	Emissivity
Densely urban	0.946
Mixed urban (Medium Built)	0.964
Vegetation	0.985
Water body	0.990
Others	0.950

The procedure involves combining surface emissivity maps obtained from the Normalized Difference Vegetation Index Thresholds Method (NDVITHM) (Sobrino and Raissouni, 2000) with LC information. The emmissivity corrected land surface temperature (Ts) were finally computed as follows (Artis and Carnhan, 1 982)

$$T_s = \frac{T_B}{1 + (\lambda \times T_B / \rho) \ln \varepsilon} \quad \text{..... (Equation 3)}$$

where, λ is the wavelength of emitted radiance for which the peak response and the average of the limiting wavelengths (λ = 11.5 μm) were used, ρ = h x c/σ (1.438 x 10^{-2} mK), σ = Stefan Bolzmann's constant (5.67 x 10^{-8} $Wm^{-2}K^{-4}$ = 1.38 x 10^{-23} J/K), h = Planck's constant (6.626 x 10^{-34} Jsec), c = velocity of light (2.998 x 10^{8} m/sec), and ε is spectral emissivity.

LST from Landsat ETM+: The TIR image (band 6) was converted to a surface temperature map according to the following procedure (Weng *et al*., 2004). The DN of Landsat ETM+ was first converted into spectral radiance LETM using equation 4, and then converted to at-satellite brightness temperature (i.e., black body temperature, $T_{ETMSurface}$), under the assumption of uniform emissivity (ε ≈ 1) using equation 5 (Landsat Project Science Office, 2002):

L_{ETM} = 0.0370588 x DN + 3.2 ….. (Equation 4)

$T_{ETMSurface}$ = K2/ln (K_1/ LETM + 1) ….. (Equation 5)

where, TETMSurface is the effective at-satellite temperature in Kelvin, LETM is spectral radiance in watts/(meters squared x ster x μm); and K_2 and K_2 are pre-launch calibration constants. For Landsat-7 ETM+, K_2 = 1282.71 K and K_1 = 666.09 $mWcm^{-2}$sr-1μm^{-1} were used(http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter11/chapter11.html). The emissivity corrected land surface temperatures Ts were finally computed by equation 3.

Results and Discussion

The supervised classified images of 1973, 1992, 1999, 2000, 2002, 2006 and 2009 with an overall accuracy of 72%, 75%, 71%, 77%, 60%, 73% and 86% were obtained using the open source programs (i.gensig, i.class and i.maxlik) of Geographic Resources Analysis Support System (http://wgbis.ces.iisc.ernet.in/ grass) as displayed in figure 3.1. The class statistics is given in table 2. The implementation of the classifier on Landsat, IRS and MODIS image helped in the digital data exploratory analysis as were also verified from field visits in July, 2007 and Google Earth image. From the classified raster maps, urban class was extracted and converted to vector representation for computation of precise area in hectares. There has been a 632% increase in built up area from 1973 to 2009 leading to a sharp decline of

79% area in water bodies in Greater Bangalore mostly attributing to intense urbanisation process. Figure 4 shows Greater Bangalore with 265 water bodies (in 1972). The rapid development of urban sprawl has many potentially detrimental effects including the loss of valuable agricultural and eco-sensitive (e.g. wetlands, forests) lands, enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use (Ramachandra and Shwetmala, 2009). Vegetation has decreased by 32% from 1973 to 1992, by 38% from 1992 to 2002 and by 63% from 2002 to 2009. Disappearance of water bodies or sharp decline in the number of waterbodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes (54%) were unauthorised encroached for illegal buildings. Field survey (during July-August 2007) shows that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervene the natural catchment flow leading to sharp decline and deteriorating quality of waterbodies. This is correlated with the increase in built up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular waterbodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times.

Study area was divided into concentric incrementing circles of 1 km radius (with respect to centroid or central business district) in each zone as shown in Figure 3.2. This illustrates radial pattern of urbanization for the period 1973 to 2010. In 1973 the growth was concentrated closer to the central business district and was very minimal. In 1992 Bangalore grew intensely in the NW and SW zones. This growth can be attributed to the policy of industrialization consequent to the globalization during early 90's. Consequent to this, the industrial layouts came up in these areas specially in the NW and SW intensified the urban growth and as a result land was also acquired for housing and urban sprawl was noticed in others parts of the Bangalore. These phenomena intensified during post 2000 as the SE and NE Bangalore saw intense growth for development of IT and BT sectors. Subsequent to this, relaxation of FAR (Floor area ratio) in mid 2005, lead to the spurt in residential sectors, paved way for large scale conversion of land leading to intense urbanization in these localities. This also led to the compact growth at central core areas of Bangalore and sprawl at outskirts which are deprived of basic amenities. The analysis showed that Bangalore grew radially from 1973 to 2010 indicating that the urbanization is intensifying from the city centre and has reached the periphery of the Greater Bangalore.

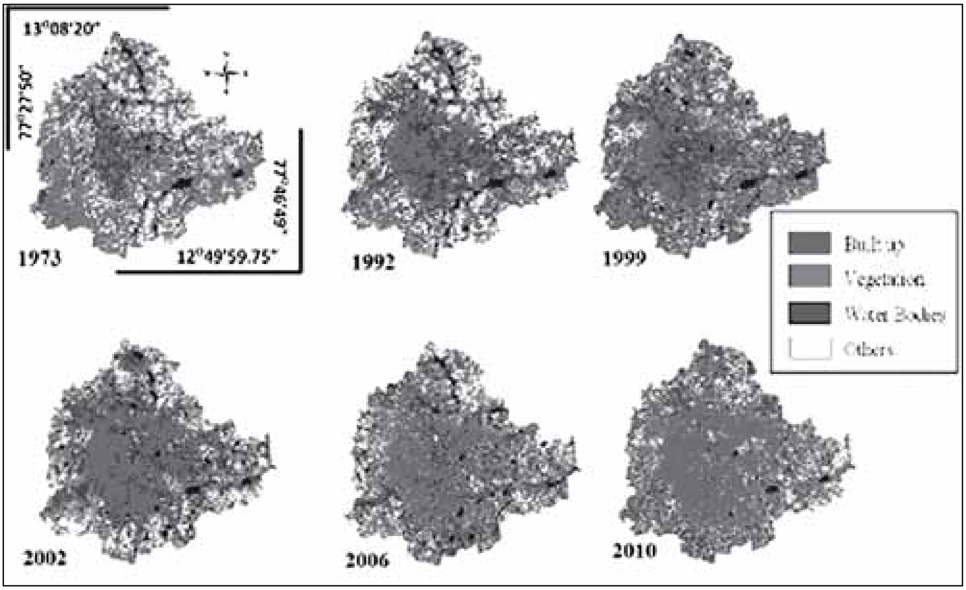


Figure 3.1: Greater Bangalore in 1973, 1992, 1999, 2002, 2006 and 2010.

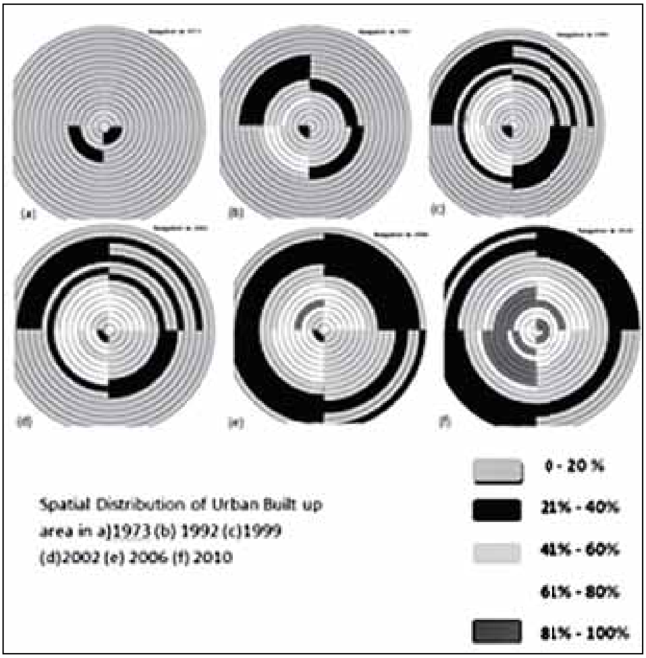


Figure 3.2: Gradient analysis of Greater Bangalore
Builtup density circlewise & zonewise from 1973 to 2010

Table 2: Greater Bangalore LC statistics

Class	Urban		Vegetation		Water		Others	
Year	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
1973	5448	7.97	46639	68.27	2324	3.40	13903	20.35
1992	18650	27.30	31579	46.22	1790	2.60	16303	23.86
1999	24163	35.37	31272	45.77	1542	2.26	11346	16.61
2002	25782	37.75	26453	38.72	1263	1.84	14825	21.69
2006	29535	43.23	19696	28.83	1073	1.57	18017	26.37
2010	37266	54.42	16031	23.41	617	0.90	14565	21.27

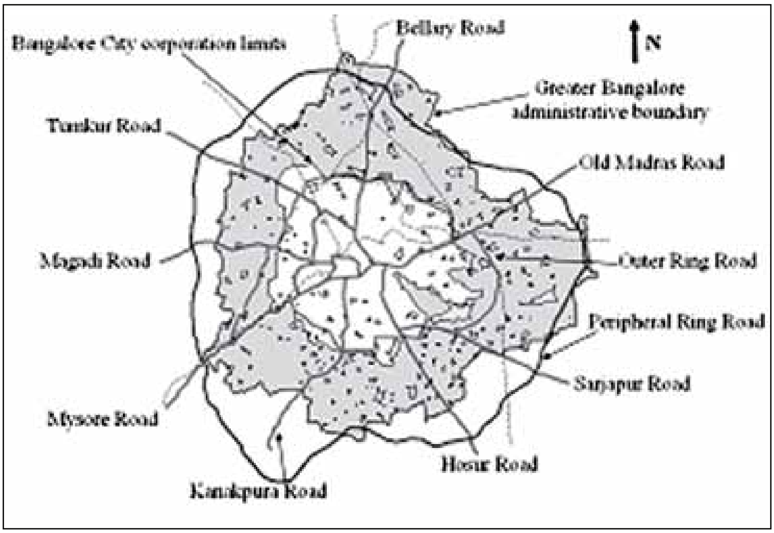
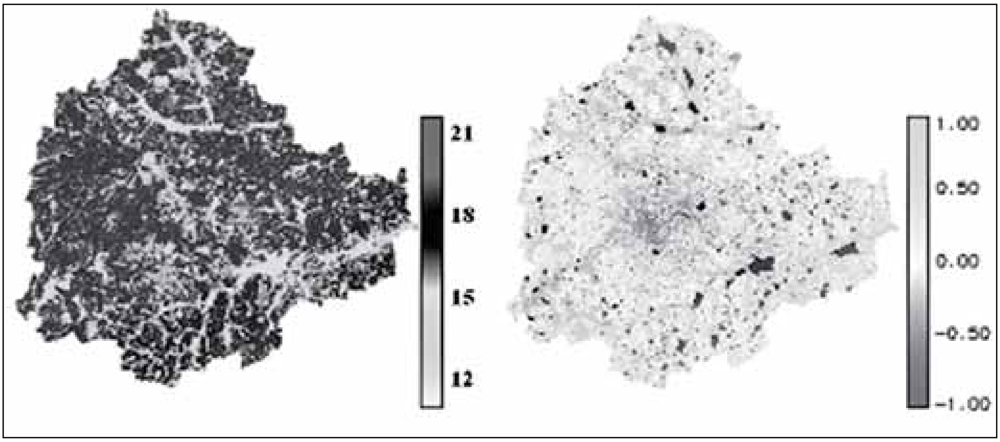


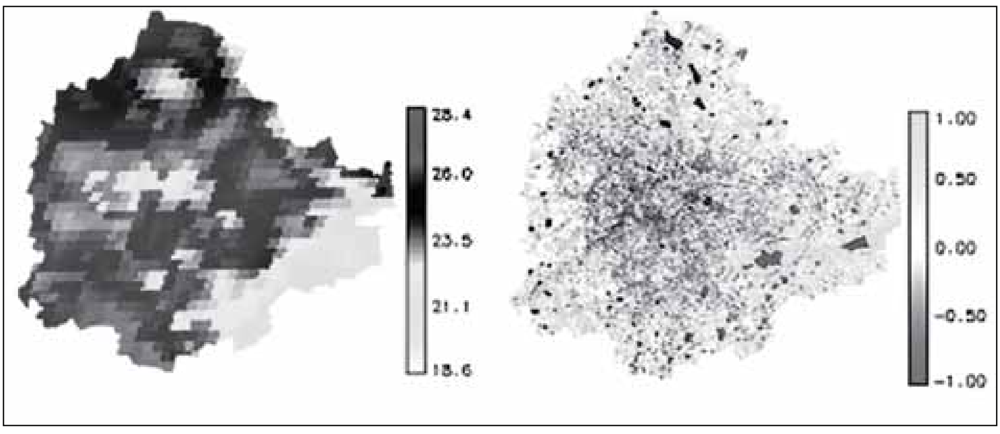
Figure 4: Greater Bangalore with 265 water bodies.

LST were computed from Landsat TM and ETM thermal bands. The minimum and maximum temperature from Landsat TM data of 1992 was 12 and 21 with a mean of 16.5±2.5 while for ETM+ data was 13.49 and 26.32 with a mean of 21.75±2.3. MODIS Land Surface Temperature/ Emissivity (LST/E) data with 1 km spatial resolution with a data type of 16-bit unsigned integer were multiplied by a scale factor of 0.02 (http://lpdaac.usgs.gov/modis/dataproducts.asp#mod11). The corresponding temperatures for all data were converted to degree Celsius.

Figure 5 shows the LST map and NDVI of Greater Bangalore in 1992, 2000 and 2007. The minimum (min) and maximum (max) temperatures were computed as 20.23, 28.29 and 23.79, 34.29 with a mean of 23.71±1.26, 28.86± 1.60 for 2000 and 2007 respectively. Data were calibrated with in-situ measurements. NDVI was computed to study its relationship with LST. The Landsat TM NDVI had a mean of 0.04±0.4543, ETM+ data had a mean of 0.0252±0.5369 and MODIS had a mean of -0.0917±0.5131.

The correlation between NDVI and temperature of 1992 TM data was 0.88, 0.72 for MODIS 2000 and 0.65 for MODIS 2007 data respectively, suggesting that the extent of LC with vegetation plays a significant role in the regional LST. Respective NDVI and LST for different land uses is given in table 3 and further analysis was carried out to understand the role of respective land uses in the regional LST's.





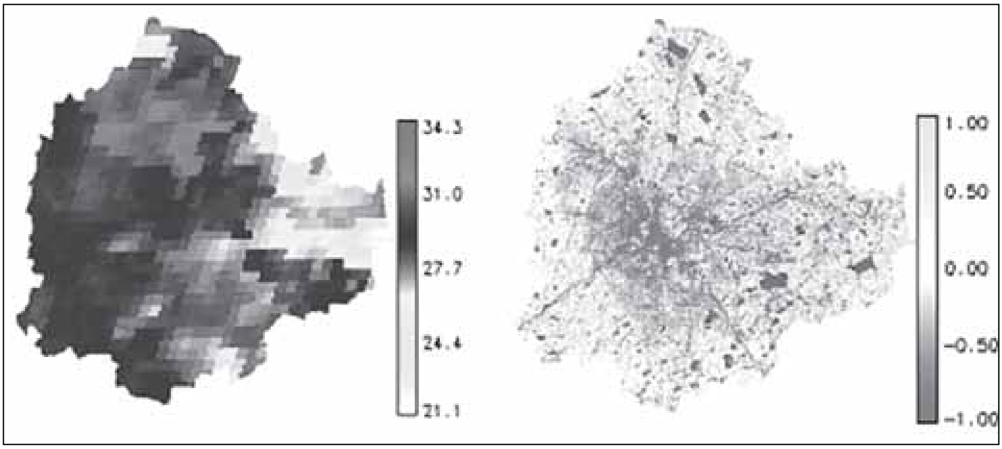


Figure 5: LST and NDVI from Landsat TM (1992), MODIS (2002 and 2007).
(Note: pixelisation of MODIS 2002 and 2007 is mainly due to coarse spatial resolution ~ 1 Km)

Table 3: LST (°C) and NDVI for various land uses.

Land use	1992 (TM)		2000 (MODIS)		2007 (MODIS)	
	LST ± SD	NDVI ±SD	LST ± SD	NDVI ±SD	LST ± SD	NDVI ± SD
Builtup	19.03 ±1.47	-0.162 ±0.096	26.57 ±1.25	-0.614 ±0.359	31.24 ±2.21	-0.607 ±0.261
Vegetation	15.51 ±1.05	0.467 ±0.201	22.21 ±1.49	0.626 ±0.27	25.79 ±0.44	0.348 ±0.42
Water bodies	12.82 ±0.62	-0.954 ±0.055	21.27 ±1.03	-0.881 ±0.045	24.20 ±0.27	-0. 81 ±0.27
Open ground	17.66 ±2.46	-0.106 ±0.281	24.73 ±1.56	-0.016 ±0.283	28.85 ±1.54	-0.097 ±0.18

It is clear that urban areas that include commercial, industrial and residential land exhibited the highest temperature followed by open ground. The lowest temperature was observed in water bodies across all years and vegetation. Spatial variation of NDVI is not only subject to the influence of vegetation amount, but also to topography, slope, solar radiation availability, and other factors (Walsh et al., 1997). The relationship between LST and NDVI was investigated for each LC type through the Pearson's correlation coefficient at a pixel level and are listed in table 4. The significance of each correlation coefficient was determined using a one-tail Student's t-test. It is apparent that values tend to negatively correlate with NDVI for all LC types. NDVI values for built up ranges from -0.05 to -0.6. Temporal increase in temperature with the increase in the number of urban pixels during 1992 to 2009 (113%) is confirmed with the increase in 'r' values for the respective years. The NDVI for vegetation ranges from 0.15 to 0.6. Temporal analyses of the vegetation show a decline of 65%, with a consequent increase in the temperature.

Table 4: Correlation coefficients between LST and NDVI by LC type (p=0.05)

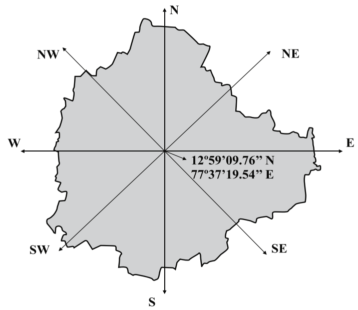
Land use	**1992**	**2000**	**2007**
Built up	-0.7188	-0.7745	-0.7900
Vegetation	-0.8720	-0.6211	-0.6071
Open ground	-0.6817	-0.5837	-0.6004
Water bodies	-0.4152	-0.4182	-0.4999

A closer look at the values of NDVI by LULC category (table 3) indicates that the relationship between LST and NDVI may not be linear. Clearly, it is necessary to further examine the existing LST and vegetation abundance relationship using fraction as an indicator. The abundance images using linear unmixing from ETM+ bands were further analysed to see their contribution to the UHI by separating the pixels that contains 0-20%, 20-40%, 40-60%, 60-80% and 80-100% of urban pixels. Table 5 gives the average LST for various land use classes.

Table 5: Mean LST for various land use classes for different abundances

Class Abundance	Mean Temperature± SD of dense urban	Mean Temperature± SD of mixed urban	Mean Temperature± SD of vegetation
0-20%	21.99±2.37	21.57±2.36	17.91±2.19
20-40%	22.06±2.15	21.58±2.36	17.39±1.37
40-60%	22.27±2.00	21.67±2.41	17.22±0.89
60-80%	22.33 ±2.22	22.28±2.02	17.13±0.85
80-100%	22.47±1.96	22.37±2.17	17.12±0.91

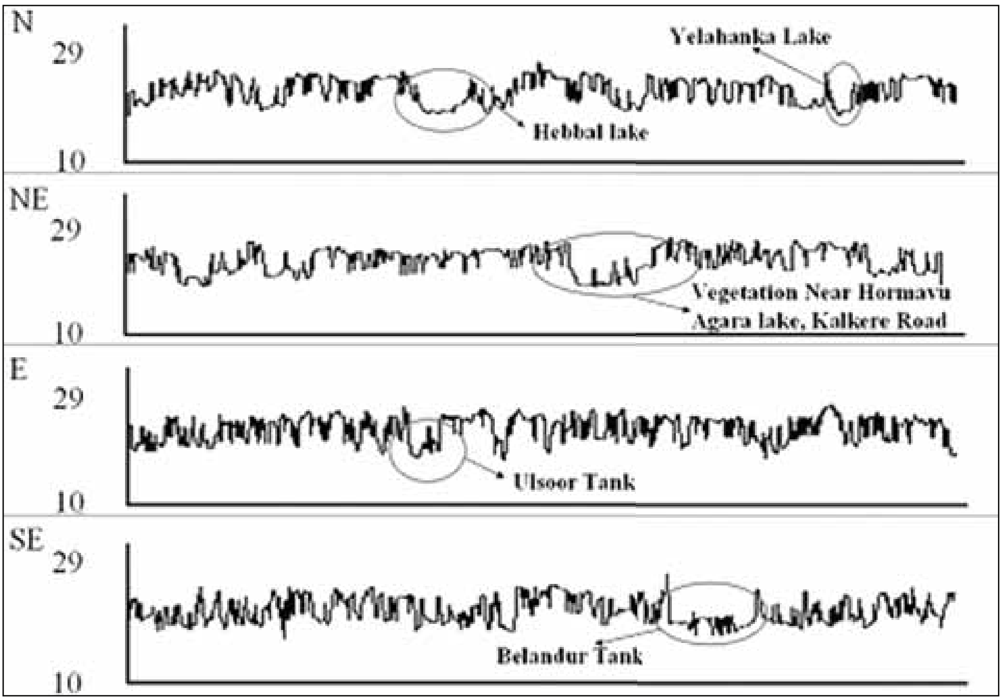
8 transacts were laid across the city in different directions (north [N], north-east [NE], east [E], south-east [SE], south [S], south-west [SW], west [W] and north-west [NW]) and LST was analysed as shown in figure 6, to understand the temperature dynamics.



Direction	Means LST±SD
N	21.30±2.39
NE	22.15±2.22
E	21.01±2.47
SE	21.34±2.30
S	21.71±2.07
SW	22.19±1.92
W	22.97±1.72
NW	22.07±2.25

Figure 6: Transect lines superimposed on Greater Bangalore boundary along with LST in various directions.

The temperature profile was analysed by overlaying the LST map on the Baye's classified map to visualise the effect of vegetation, builtup, water bodies and open ground. The temperature profile plot fell below the mean when a vegetation patch or water body was encountered on the transact beginning from the center of the city and moving outwards along the transact. The corresponding graphs are shown in figure 7. The major natural green area and water bodies responsible for temperature decline are marked with circle. The spatial location of these green areas and water bodies are shown in figure 8.



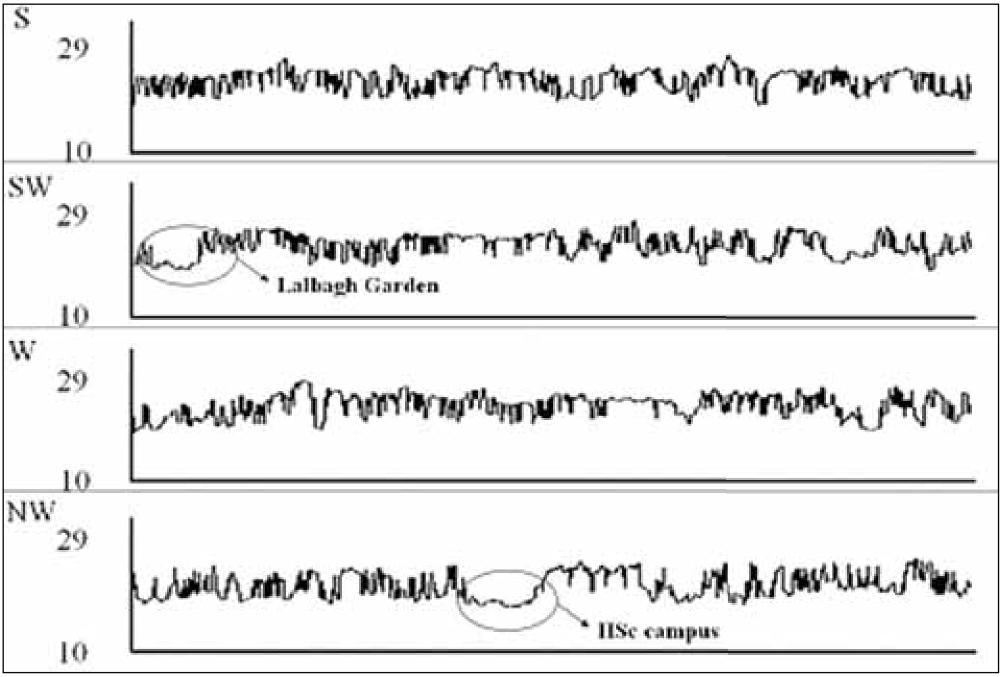


Figure 7: Temperature profile in various directions. X axis – Movement along the transacts from the city centre, Y axis - Temperature (°C).

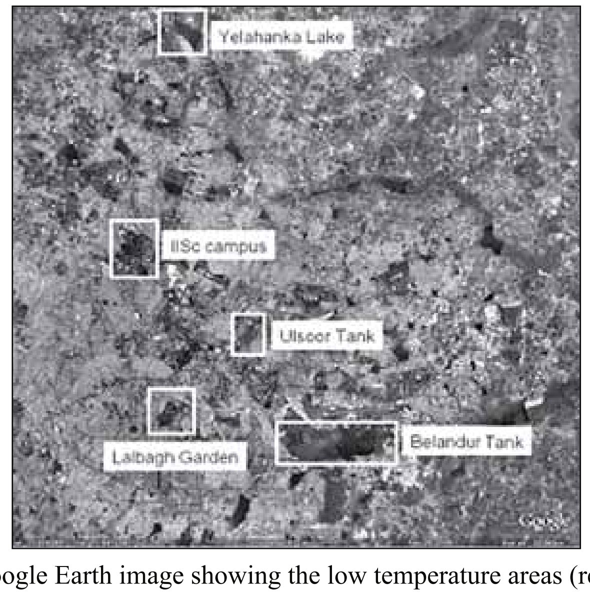


Figure 8: Google Earth image showing the low temperature areas (refer figure 7). [Source: http://earth.google.com/]

Conclusion

Urbanisation and the consequent loss of lakes has led to decrease in catchment yield, water storage capacity, wetland area, number of migratory birds, flora and fauna diversity and ground water table. As land is converted, it loses its ability to absorb rainfall. The relationship between LST and NDVI investigated through the Pearson's correlation coefficient at a pixel level and the significance tested through one-tail Student's t-test, confirms the relationship for all LC types. Also, increased urbanisation has resulted in higher population densities in certain wards, which incidentally have higher LST due to high level of anthropogenic activities. The growth poles are towards N, NE, S and SE of the city indicating the intense urbanization process due to growth agents like setting up of IT corridors, industrial units, etc. Newly builtup areas in these regions consisted of maximum number of small-scale industries, IT companies, multistoried building and private houses that came up in the last one decade. The growth in northern direction can be attributed to the new International Airport, encouraging other commercial and residential hubs. The southern part of the city is experiencing new residential and commercial layouts and the north-western part of the city outgrowth corresponds to the Peenya industrial belt along with the Bangalore-Pune National Highway 4.

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References

1. Artis, D. A., and Carnahan, W. H. (1982), Survey of emissivity variability in thermography of urban areas. *Remote Sensing of Environment* 12: 13-329.
2. Kulkarni, V. and Ramachandra T.V. (2006), *Environmental Management,* Commonwealth Of Learning, Canada and Indian Institute of Science, Bangalore.
3. Landsat Project Science Office. (2002), Landsat 7 *science data user's* handbook. Goddard Space Flight Center, Available at: http://ltwww.gsfc.nasa.gov/IAS/handbook/ handbook_toc.html.
4. Li, F., Jackson, T. J., Kustas, W, Schmugge, T., J., French, A. N., Cosh, M. L., and Bindlish, R. (2004), Deriving land surface temperature from Landsat 5 and 7 during SMEX02/SMACEX. *Remote Sensing of Environment 92*: 521-534.
5. Nikolakopoulos, K. G, Vaiopoulos, D. A, Skianis, G. A. (2003), Use of multitemporal remote sensing thermal data for the creation of temperature profile of Alfios river basin. *Geoscience and Remote Sensing Symposium, 21-25 July 2003, IGARSS '03. Proceedings,IEEE International,* 4: 2389-2391.
6. Ramachandra T V and Uttam Kumar (2009), Land surface temperature with land cover dynamics: multi-resolution, spatio-temporal data analysis of Greater Bangalore, *International Journal of Geoinformatics,* 5 (3):43-53
7. Ramachandra T.V and Uttam Kumar (2008), Wetlands of Greater Bangalore, India: Automatic Delineation through Pattern Classifiers, *The Greendisk Environmental Journal.* Issue 26 (http://egj.lib.uidaho.edu/index.php/egj/article/view/3171).
8. Ramachandra T.V. and Shwetmala (2009), Emissions from India's Transport sector: Statewise Synthesis, *Atmospheric Environment,* 43 (2009) 5510–5517.
9. Singh, S., M. (1998). Brightness Temperatures Algorithms of Landsat Thematic Mapper Data. *Remote Sensing of Environment* 24: 509-512.
10. Snyder, W. C., Wan, Z., Zhang, Y., and Feng, Y. Z. (1998), Classification based emissivity for land surface temperature measurement from space. *International Journal of Remote Sensing 19*: 2753-2774.

11. Sobrino, J. A., and Raissouni, N. (2000), Toward remote sensing methods for land cover dynamic monitoring: Application to Morocco. *International Journal of Remote Sensing 21*: 353-366.

12. Stathopoplou, M., Cartalis, C. and Petrakis, M. (2006), Integrating CORINE land cover data and landsat TM for surface emissivity definitions: an application for the urban area of Athens, Greece, *International Journal of Remote Sensing. 20*: 2367–2393

13. Stathopoulou, M., and Cartalis, C. (2007), Daytime urban heat island from Landsat ETM+ and Corine land cover data: An application to major cities in Greece. *Solar Energy 81*: 358-368.

14. Streutker, D. R. (2002), A remote sensing study of the urban heat island of Houston, Texas. *International Journal of Remote Sensing* 23: 2595-2608.

15. Sudhira H.S., Ramachandra T.V., Bala Subramanya M.H. (2007), City Profile: Bangalore., *Cities l24*(4): 379-390.

16. Sudhira, H.S., Ramachandra, T.V., and Jagadish, K. S. (2003). Urban sprawl: metrics, dynamics and modelling using GIS, *International Journal of Applied Earth Observation and Geoinformation* 5(2004): 29-39.

17. UN, (2005), World U*rbanization Prospects.* Revision, Population Division, Department of Economic and Social Affaris, UN.

18. Walsh, S. J., Moody, A., Allen, T. R., and Brown, D. G. (1997), Scale dependence of NDVI and its relationship to mountainous terrain. In *Scale in Remote Sensing and GIS* edited by Quattrochi D. A. & Goodchild M. F., pp. 27-55, Boca Raton, FL: Lewis Publishers.

19. Weng, Q. (2001), A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. *International Journal of Remote Sensing 22:* 1999-2014.

20. Weng, Q. (2003), Fractal analysis of satellite-detected urban heat island effect. *Photogrammetric Engineering and Remote Sensing 69:* 555-566.

21. Weng, Q., Lu, D., and Schubring, J. (2004), Estimation of land surface temperature – vegetation abundances relationship for urban heat island studies. *Remote Sensing of Environment 89:* 467-483.

8

Managing Fire and Pests in Forestry: Approach to Ecosystem Health

Anil K. Gupta and A. D. Kaushik

Concept of ecosystem health can be better illustrated through "forest health" as forests are the most productive among natural ecosystems. Most recent definitions of forest health range between utilitarian and ecosystem perspectives. From a utilitarian perspective, a desired state of forest health can be considered "a condition where biotic and abiotic influences on forests (e.g. pests, pollution, silvicultural treatments, harvesting) do not threaten management objectives now or in the future" (USDA Forest Service, 1993a). "A healthy forest is one that is resilient to changes" (Joseph et al., 1991). The term "forest health" denotes the productivity of forest ecosystems and their ability to bounce back after stress (Radloff et. al., 1991). Haskell et. al. (1992) suggests that a healthy ecosystem should be free from "distress syndrome". This syndrome is characterized by reduced primary productivity, loss of nutrient capital, loss of biodiversity, increased fluctuations in key populations, retrogression in biotic structure (a reversal of normal succession processes whereby opportunistic species replace the species more specialized in habitat and resource use); and widespread incidence of severity of disease (Rapport, 1992).

A useful ecosystem concept of forest health must consider patterns and rates of spatial and temporal changes in forest composition and structure. According to Leopold (1949) "health is the capacity for self-renewal". Forest health is also defined (Sampson et. al., 1994) as a condition of forest ecosystems that sustains their complexity while providing vital resources for human needs. Therefore, evaluations of forest health must be made within the context of successional process and ecosystem dynamics (Siegel, 1994). The present paper deals with the problems of forest fire and pests, and their integrated management with the ecosystem-health approach.

The Destruction of Forests

World forests and woodlands at present occupy more than three million hectares (Ramade, 1984). These forests have been steadily receding ever since the earliest Paleolithic times, but the pace of retreat has accelerated since the Neolithic age and has become particularly

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rapid over the last 100 years as population have exploded. Deforestation has arisen from four principal causes, often in combination with each other : excessive felling of trees for timber, overgrazing, fire and clearance of land for cultivation and pasture. Besides these, pests (insects and pathogens) also cause significant tree mortality and growth loss on millions of acres of forestlands each year (Haack and Byler, 1993). Ecosystem management, the term, is described as keeping forest ecosystems functioning well over long periods of time in order to provide resilience to short-term stress and adaptation to long-term change (SAF, 1993). Integrated forest management thus re-evaluates the approaches to managing forest fire and pests, and consider more fully their effects on the sustainability of forest ecosystems.

Problem of Forest Fire

Fire is one of the significant causes of deforestation throughout the world. It poses a permanent threat to dry forests (Ramade, 1984). Dating of the oldest prehistoric sites of fires in caves in South Africa indicates that hominids have been able to use fire for about the last 1.5 million years. Fire was used for a wide variety of purposes in the earliest cultural stages of development : in addition to purely "household" applications (cooking, heating), fire was used for hunting, or to clear forested and busk-covered landscape for security reasons, and later because it was the only effective tool for clearing land (slash and burn technique) and keeping it open for grazing (Goldammer, 1994).

Causes of Forest Fire

Forest fire may occur due to the following causes (Negi, 1991):

1. Intentional causes: More than half of the occurrences of fires in India are due to intentional causes. The intentions to set fire to the forests are -
   a) Villagers set fire to the forest floor to obtain a good growth of grass in the months following rains (Pande, 1995). This fire develops into an inferno and destroys a large forest area
   b) Wild grass or undergrowth is burnt by the tribals to search for wild animals (Goldammer, 1994)
   c) The local people set fire to the forest to scare away wild animals from villages and fields (Goldammer, 1994)
   d) Forest fires are used as a tool by miscreants for taking revenge on forest officials - they set fire to the forest in a bid to settle scores with the forest departments
   e) Attempts are made to destroy the evidence of illicit fellings by setting fire to the forest (Pande, 1995)

2. Unintentional Causes: This includes all types of forest fires which occur unintentionally or accidentally. The fire breaks out due to oversight and there is no intention to set fire to the forest. Some causes are -
   a) Unextinguished camp fires of trekkers or labour camps in the forest vicinity may develop an inferno (Ramade, 1984)
   b) Sparks of fire from steam/diesel engines

c) Unextinguished cigarette butts or matchsticks carelessly thrown by villagers or people passing along a forested area may set off a forest fire (Ramade, 1984)
d) When a fires lit to burn agricultural fields are left unattended, it may spread to the adjoining forest areas
e) Careless throwing of flamming torchwood by travelers or villagers passing through a forest at night
f) During controlled operations being carried out by the forest department, the fire may spread to other forest areas due to negligence of the staff

3. Natural Causes:
   a) Fire caused by lightning
   b) Fires caused by friction generated by rolling stones, bamboo culms, etc.
   c) Fires may also be caused by volcanic eruptions

Classification of Forest Fires

Forest fires cause the degradation of forests by exerting potential impact on forest crop, regeneration, productivity, protective power, soil, wildlife and aesthetics. The overall damage to the forest crop by fire depends upon (1) the species forming a part of the crop or composition of the forest, (2) condition of the crop, (3) time and season during which the fire occurs, (4) age of the crop, and (5) intensity of the fire (Negi, 1991). Broad-leaved trees are more affected than coniferous ones. Deodar, fir and spruce are extremely sensitive to fire while chir, due to its corky bark is being tapped for resins and various other terpenes they secrete, is vastly more inflammable than other species (Ramade, 1984). Crops of tender age are more susceptible to damage by fire. The thickness of the bark increases as the crop grows older and this makes the trees more resistant to damage by fire.

Surface or ground fires may wipe out the entire regeneration of a forest area (Negi, 1991; Goldammer, 1994). Regeneration may appear as a seedling coppice in case of species with good coppicing power but repeated burning affects its ability of producing coppice shoots.

Repeated forest fires considerably reduce the productive capacity of a forest. Valuable evergreen forests may be degenerated into an inferior quality deciduous forest or may even be reduced to a grassland stage. Fire affected forests yield less economic returns (Negi, 1991).

It is well known fact that forests have an important protective function. They maintain a decline balance for the ecosystem protection through (1) binding the soil together, (2) preventing the soil from being washed or blown away by water or wind, (3) breaking the force of the falling raindrops, (4) maintaining the balancing of gases like oxygen and carbon dioxide in the atmosphere, and (5) maintaining the nature's hydrological cycle (Ramade, 1984). Repeated burning breaks down this protective role of a forest and adversely affects nature's ecological balance (Negi, 1991).

Due to forest fires, soil is exposed to the action of different geological agencies such as wind and water, and the nutrient status of the soil is adversely affected (Negi, 1991). The decomposition of organic and even inorganic compounds of nitrogen by the heat causes an extra loss of nutrients. Forest fires are a real ecological disaster in regions with an intense summer drought because the soils become impoverished and their structure degraded. Enrichment of the soil by burning organic matter is only apparent, since the ashes are often either blown and dispersed by the wind or more severely leached by the first violent rainstorms (Ramade, 1984).

Forest fires cause extensive loss of wildlife by burning the eggs of birds, destroying the young ones, and damaging their habitat which is an integral part of the forest ecosystem. Fires, by destroying the forests, affect the acres of recreational and scenic values, making it ugly and scary, thus, being avoided by the tourists and picnickers.

Problem of Forest Pests

Several reports (USDA Forest Service, 1993) have consistently shown that insects and pathogens cause more losses than any damaging agent, including fire. But allocating losses to a single agent is questionable because insects and pathogens often interact with each other (Schowalter and Filip, 1993), as well as with climate and fire (Wickman, 1992). The stage of epidemics is often set by certain environmental stresses like, drought, air pollution, late spring forest and wind throw (Mattson and Haack, 1987).

Insects pests are one of the major factors responsible for the deterioration of the forest ecosystem. Negi (1991) has outlined the major forms of damage as following :

1. Before the occurrence of seed fall and seed-dispersal the seeds may be attacked by a number of insect pests including weevils and pulse beetles. This has an adverse impact on forest regeneration.
2. Young seedlings are injured in the first year of their lives by some leaf eaters e.g. crickets.
3. The roots of young seedlings may be devoured by root eaters like cockchafers.
4. Leaf eating sap sucking insect pests cause damage to the forest irrespective of whether it has been raised through artificial or natural means.
5. Plants are injured by insect pests even after they have reached the pole or the sapling stage. These insects are the borers, sap-suckers and root eaters. Trees continue to be prone to damage by insect pests even after they have attained maturity.
6. When the trees die or are felled they are likely to be attacked by bark insects, longicorn beetles, shoot-hole beetles.
7. The damage caused by insect pest to forest trees becomes more acute due to certain reasons like (a) high reproductive capacity of the insect pests (b) more than one generation of insect pests may appear in a year and thus, their multiplication is in geometrical progression.

Insect pest of Indian forest trees are listed by Negi (1991). He has described the major pests of certain important Indian tree species like Teak, Shishum, Tun, Semal, Chir, Pine, and Sal. Teak (Tectona grandis) is a very important timber species found in India. Its leaves are attacked and skeletonized by two insect pests (1) Teak skeletonizer (Hapalia machaeralis) and (2) Teak defoliator (Hyblaea purea). Etropis deodarae, is observed to cause the defoliation of Deodar (Cedrus deodara). Shishum (Dalbergia sissoo) trees are defoliated by the shishum defoliator or Placoptera reflexa. It renders the tree leafless for a large part of the year and hampers its growth. Prolonged attack may even lead to mortality in saplings and poles.

Tun (Cedrella toona) is attacked by the tun shoot borer or Hypsiphyla robusta). It also attacks the trees of Swietenia and Chukrasia. In case of tun, the first two generations of the pest attack its flowers and fruits. This has an adverse effects on the production of seeds. The subsequent generations attack the shoots of these trees. Thus, rate of growth is checked and the young plants assume a bushy and stunted form.

Tonica niviferna, is known as Semal shoot borer. The young larva bores the saplings of semal near the leaf axile. It lives inside the shoot by boring a tunnel. The pest may make the shoot completely hollow, thus, killing the tree. Chir pine forest occupy large tracts in the Himalaya. It is attacked by the pine shoot borer or Ipis lingifolia. The damage is more sever in young crops though even older forests may be affected. Sal is another important timber species of India. Hoplocerymbax spinicornis is the most damaging insect pest of Sal forests. It causes damage to Sal (Shorea robusta) trees in two forms : (1) the larvae devour the calcium and kill the tree and (2) thus weakening the tree and affecting their overall growth (Negi, 1991).

The pine needle scale insects (Hemiberlesia Pitysophila) are the ivadors of new territories, and they develop rapidly when there is more than one generation per year (Rosen and DeBach, 1979). The tropical climate may permit four or five overlapping generations of the pine needle scale annually, so most stages are present at all the times of the year. The first nymphal instar, called a crowler, is the disperal stage of the insect. After dispersing, crowlers settler down on the foliage to become secondary scales. The scale rapidly rises to outbreak status because of multiple generations, high fecundity, and a paucity of natural enemies (Wilson, 1993).

Table 1. Global estimates of amounts of biomass burning and of resulting release of carbon into the atmosphere

Sources of burning	**Biomass burned** (Tg dry matter / year)	**Carbon released** (Tg carbon / year)
Savannas	3690	1660
Agricultural wastes	2020	910
Tropical forests	1260	570
Fuel wood	1430	640
Temperate and boreal forests	280	130
Charcoal	21	30
World Total	8700	3940

(Source: Levine et al., 1995)

Biomass Burning and Global Change

Biomass burning includes the burning of the worlds' vegetation-forests, Savannas, and agricultural lands- to clear the land and change its use. Biomass burning is recognized as a significant global source of emissions, contributing as much as 10 percent of gross carbon dioxide and 38 percent of tropospheric ozone (Levine et al., 1995).

Biomass burning serves a variety of land-use changes, including the clearing of forests and savannas for agriculture and grazing use; shifting agricultural practices; the control of grass, weeds and litter on agricultural and grazing lands; the elimination of stubble and waste on agricultural lands after the harvest; and the domestic use of biomass matter (Levine et al., 1995). While in the case of traditional shifting agriculture the gases released by burning and rottening is resequestered during the recovery phase, permanent clearing of the forests create a net flux of carbon into the atmosphere (Goldammer, 1994).

The vast majority of the worlds' burning is human-initiated, with lightening-induced natural fires accounting for only a small percentage of the total (Levine et al, 1995). The immediate effect of burning is the production and release of gases and particulates into the atmosphere. The instaneous combustion products of burning vegetation include carbon dioxide, carbon monoxide, methane, non-methane hydrocarbons, nitric oxide, methyl chloride, and various particulates. during th burning of a forest, carbon dioxide that was sequestered for periods ranging from decades to centuries is suddenly released and returned to the atmosphere in a matter of hours. The burning of forest also destroys an important sink for atmospheric carbon dioxide. Hence, burninghas carbon dioxide budget. If the burned ecosystem regrows, the carbon dioxide is eventually remove from the atmosphere via photosynthesis and is incorporated into the new vegetative growth. Other gaseous emissions, however, remain in the atmosphere. Fig. 1. shows the interrelationship of the factors which determine the ecosystem-health impacts of forest fire.

Because the vegetation fires described are not systematically monitored on a regional or worldwide scale, for example by spaceborne sensors, neither the aerial extent of these fires nor the amount of plant biomass combusted can be determined accurately or over long periods of time. The data available (table 1) for the amount of biomass burned annually and the amounts of carbon thus released, according to type of vegetation and fire event, are therefore only estimates which have been extrapolated from individual observations and various statistics, and they are not very reliable (Goldammer, 1994).

The gases produced by biomass burning are environmentally significant. The green house gases, carbon dioxide and methane influence global climate. Combustion particulates affect the global radiation budget and climate (Levine et al., 1995). Carbon monoxide, methane, and non methane hydrocarbons and nitric oxide are all chemically active gases that affect the oxidizing capacity of the atmosphere and lead to the photochemical production of ozone in the troposphere. Recently it was discovered that biomass burning is also an important global source of atmospheric bromine in the form of methyl bromine (Mano and Andreae, 1994). Bromine leads to the chemical destruction of ozone in the stratosphere and is about 40 times more efficient in the process than is chlorine on a molecule-for-molecule basis (Levine et a;., 1995)

Measurements have shown that in addition to instantaneous production of trace gases and particulates resulting from the combustion of biomass matter, burning also enhances the biogenic emissions of nitric oxide, and nitrous oxide from soil (Anderson et al., 1988; Levine et al., 1991). It is believed that these emissions are related to increased concentrations of ammonia found in soil following burning.

A high or excessively elevated supply of cloud condensation nuclei is another consequence of emission of smoke particles. This means that, given the same amount of water vapour available, more water droplets can form in the atmosphere than if no smoke particles were present. Because these droplets are comparatively lighter than normal, they do not form rain but merely a haze.

Therefore, one of the consequences of the oversupply of condensation nuclei may be a reduction of precipitation (Goldammer, 1994). The total amount of biomass burned in a particular ecosystem can be calculated from measurements of the total land area burned annually, the average organic matter per unit area in the ecosystem, the fraction of the above ground biomass (Levine et al., 1995). The emission ratio for a particular compound varies with both the particular ecosystem burned and the phase of burning (e.g. Flaming, or smoldering). emissions depend on the type of the ecosystem, the moisture content of the vegetation, and the nature, behaviour, and characteristics of the fire (Cofer et al, 1990, 1991).

In addition to bring a significant instantaneous global source of atmospheric gases and particulates, burning enhances the biogenic emissions of nitric oxide from the worlds' solid. Biomass burning affects the reflectivity and emissivity of the earths' surface as well hydrological cycle by changing rates of land evaporation and water run-off. For these reasons, it appears that biomass burning is a significant driver of global change (Pyne, 1991).

Table 2. Comparison of global emissions from biomass burning with emissions from all sources, including biomass burning

Species	**Biomass burning (Tg element / year)**	**All sources (Tg element / year)**	**Biomass**
burning %	3500	8700	40
Carbon dioxide (net)	1800	7000	26
Carbon monoxide	350	1100	32
Methane	38	380	10
Nonmethane hydrocarbons (Excluding isoprene and terpenes)	24	100	24
Nitric oxides	8.5	40	21
Ammonia	5.3	44	12

Sulphur gases	2.8	150	2
Methyl chloride	0.51	2.3	22
Hydrogen	19	75	25
Topospheric ozone	420	1100	38
Total particulate matter	104	1530	7
Particulate organic carbon	69	180	39
Elemental carbon	19	22	86

(Source: Levine et al., 1995)

Ecological Significance of Pests and Pathogens

Tree death is a natural event as overmature, weakened, or susceptible trees are preferentially attacked by certain insects and pathogens. These organisms tend to specialize in one particular species or genes of trees, they strongly control the rate and direction of succession (Edmonds, and Sellins, 1974; Franklin et al; 1987). Thus, insects and pathogens alter forest composition, structure and succession by selectively affecting tree growth and mortality (Haack and Byler, 1993). Selective killing of susceptible trees tends to increase overall stand fitness and resistance (Burdon, 1991). Through this process of natural selection, most native insects and pathogens reach a dynamic state of equilibrium with their hosts and natural enemies.

Insects and other invertebrates, and pathogens and other microbes contribute significantly to biomass decomposition, carbon cycling, nutrient cycling, and energy flow in forest ecosystems and are thus pivotal to maintaining soil fertility and long-term forest health (Haack and Byler, 1993). Defoliation accelerates litterfall as well as nutrient leaching from damaged foliage. Also, insect feces decompose faster than do fallen leaves and needles, which leads to faster cycling of elements such as calcium, potassium, nitrogen, and phosphorous (Schowalter et al., 1986). many insects and pathogens initiate carbon and nutrient cycling of woody tissue (Kile et al., 1991). Microbes are the principal degraders of cellulose, hemicellulose, and lignin (Edmonds and Sollins, 1974).

Insects and microbes create wildlife habitat primarily by killing trees that either remain standing (Snags) or fall to the ground or in water, and by decomposing wood, which allows easier access by vertebrates (Ackerman, 1993). Insects are also responsible for pollinating several hardwood trees and many herbaceous plants. The principal insects involved in pollination are bees and wasps, beetles, flies, and butterflies and moths.

Management of Forest Pests

Integrated forest vegetation management is defined (Wagner, 1994) as "managing to achieve silvicultural objectives by integrating knowledge of plant ecology with a wide variety of complementary method that are ecosystem-based, economical and socially acceptable". For many forest insects and diseases, the best control is maintenance of the health of trees and stands (Forbes, 1956). Both in diagnosing injuries and in preventing them, the forester should draw heavily on his knowledge of silvics. In this line, following factors should be considered :

1. Quality site (a. Drainage should neither be excessive nor imperfect b. Soil should neither be thin nor with compacted lower horizons)
2. Species-adaptation to site (whether the species is poorly adapted or occurring near limits of range, or as a transient type in the succession)
3. Habitat (a. Water table, b. Exposure to increased light or wind movement)
4. Weather influences (prolonged drought, spring rains, high temperature, late spring frost, winter injuries like wilting of foliage or injury to bark tissues, etc.)
5. Anthropogenic pressure (Fire, Grazing, Pesticides)
6. Age of the tree stand (Overmaturity)
7. Stagnation as a result of overstocking.

In the natural forest, the better the silvicultural management, the greater the resistance to most native insect and disease. Prevention of severe damage through silvicultural practices is, in many cases, entirely feasible. A few insects and diseases introduced from abroad remain a very serious problem because they have found the environment favourable and lack biological controls (Forbes, 1956).

The damage of certain species might be reduced to insignificance if forest can be kept in a fast growing, vigorous condition. measures to that end includes :

1. Protecting against the uncontrolled fire
2. Fencing of woodlands against domestic animals and measures to prevent overpopulation by wildlife
3. Thinning to prevent the excessive reduction in width and depth of live, crowns, which result from overcrowding
4. Harvest cuttings of mature age classes and individuals

There are a few insects and diseases which successfully attack even fast-growing, thrifty forests, and hence are not controllable by silvicultural measures known today (Forbes, 1956). It has been demonstrated through research in recent years (Smith, 1966) that some of the newer insecticides can be effectively and economically applied by means of aircraft. The cost depends largely on the size of the area treated, the cost of the insecticide, the type of aircraft and the equipment used, and the accessibility of the area to a suitable landing fields (Forbes, 1956). Due to public perceptions, pest managers will have to develop control methods that minimize ecological disruption. A recent survey of 2,500 Canadians indicated that 71% oppose to the use of the chemicals in forests. Most of those surveyed believe that pesticides are harmful to wildlife and people living in near the forest, and that application of chemicals, if necessary, should be by ground rather than air (Wagner, 1994).

Preventive measures include the detection of outbreaks and prompt applications of control measures. Special vigilance is required during drought. Sanitation-Salvage is also an important preventive measure in which "high risk" trees (susceptible tree classes) are removed and utilized (Forbes, 1956). Direct control methods may use certain pesticides like Benzene hexachloride (aqueous or oil solution with gamma isomer), lead arsenate, lime-sulphur, etc.

Future semiochemical use may offer either alternative to insecticides or tools that can be combined effectively in integrated pest management approaches. These behaviour-modifying chemicals have potential for a range of application, from enhancing the effectiveness of natural enemies to aggregating pests or non-crop substrates. Ground or aerial applications of antiaggregation pheromones may eventually replace broad-spectrum insecticides in controlling some pests (Berisford, et al., 1994).

Potential alternatives to herbicides include prescribed fire, mechanical equipment, manual cuts, mulches, grazing animals, cover crops, and biological methods (Wagner, 1993). Trees are also relatively tolerant to damage from many pests, which often makes it possible to achieve control without heavy pesticide use (Nealis, 1988).

There will also be continuing efforts to develop microbial insecticides. After three decades of research and development, it is now used operationally for forest defoliators in both the United States and Canada. This tool has many advantages over chemical insecticides, but acceptance may be limited due to a narrower window of application and less predictable results. Viruses offer great potential because they are host specific and can be very effective (Berisford et. al., 1994).

Another less disruptive approach with prospects for forestry is the development of natural chemical insecticides produced by plants and micro-organisms. For example, an extract from Neem tree, has a variety of insecticidal effects. Researchers and managers have employed these materials in India for years. Although, such naturally derived insecticides offer potential for forest use, they are in early stages of development (Helson, 1992).

Control of Forest Fires

The purpose of fire prevention is to reduce the number of man caused fire to the lowest practicable minimum. In planning and action, prevention efforts should be on a parity with phases of fire control (Forbes, 1956). An analysis of the problem with which prevention must deal, requires that localised risk and hazards survey should be made to determine:

(a) where fire occurs (zones of different intensity and the reasons for this)

(b) when fire occurs (time of year and length of risk season)

(c) what causes fires (general and specific causes)

(d) who causes fire (class and source of people responsible)

(e) how fires start (specific and contributory conditions and circumstances)

(f) why fires occur (motives and reasons)

The programme of action at fire prevention should include (a) selection of appropriate prevention measure, (b) administrative organisation and timely application of selected measures, and © systematic, recurring evaluation as to relative success. In order to prepare an action plan of fire control, following factors should be taken into consideration :

1. Debris burners,
2. Hunters, fisherman, campers,
3. Rail Roads,
4. Logging, lumbering, and other wood operations,
5. Incondiarists

In order to improve the fire prevention efforts, following measures are suggested (Forbes, 1956):

(a) Analysis and then attack on the real reason for fires

(b) Promotion of friendly, co-operative relations with the people who live, work, or travel in the area, to attain their help

(c) Impression upon individuals their personal responsibilities for fire control

(d) Carrying out the hazard and risk reduction activities

Reduction in the number of man-caused forest fires is the primary objective of protection. When friendly, tactful, and appropriate instructions, reminders, and appeals fail to accomplish results, and for those individuals who maliciously or negligently cause serious hardening of legal actions is essential if the desired results are to be attained (Forbes, 1956 & Ramade, 1984).

Fire weather forecast is also an important tool in prevention, presuppression and suppression of forest fires. Pertinent weather forecasts, when combined with the current fire danger rating and tempered by fire causes known to be at during the season, provide needed information for planning current fire control. Fire weather forecasts may be supplementing the fire danger rating. The term fire danger, or preferably "total" fire danger, refers to the total of both the constant and variable factors which determine whether forest, brush or green fires will start, spread, and do damage, and which determine the difficulty of their control. Fire danger ratings cannot replace experience and good judgment, but they provide a valuable guide to judgment in making administrative decisions. (FCFDG, 1992; Forbes, 1956).

The objective of presuppression planning is to have available when and where needed an effective fire control organisation well equipped, instructed and supervised, and with the sound experience necessary to handle fires efficiently. All adjoining agencies and ownerships should co-operate actively in the control of fires if efficient action and reduction in costs and losses are to be attained. Early observation, accurate location, and prompt report of every forest fire are the objectives of efficient fire control. The more rapid the spread of fires, the more important the prompt action becomes (Forbes, 1956).

Prescribed Fire as a Management Tool

Ecosystem management encourages regeneration, stand development, and harvest that includes and/or mimics natural ecosystem process (Brennam and Hermann, 1994). Lightning fires,

however are a viable forest management option (except in wilderness and other vast wildland areas) because of fragmentation, human occupation, and other considerations (such as smoke management, extreme weather, or high fuel-loading conditions). Fire as a management tool must be based on specific management prescriptions.
Fires and ecosystems have interacted throughout time, establishing fire as an influence in such ecosystem function (Mulch, 1994) as:

- recycling of nutrients
- regulating plant succession and wildlife habitat
- maintaining biological diversity
- reducing biomass, and controlling insect populations and diseases

Fire can either kill forest pests or alter their habitat (Mitchell, 1990). Outright mortality of pests and pathogens varies with fire behaviour and/or fuel characteristics. Habitat alteration can be important over space (creation of patches) or time (shifting successional stages of forest stands) and in most cases post burn effects are complex (Hardy, 1976). Weber and Taylor (1992) predicted that prescribed fire will continue to be a cost effective tool against forest pests in western canadian forests.

Prescribed burning is the knowledgeable application of fire on a specific area to attain predetermined objectives. To accomplish a prescribed burn safely, managers must write a prescribed burn plan detailing how the burn will be executed (Mc Rae, 1994). A written burning prescription contained within the overall burn plan defines the objectives to be attained and the burning conditions under which the fire will be ignited. Generally, prescriptions focus on various weather and fire behaviour indices. In canada, managers use the fuel-moisture codes and fire behaviour indices of the Canadian Forest Fire Weather Index (FWI) System (CFS, 1987). Values of the FWI are used to plan for attaining objectives such as residue reduction and organic forest floor removal and to meet safety concerns such as rate of fire spread (McRae, 1980).

Many forest fires start from natural causes such as lightning which set trees on fire. Periodic lightning induced fires have been recorded throughout history from India, Southeastern and Central United States, Australia, Finland and Eastern and Southern Africa. In the United States and some other countries such natural fires are allowed to burn and die out as a part of Forest Management strategy (Kaushik, 2004). Natural or prescribed fire sometimes may become a potential hazard to the forest by causing damage to vegetation and wildlife, and releasing huge amount of particulate and gaseous pollutants into the atmosphere. One study (Hardy, 1992) estimated that more than 53 million pounds of respirable particulate matter were produced over a 58 day period by the 1987 silver fire in south-western Oregon. Because of the amount of dry fuel, tree crowns are totally consumed in flame immediately after ignition (Mc Rae, 1994). In freshly killed forests where dead trees are still standing, the fire danger is alleviated when understorey vegetation emerges. This vegetation makes the microclimate more moist and renders fire spread virtually impossible. However, after 4 to 5 years, the standing dead stems break off in high winds and accumulate on the ground. These stems then resemble slash left behind after a harvest operation. Under this condition, fire will spread, even in summer, due to surface-fuel build-up (FCFDG, 1992). Fire danger decreases only as the fallen stems decompose.

Relationship between fire and bark beetles are extremely complex. Some research indicates that fire may weaken trees and therefore predispose them to beetle infestation (Fellin, 1979). On the other hand, Martin et. al. (1977) noted that prescribed fire could be used to decrease tree density, which subsequently reaches the severity of attacks by mountain pine beetles. With appropriate silvicultural prescriptions, fire can be used as an alternative to thinning for developing pine stands to a predetermined basal area and stocking rate.

Fire sanitizes a site but allow many infected longleaf seedlings to survive and subsequently recover from disease. Although diseased needles are destroyed; the seedlings remain intact and can grow into healthy trees. This contrasts with some forests where fire must kill infected trees in order to suppress a disease. Apparently, fire is an effective sterilizing agent that kills brown spot spores and therefore limits the distribution of wind-dispersed inoculums (Brennan and Hermann, 1994).

For years people thought frequent burning of forest stands reduced populations of vertebrate parasites such as ticks (for example Ambylomma spp., Ixodes spp.). Current information also indicates that fire can depress local populations of ticks. Scifres et. al. (1988) documented a reduction of Gulf Coast tick populations in Texas landscapes, such as mesquite, chaparral, and grasslands, during the first postburn growing season. They predicted that greater exposure time to fire resulted in greater mortality. Doster (1991) reported that either annual or biennial burning significantly decreased populations of adult, nymph, and larval ticks.

Prescribed fire has been used in an attempt to reduce populations of ticks that carry lyme disease (Mather et. al., 1993). Although, saplings and understorey shrubs where ticks were most common, were destroyed, adult trees appeared unharmed by the treatment. It also lowered the presence of larval ticks by 49 percent. Curiously, however, the risk of encounterimg the lyme disease pathogen was not affected.

Forest Fire in Kumaon and Garhwal Himalaya: A Case Report

Forest fire are ravaging the once-picturesque Kumaon and Garhwal hills of the lower Himalayas in northern Uttar Pradesh (India). While distant rain clouds promise respite, increasingly hot weather persists in the area, with almost daily incidence of fire in every summer (Plate 1 and 2). The hills are at times seen enveloped in thick clouds of smoke from burning trees, near and far (Pande, 1995).

In Kumaon alone, one lakh hectares have been ravaged, through absolute figures of the total forest cover lost are not immediately available. About 58 percent of the green cover here is notified as reserve forest and it was officially estimated that on june 9th six percent of this belt had vanished (Frontline, June 30, 1995).

According to the District Magistrate of Almora District in the Garhwal region, “forest fires take place annually and the main culprits are the pine needles which catch fire. Careless villagers relaxing with beedis in the jungle add to the problem”. Forest department officials complained they were fighting against heavy odds, the situation compounded by acute staff shortage, scarcity of fire-fighting equipment and an inadequate communications network (Pande, 1995).

Pande (1995) in his article “Darkness at Noon” appeared in “Frontline” (June 30, 1995) has written that several forest fires in Himalayan region, occurred this year, are witnessed by an authority on History and Environment of the Himalaya region, Dr. Ajay Rawat. Dr. Rawat told “At first glance it was beautiful sight - as if myriads of bulbs had been suspended from trees for about a kilometre. I knew it was a forest fire. By the next morning, the fire had engulfed a large area. I was a menacing sight, thick blue smoke rising in the sky, dimming the soaring sun”. Later, it was discovered that the blaze had spread from a cremation ground.

During another 10 days a fire in the pine forests near Sitlakhet in Almora district was seen, and villagers were suspected to be responsible for it because the burning of pastures and forests during summer is usual in the hills to aid the sprouting of fresh grass. The burning of accumulated, slippering litter makes grazing safe.

A visit to Nainital, Almora, Ranikhet, Sitlakhet, Tarikhet and Bhowali and a part of Bhimtal revealed that some forests were illuminating. The area was covered with smoke. At a distance from Ranikhet was another forest fire. It was dark but there was a growing holom of light. At the same time, Binser was observed clouded with smoke and with smell of fire all around. Once famous for its orchards, Bhowali is now known for a building boom and wears the scars of this year’s fire. An old resident termed the latest fire sweeping Kumaon and Garhwal fire the worst in two decades, another, after a visit to Garhwal, referred to it as “Darkness at Noon”. Maximum damage due to forest fires was observed in Chamoli district. Forest fires are also affecting the tourists in many ways (Deshbandhu, June 2, 1995). The fire lines in the forests have disappeared beneath the undergrowth. They were natural protectors against fire but with paucity of funds the lines could not be maintained (Pande, 1995).

Conclusion

Understanding the relationship between fire and forest pests requires a clear distinction between prescribed fire and wildfire. Forest managers must have knowledge of how fire behaves under specific atmospheric conditions. A thorough understanding of past stand history and an ability to judge potentially dangerous conditions is invaluable and can make the difference between successful and disastrous use of prescribed fire (Brennan and Hermann, 1994).

On some sites, understorey vegetation can quickly shade the ground and increase fuel-moisture levels. This makes fire spread difficult, especially when the burning conditions are poor. In these cases brown-and-burn operation-herbicide spray used prior to the burn in order to kill the vegetation tops can be helpful (Mc Rae, 1994).

Fire almost always has some negative effects, even on species that are fire adapted (Chambers et. al., 1986). Whenever fire is prescribed, managers must weigh negative influences against positive ones. For example, fire may result in the loss of photosynthetic tissue but produce a competition free site. In addition, fire may eliminate some pathogens from a site but create additional points for infection, such as developments of fire scars on tree boles (Thies, 1990). Recent fire may also limit the effectiveness of insecticide.

A prescribed burn will also be safer and more successful if the perimeter of the treated area is extended to natural boundaries such as lakes, rivers, and marshes. Narrow roads on single-blade bulldozed firelines are not wide enough to prevent the fire from crossing the fire brands. Ignition and control of the convection column become important in preventing the column from collapsing and dropping firebrands onto unburned areas outside of the perimeter. A center-fire ignition pattern may help draw firebrands up and into the convection column, thereby reducing fire spotting (McRae, 1994).

References

1. Ackerman, J. 1993. When the bough breaks. Nature Conser., 43 (3): 8-9.
2. Anderson, I. C. et. al. 1988. J. Geophys. Res., 93: 3893-98.
3. Berisford, C.W.; T.J. Eager and D.C. Allen 1994. Meeting tomorrows challenges in forest entomology. J. Forestry, 92 (11): 10-15.
4. Brennan, L.A and S.M. Hermann 1994. Prescribed fire and forest pests: Solutions for today and tomorrow. J. Forestry, 92 (1): 4-37.
5. Burdon, J.J. 1991. Fungal pathogens as selective forces in plant populations and communities. Australlian J. Ecology, 16: 423-32.
6. Canadian Forestry Service, 1987. Ed. 4. Tables for the Canadian Forest Fire Weather Index System.
7. Chambers, J.L.; P.M. Dougherty and T.C.Hennessey. 1986. Fire : its effects on growth and physiological processes in conifer forests. In: Stress physiology and forest productivity. (Eds: Hennesey, P.M. Dougherty, S.V. Kossuth). p 171-89. Kluwer Acad. Publi., Boston.
8. Cofer, W.R. et al. 1990. Atmos. Environ. (Part A), 24: 1653-59.
9. Cofer, W.R. et. al. 1991 In : Global Biomass Burning - Atmospheric, climatic and Biospheric Implications. (Ed: J.S. Levine). MIT Press Cambridge, MA.
10. Doster, G. (Ed.) 1991. South-Eastern co-operative Wildlife disease study. Newsletter. Univ. of Georgia. Athens. 6 :2-3.
11. Edmonds, R.I. and P. Sollins. 1974. The impact of forest diseases on the energy and nutrient cycling and succession in Coniferous Ecosystems. In : Impact of diseas epidemics on natural plant ecosystems p. 175-80. Am. Phytopathol. Soc. Vancouver, BC.
12. Fellin, D.G. 1976. A review of some interactions between harvesting, residue management, fire and forest insects and diseases. In : Environmental Consequences of timber harvesting in Rocky Mountian Coniferous Forests. 335-414 pp. USDA. For. Ser. Gen. Tech. Rep. INT 90.
13. Forbes, R. D. (Ed.) 1956. Forestry Handbook. The Ronald Press Company, New York. p. G-41.
14. Forestry Canada Fire Danger Group. 1992. Development and Structure of Canadian Forest Fire Behaviour Protection System. For. Can. Ottawa, Ont. Inf. Rep. XT -X-3. 63p.
15. Franklin, J.H.; H.H. Shugart and M.E. Harmon. 1987. Tree death as an ecological process. Bioscience, 37: 550-56.
16. Goldammer, J.G. 1994. Vegetation Fires and their effects on Global Climate. Natural Resources and Development, 40 : 99-111.
17. Haack, R.A. and J.W. Byler. 1993. Insects and Pathogens : Regulators of Forest Ecosystems. J. Forestry, 32-37.
18. Hardison, J.R. 1976. Fire and flame for plant disease control. Ann. Rev. Phytopath, 14 : 355-79.
19. Hardy, C.C. 1992. Wildlife smoke production : The silver fire as a case example. In : Fire in Pacific Northwest ecosystem symposium (Advance Proceedings). Portland, OR, P 32-34.
20. Haskell, B.D., B.G. Norton and R. Costanza. 1992. what is Ecosystem health and why should we worry about it ? In : Ecosystem health (Eds. R. Costanza, B.G. Norton, and B.D. Haskell) pp.3-20. Inland Press, Washington, D.C.
21. Helson, B. 1992. naturally derived insecticides : Prospects for forestry use. For. Chron. 68 : 348-54.
22. Joseph, P., T. Keith; L. Kline; J. Schwanke; A Kanaskie, and D. Overhulser. 1991. Restoring forest health in the Blue mountains : A 10 - years strategic plan. For, Log., 61 (2) : 3-12.
23. Kile, G.A.; G.I. McDonald and J.W. Byler 1991. Ecology and disease in natural forests. In : Armillaria root disease (Eds. C.G. Shaw and G.A Kile) pp 102-21. USDA For. Serv. Handbook, 691.
24. Kaushik, A.D. 2004. Forest Fire as a natural disaster in India.Indian Journal of Public Administration. Vol.L.No.2, April-June, p. 475-482.
25. Leopold, A. 1949. A sand country almanac and sketches here and there. Oxford. Univ. Press, New York. 228 pp.
26. Levine, J.S. et al., 1991. In : Global Biomass Burning Atmospheric, Climatic and Biospheric Implication (Eds. J.S. Levine). The MIT Press, Cambridge, MA.
27. Levine, J.S.; W.R. Cofer III; D.R. Cahoon, Hr.; E.L. Winstead. 1995. Biomass burning : A driver for global change. Environ. Sc. and Tech. 29 (3) : 120A-125A.
28. Mano, S. and M.O. Andreae. 1994. Science, 264 : 1255-57.
29. Martin, E.R.; R.W. Cooper..; A.B. Crow.; J.A. Cumming.; and C.B. Phillips. 1977. Report of the Task Force on prescribed burning. J. Forestry. 75 : 297-301.
30. Mather, T.N.; D.C. Duffy, and S.R. Campbell. 1993. An unexpected result from burning vegetation to reduce Lyme disease transmission risks. J. Med. Entomol. 30 : 642-45.
31. Mattson, W.J. and R.A. Haack. 1987. The role of drought in outbreaks of plant-eating insects. Bioscience, 37 : 110-18.

32. McRae, D.J. 1994. Prescribed fire converts spruce Budworm -Damaged forest. J. Forestry, 92 (11) : 38-40.
33. Mulch, R.W. 1994. Fighting fire with prescribed fire : A return to ecosystem health. J. Forestry, 92 (11) : 31-33.
34. 33. Nealis, V.G. 1988. natural enemies and forest pest management. For. Chron. 67 : 500-05.
35. Negi, S.S. 1991. Environmental Degradation and Crisis in India. Indus Publishing Company, New Delhi. 344 p.
36. Pande, S.K. 1995. Darkness at Noon : Forest Fires ravage Kumaon, Garhwal. Frontline, June 30 : 129-132.
37. Pyne, S.J. 1991. In : Global Biomass Burning - Atmospheric, Climatic and Biospheric Implications (Eds. J.S. Levine) The MIT Press, Cambridge, MA.
38. Radloff, D.; R. Loomis.; J. Bernard and R. Birdsey. 1991. Forest health monitoring : taking the pulse of Americas' forests. In : Agriculture and the environment - the 1991 yearbook of Agriculture. P 41-47 USDA For. Serv. Washington, D.C.
39. Ramade, F. 1984. The Ecology of Natural Resources. John Wiley & Sons, New York. p. 321.
40. Rapport, D.J. 1992. What is clinical biology ? In : Ecosystem health (Eds. R. Costanza, B.G. Norton and B.D. Haskell) p. 144-56. Island Press, Washington, D.C.
41. Rosen, D. and P.D. DeBach. 1979. Species of Aphutis of the world. Dr. W. Junk Publishers, London. 212p.
42. Sampson, R.N.; D.L. Adams; S. Hamilton; S.F. Mealey.; R. Steele and D. Van de Graaff. 1994. Look out : Assessing Forest health in the Inland West. Am. For. (March/April) 100 (3/4) : 13-16.
43. Schowalter, T.D. W.W. Hargrove, and D.A. Crossley, Jr. 1986. Herbivory in Forested ecosystems. Annu. Rev. Entomol. 31 : 177-96.
44. Schowalter, T.D. and G.M. Filip. (Eds.) 1993. Beetle-pathogen interactions in coniferous forests. Acad. Press. Orlando. Fl. 252p.
45. Scifres, C.J.; T.W. Oldman.; P.D. Teeland.; D.I. Drane. 1988. Gulf Coast tick (Ambylomma maculatum) populations and responses to burning of coastal rairie habitats. Sw. Nat. 33 : 55-64.
46. Siegel, W.C. 1994. Studying long term forest health nad productivity. J. Forestry. 92 (7) : 6-8.
47. Smith, R.L. 1966. Ecology and Field Biology. Harper and Roe, New York.
48. Society of American Foresters. 1993. Task Force Report on Long Term Forest Health and Productivity. Soc. Am.For., Bethesda, MD. 83p.
49. Thies, W.G. 1990. Effects of prescribed fire on diseases in Conifers. In : Natural and prescribed fire in Pacific northwest forests (Eds. J.D. Walstad, S.R. Radosevich and D.V. Sandberg). p. 117-21. Oreg. State Univ. Press. Corvallis.
50. USDA Forest Service. 1993. Healthy Forests for Americas' Future - A strategies Plan. USDA For. Serv. NATP. -03-93. 57p.
51. Wagner, R.G. 1993. Research directions to advance forest vegetation management in North America. Can. J. For. Res. 23 (2) : 317-27.
52. Wagner, R.G. 1994. Towards integrated forest vegetation management. J. Forestry. 92 (11) : 26-30.
53. Weber, M.G. and S.W. Taylor. 1992. The use of prescribed fire in the management of Canadas' Forested lands. For. Chron. 68. 324-34.
54. Wickman, B.E. 1992. Forest health in the blue Mountains : The influence of Insects and diseases. USDA For. Serv. Gen. Tech. Rep. PNW - 295.
55. Wilson, L.F. 1993. Chinas' Masson Pine Forests : Cure or Curse ? Scale insect inhibit future wood supply. J. Forestry, 91 91) : 30-33.

9

Integrated Water Resources Management for Climate Change Adaptation and Disaster Risk Reduction

Indrani Phukan and Sanjay Tomar

Introduction

Water is essential to human existence and a major requirement in agricultural and other commercial production systems. An integrated approach for natural resources management, on a watershed basis has emerged as the cornerstone of rural development in dry and semi arid regions. Integrated watershed development draws strength from its inherent interconnectedness of the biophysical, the social and the economic elements of ecosystem processes. It recognizes that human activities within a watershed are motivated by multiple and often conflicting objectives and/or constraints, such as maximizing farm income, protecting soil and water resources as well as securing and maintaining drinking water supplies. In the Indian context, more than half of its land is degraded due to various factors like water and wind erosion, ravines, gully erosion, salt affected lands, water logging, shifting cultivation etc. Since the Third Assessment Report of the Inter Governmental Panel on Climate Change (IPCC 2001) there have been warnings that climate change will further exacerbate water shortage and quality problems and impacts are likely to be felt on ecosystems, water resources and agriculture. For the agrarian population practicing rainfed agriculture, seasonal and inter-annual fluctuations in hydro-meteorological parameters have disastrous implications. Increasingly variable rainfall, cyclones / hurricanes, accelerating storm water runoff, floods, droughts, decreasing water quality and increasing demand for water are so significant that they threaten the economic development and human health. Low skill levels of climate forecasts are preventing reliable predictions exceeding a period of 3 months. However, the expected increase in climatic extremes should provide sufficient incentives to 'no regrets' approaches dealing with both floods and droughts. Hagen et al (2003) concluded that Integrated Watershed management is a feasible no-regret-strategy to adapt to climate change. It has immense potential for adaptation and mitigation and building resilience amongst communities to face adverse impacts of climate change in the form of extreme events. The challenge here is that since climate change is inherently uncertain and the trends are without quantifiable boundary conditions, concrete water management strategies and measures for operational water management becomes extremely difficult.

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

Box 1 : Climate change and related risks in South Asia:
The IPCC AR4 (2007) states the following observed and projected changes in South Asia:
1. Frequency of occurrence of climate change induced diseases and heat stress has increased with rising temperature and rainfall variability.
2. By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease.
3. Accelerated glacier melt is likely to cause increase in the number and severity of glacial melt-related floods, slope destabilization and a decrease in river flows as glaciers recede (medium confidence)
4. Coastal areas, especially heavily populated mega delta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some mega deltas, flooding from the rivers.
5. Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development.
6. Endemic morbidity and mortality due to diarrheal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.
7. Extreme rainfall and winds associated with tropical cyclones are likely to increase in East, Southeast and South Asia.

(Source : http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch10s10-es.html)

The South Asian region is highly sensitive to the consequences of climate change. It is also known to be the most disaster prone region in the world supporting a huge population of more than 1.3 billion (UNEP 2003). Fourth assessment report of Intergovernmental Panel on Climate Change (IPCC) highlights this region as critical as climate predictions for the future highlight increase in frequency and intensity of extreme weather events like droughts and floods (IPCC 2007).

IPCC analyses the impacts of climate change on freshwater systems and their management mainly due to the observed and projected increases in temperature, evaporation, sea level and increased variability in precipitation. With higher temperatures, the water-holding capacity of the atmosphere and evaporation into the atmosphere increase, and this favours increased climate variability, with more intense precipitation and more droughts (Trenberth et al., 2003).

IPCC estimates of monetary damages under the conditions of doubling of CO2 (damage expressed as percentage of GDP) indicate that on an average, the economic losses worldwide would be between 1.5% and 2%. This figure lies between 1% and 2% for developed and 2% and 9% for developing countries. Most of the climate models projects that up to 20% of the world’s population living in river basins will be affected by flood hazards by the 2080s due to global warming (IPCC 2007). Higher water temperatures, increased precipitation intensity, and longer periods of low flows will further intensify adverse impacts on human activities and ecosystems functioning.

Box 2: Global impacts of climate change on water sector:

- Africa: by 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change.
- Central, South, East and South-East Asia: by the 2050s, freshwater availability in, particularly in large river basins, is projected to decrease
- Southern & Eastern Australia, New Zealand, Northland and some Eastern Regions: 2030, water security problems are projected to intensify.
- Southern Europe: climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability and to reduce water availability.
- Latin America: changes in precipitation patterns are projected to significantly affect water availability for human consumption, agriculture and energy generation.
- By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods.

Source: IPCC 2007

Over the past few decades, the challenge of reducing socio-economic vulnerability to climate and weather-related hazards has been taken on by four distinct research and policy communities namely; disaster risk reduction; climate change adaptation; environmental management and poverty reduction. These communities have largely developed and operated independently from each other (Frank et. al 2006). There is growing need for better collaboration between these communities to learn from one another and to identify opportunities to develop a joint agenda.

Water management efforts in context of climate change

Ecosystems and biodiversity, agriculture and food security, land use and forestry, human health and sanitation, settlements and infrastructure, industry and energy all depend on good water management. Dealing with climate change and climate variability is considered to be one of the largest challenges for the coming decades, on all geographical scales, across all economic sectors. Water managers see themselves confronted with a continuous stream of increasingly credible scientific information on the potential magnitude of climate change and climate variability and the vulnerability of water resources to its impacts. Vulnerability of South Asian countries in the event of climate change is more pronounced due to their dependency on agriculture, excessive pressure on natural resources and poor coping mechanisms. The impacts of climate change in the water sector have significant repercussions for an agrarian country like India. In India, 1-m sea level rise would result in inundation of 5763 km2 of land in India (TERI 1996) and could result in large loss to life and economy, as huge populations reside in the coastal areas. Snow and glacial melt from the Himalayan region contribute up to 50% of water resources feeding 10 of the largest rivers of Asia. The Himalayan glaciers are receding faster than the global average and the foreseeable impacts are that though there will be an initial increase of base flow and variability of downstream runoff the base flow is likely to substantially reduce. This in turn will have serious implications on lives and livelihoods of those dependent on river basins fed by the Himalayan glacial melts.

Water management strategies that are viable in terms of coping with present problems as well as recognizing the uncertainties regarding future climate are termed as “no regret strategies”. Priority action 4 of the Hyogo Framework of Action (HFA, 2005 to 2015) adopted by 168 member states of the United Nations state that “Disaster risks related to changing social, economic, environmental conditions and land use, and the impact of hazards associated with geological events, weather, water, climate variability and climate change, are addressed in sector development planning and programmes as well as in post-disaster situations”. HFA commitments also include efforts to integrate climate change adaptation into disaster risk management in order to increase resilience especially of vulnerable communities in disaster prone areas. These are being achieved through national instruments for addressing the climate change challenge in multiple sectors like the National Action Plan for Climate Change in India, Bangladesh etc. The National Adaptation Programme of Action (NAPA), a requisite for Least Developed Countries to access the Adaptation Fund has been developed in Nepal in 2010 (http://www.napanepal.gov.np/ accessed on 4th December 2011).

Box 3: Some adaptation options that increase the resilience of people and ecosystems by improving access to water and ecosystem services in order to establish and maintain sustainable environments and livelihoods

Increasing water supply and ecosystem services:

- Expansion of rainwater harvesting to improve rainfed cultivation and groundwater recharge
- Adoption of water transfer schemes
- Restoration of aquatic habitats and ecosystem services
- Increased storage capacity by building reservoirs

Decreasing water demand and increasing use efficiency:

- Removal of invasive non-native vegetation from riparian areas
- Improvement of water-use efficiency by water recycling
- Spread of drought-resistant crops
- Improved management of irrigated agriculture, e.g., changing the cropping calendar, crop mix, irrigation method and repair and maintenance of irrigation infrastructure
- Expanded use of economic incentives to encourage water conservation
- Improvement of urban water and sanitation infrastructure

Improving flood protection:

- Construction of flood protection infrastructure
- Enlargement of riparian areas
- Increased upstream storage
- Restoration and maintenance of wetlands
- Improved flood forecasting

(Source: Wilk, J. and Wittgren, H.B. (eds). Adapting Water Management to Climate Change. Swedish Water House Policy Brief Nr. 7. SIWI, 2009).

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In India, one of the key missions of the National Action Plan on Climate Change is the National Water Mission which aims at "conservation of water, minimizing wastage and ensuring more equitable distribution both across and within the states through integrated water resources development and management". The main goals of this Mission are:

- Comprehensive water database in public domain and assessment of impact of climate change on water resources
- Promote citizen and state action for water conservation, augmentation and preservation
- Focused attention on over-exploited areas
- Increasing water use efficiency by 20 percent, both on the demand side and the supply side, particularly in the agriculture and commercial sectors.
- Promote basin-level integrated water resources management

(Source: http://pmindia.nic.in/climate_change.htm)

Bangladesh is one of the most vulnerable countries of the world to hydro-meteorological disasters and climate change is likely to increase frequency and severity of floods, tropical cyclones, storm surges and droughts. In the Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009), the Government of Bangladesh outlines a vision to eradicate poverty and achieve economic well being through a pro poor climate change management strategy which prioritizes adaptation and disaster risk reduction as well as addresses low carbon development, mitigation, technology transfer and mobilization of adequate finances. Comprehensive disaster management to deal with more frequent and severe natural calamities is one of the 6 pillars of the Bangladesh Climate Change Strategy and Action Plan.

(Source: www.moef.gov.bd/climate_change_strategy2009.pdf).

It can be seen that progressively more attention is been given to integrate and converge Climate Change Adaptation and Disaster risk management agendas, conceptually and in practice at sub-national, national and international levels. Despite a considerable body of work, the 2009 UNISDR Global Assessment Report on Disaster Risk Reduction (GAR/DRR) suggested that the majority of national processes for tackling DRR and CCA exist in parallel and have separate policy and institutional frameworks. As the focus of the GAR/DRR was on poverty and extensive risk rather than on the interface with climate change, there was little empirical analysis of how DRR and CCA are actually being linked (or not) in practice through legislation, institutions, policy and budgetary processes at the national scale (Mitchell et al

2010). It is seen that while a holistic approach towards the integration of DRR and CCA has not been translated into national policies in most countries, evidence shows that efforts are already taking place, particularly those aiming at sectoral level integration such as water and agricultural management (UNISDR 2009; UNFCCC 2008).

Integrated Water Resource Management (IWRM)

"Integrated Water Resources Management (IWRM) is a process that 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" (Global Water Partnership, 2000).

Box 4: Principles of Integrated Water Resources Management (IWRM)

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
- Women play a central part in the provision, management and safeguarding of water.
- Water has an economic value in all its competing uses and should be recognised as an economic good.

Source: Wilk and Wittgren, 2009

IWRM has been identified as one of the best instrument to explore adaptation measures to climate change, but so far is in its infancy. Successful integrated water management strategies include, among others: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems, and including consideration of climate change. Setting priorities for action involves assessing exposure to threats, determining sensitivity to a changing climate, and assessing the national capacity to adapt. Key indicative priorities for initial action include addressing current and expected water scarcity problems, expanding the knowledge base on water resources and climate change exposure and impacts, and strengthening the national capacity for integrated water resource planning.

IWRM is the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. It is cross-sectoral and therefore in stark contrast to the traditional sectoral approach that has been adopted by many countries. It has been further broadened to incorporate participatory decision-making of all stakeholders. IWRM is a paradigm shift. It departs from traditional approaches in three ways:

- The multiple goals and objectives are cross-cutting so that IWRM departs from the traditional sectoral approach.
- The spatial focus is on the river basin instead of on single water courses.
- It entails a departure from narrow professional and political boundaries and perspectives, broadening them to incorporate participatory decision-making among all stakeholders (i.e., inclusion versus exclusion)

Climate Change Adaptation (CCA), Disaster Risk Reduction (DRR) and their convergence

Both CCA and DRR have a lot of common ground as both aim to reduce the impacts of shocks by anticipating risks and uncertainties and addressing vulnerabilities. A significant portion of climate change impacts will materialize through exacerbating climate variability (for example an especially wet rainy season) and extreme weather events (such as heavy rainfall events). The main overlap between DRR and CCA is the management of hydro-meteorological hazards, where DRR needs to take account of changes in these hazards, and CCA aims to reduce their impacts (Mitchell et al 2010). However, while reducing the risk of weather extremes is a substantial component of managing climate risk and of the overlap between DRR and CCA (see Figure 1), DRR does not equal CCA, and effective disaster risk management in a changing climate is more than business as usual. For both CCA and DRR, key shared objectives include protecting development gains and effective planning and programming: managing risks and uncertainties for all shocks and stresses is simply good business, particularly in the face of mounting evidence that disasters are hampering development and poverty alleviation (UN-ISDR 2009). Natural hazards and climate change present considerable challenge for poverty reduction and sustainable development as they affect a wide range of social and ecological systems.

Box 5: Defining CCA and DRR

- IPCC defines climate change adaptation as 'An adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits benefit opportunities'
- Disaster risk reduction can be defined as: 'The broad development and application of policies, strategies and practices to minimize vulnerabilities and disaster risks throughout society, through prevention, mitigation and preparedness'.

Source: UNISDR, 2004: p3

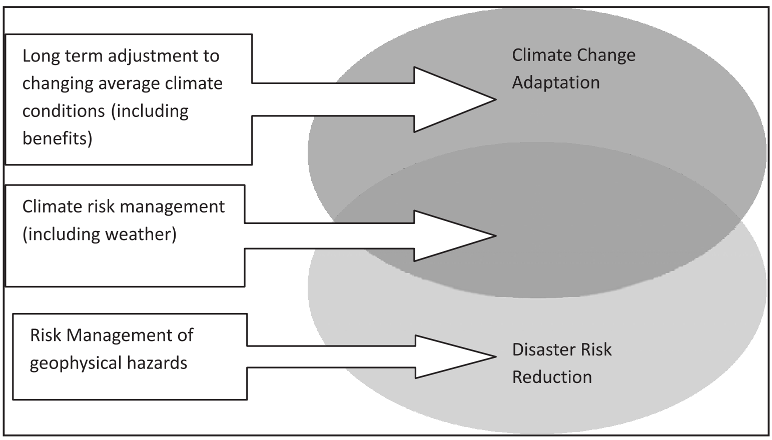

Figure 1: Overlap between DRR and climate change adaptation (Source: Mitchell and Van Aalst 2008)

Many of the differences between climate change adaptation and disaster risk reduction communities are related to differences in the perception of the nature and timescale of the threat. CCA also considers the long-term adjustment to changes in mean climatic conditions, including the opportunities that this can provide, and how people and organizations can develop the capacities to stimulate and respond to longer-term change processes. This has not been a traditional focus of practical applications of DRR (Mitchell 2010). Disaster statistics shows that the natural hazard impacts are unevenly distributed around the world. Certain regions are more vulnerable as compared to the others because of their geographical locations, climate, geology or the capacity to cope with the extreme conditions. Till now the climate change community has concentrated on how individual actors and sectors may be able to adapt to shifting environmental conditions rather than tackling the wider structural constraints that determine the vulnerability. The disaster risk reduction community has mainly focused on the warning/response/relief models where technological advances in climate monitoring and short term forecasting are linked to effective dissemination of hazard information and response that saves human lives.

Areas of convergence

There is a growing understanding that the natural hazards and climate change impacts needs to be addressed in a holistic and integrated manner at different levels. Table 1 highlights the key areas of convergence for DRR and CCA communities. DRR is multi-disciplinary in nature, recognizing the importance of links between hazards and the wider environment (Lewis, 1999; Wisner et al., 2004; Tran and Shaw, 2007). Similarly climate change adaptation is also multidisciplinary in nature and requires links between various sectors and socio economic parameters. CCA strategies aim to reduce vulnerability to expected impacts of climate change and exist across local and global scales, from community level responses through to local, national and international government interventions (UNFCCC, 2006; McGray et al., 2007).

Box 6: Key areas of convergence

- Tools and methodologies: a range of anlytical tools and methodologies based on risk management approach to assess rick and vulnerability assessment.
- Time Scale: DRR community is increasinlgy adopting more anitcipatory and forward looking approach, bringing it in line with the longer-term perspective of the climate change community on future vulnerabilities.
- Capacity development: Both communities increasingly emphasise on capacity of various stakeholders including governments.
- Poverty reduction: For both communities poverty reduction is an essential component of reducing vulnerability to natural hazards and climate change.
- Sustainable resources management: Both communities recognise the importance of sustainable resource management for ecological reselience and livelihood security.
- Mainstarem in development process: Both need to be mainstraemed with sectoral activities and development processes.

Source: Sperling, 2005.

Table 1: Linking Climate Change Adaptation and Disaster Risk Reduction

Differences		Signs of Convergence
DRR	CCA	
Relevant to all hazard types	Relevant to climate and weather related hazards	DRR programmes have always considered weather-related hazards but there are indications that some are now taking into account the impact of climate change on hazard frequency and magnitude and on vulnerability and planning interventions accordingly
Practice of DRR strongly influenced by post-disaster humanitarian assistance	Origin and culture of CCA derived from scientific theory and international climate change policy processes	Common ground being found in joint mainstreaming into development sectors – so specialists on both adaptation and DRR working in infrastructure, water/sanitation, agriculture and health for example.
Most concerned with the present and near future: addressing existing risks based on assessment of local experience and historical record, for example	Most concerned with the short, medium and long-term future – addressing uncertainty and new risks derived from the impacts of climate change	DRR increasingly forward-looking and CCA increasing using and existing climate variability as the entry point for activating adaptation processes. The idea of 'no regrets' options is a key area of convergence.
Traditional and local knowledge is the basis for community-based DRR and resilience building	Widely held view that traditional and local knowledge at community level may be insufficient as impacts of climate change introduces new risks and changes to the frequency and magnitude of existing hazards. However, increasingly recognized that local knowledge also includes people's ingenuity in facing risks.	Growing number of examples where local knowledge and meteorological/climatological knowledge being considered side-by-side to inform DRR interventions
Traditionally has considered risk a function of hazard, vulnerability, exposure and capacity	Traditionally has treated vulnerability interchangeably with physical exposure	IPCC special report on 'managing the risks of extreme events and disasters for advancing adaptation (due in 2011), promises convergence in this area
Full range of established and developing tools	Range of tools under development	Significant progress made in integrating learning from DRR into adaptation tool development
Incremental development, moderate political interest	New, emerging agenda, high political Interest	Disasters more often seen as linked to climate change, and governments recognizing the need to consider both simultaneously
Funding streams often ad hoc, unpredictable and insufficient	Funding streams increasing and promise to be considerable, though problems of delivery and Implementation widespread	DRR community demonstrating signs of being increasingly savvy in engaging in climate change adaptation funding mechanisms

Source: Modified from Tearfund (2008) The need for a holistic approach to improve DRM policy and practice in response to a changing climate was the focus of the 2009 Global Facility for Disaster Reduction and Recovery (GFDRR) 'Stockholm Policy Forum on Climate Smart Disaster Risk Management'. The forum concluded that the world needs a more coherent, integrated approach to managing and adapting to disaster and climate risks. This can only be achieved through greater co-ordination and learning between sectors with more meaningful engagement with grassroots groups and networks, which, if harnessed and strengthened, will provide a front line defense against growing threats (GFDRR 2009).

One recent effort on convergence of DRR and CCA is the Climate Smart Disaster Risk Management (CSDRM) Approach (Figure 2) developed in consultation with diverse stakeholders from ten "at risk" countries of Asia and Africa (Mitchell, T. et al 2010).The Approach was broadly categorized into three pillars viz., 1) Tackle changing disaster risks and uncertainties, 2) Enhance adaptive capacity and 3) Address poverty, vulnerability and their structural causes. The Approach initiates one to take a step back and consider wider common objectives and opportunities for collaboration across the three pillars (Table 2).

Table 2: The Climate Smart Disaster Risk Management Approach (Mitchell et al 2010)

1. Tackle changing disaster risks and uncertainties	2. Enhance adaptive capacity	3. Address poverty, vulnerability & their structural causes
1a Strengthen collaboration and integration between diverse stakeholders working on disasters, climate and development To what extent are climate change adaptation, disaster risk management and development integrated across sectors and scales? How are organizations working on disasters, climate change and development collaborating?	**2a Strengthen the ability of people, organizations and networks to experiment and innovate** How are the institutions, organizations and communities involved in tackling changing disaster risks and uncertainties creating and strengthening opportunities to innovate and experiment?	**3a Promote more socially just and equitable economic systems** How are interventions challenging injustice and exclusion and providing equitable access to sustainable livelihood opportunities? Have climate change impacts been considered and integrated into these interventions?
1b Periodically assess the effects of climate change on current and future disaster risks and uncertainties How is knowledge from meteorology, climatology, social science, and communities about hazards, vulnerabilities and uncertainties being collected, integrated and used at different scales?	**2b Promote regular learning and reflection to improve the implementation of policies and practices** Have disaster risk management policies and practices been changed as a result of reflection and learning-by-doing? Is there a process in place for information and learning to flow from communities to organizations and vice versa?	**3b Forge partnerships to ensure the rights and entitlements of people to access basic services, productive assets and common property resources** What networks and alliance are in place to advocate for the rights and entitlements of people to access basic services, productive assets and common property resources?

1c Integrate knowledge of changing risks and uncertainties into planning, policy and programme design to reduce the vulnerability and exposure of people's lives and livelihoods How knowledge about changing disaster is risks being incorporated into and acted upon within interventions? How are measures to tackle uncertainty being considered in these processes? How are these processes strengthening partnerships between communities, governments and other stakeholders?	**2c Ensure policies and practices to tackle changing disaster risk are flexible, integrated across sectors and scale and have regular feedback loops** What are the links between people and organizations working to reduce changing disaster risks and ncertainties at community, sub-national, national and international levels? How flexible, accountable and transparent are these people and organizations?	**3c Empower communities and local authorities to influence the decisions of national governments, NGOs, international and private sector organizations and to promote accountability and transparency** To what extent are decision-making structures de-centralized, participatory and inclusive? How do communities, including women, children and other marginalized groups, influence decisions? How do they hold government and other organizations to account?
1d Increase access of all stakeholders to information and support services concerning changing disaster risks, uncertainties and broader climate impacts How are varied educational approaches, early warning systems, media and community-led public awareness programmes supporting increased access to information and related support services?	**2d Use tools and methods to plan for uncertainty and unexpected events** What processes are in place to support governments, communities and other stakeholders to effectively manage the uncertainties related to climate change? How are findings from scenario planning exercises and climate-sensitive vulnerability assessments being integrated into existing strategies?	**3d Promote environmentally sensitive and climate smart development** How are environmental impact assessments including climate change? How are development interventions, including ecosystem-based approaches, protecting and restoring the environment and addressing poverty & vulnerability? To what extent are the mitigation of greenhouse gases and low emissions strategies being integrated within development plans?

Challenges and ways forward

One of the foremost steps towards formulating sustainable "no regrets" IWRM strategies or adaptation measures is knowledge of current and future climate change scenarios and prioritization of the most vulnerable through inclusive vulnerable assessments. And, assessing the impacts of and vulnerability to climate change requires quality information on climate data like temperature, rainfall, frequency of extreme events, sea surface temperatures, sea level rise, wind speeds, tropical cyclones, storm surges, snow and ice cover, non-climatic data like the current situation on the ground for various sectors like water resources, agriculture, food security, terrestrial ecosystems, biodiversity, coastal zones and human health. Lack of systematic data of the climate system can be a major impediment to informed decision making during planning of IWRM strategies and adaptation measures. UNFCCC recognizes the need for the international community to support and further develop systematic observation systems

Lack of capacity for assessing climate change impacts and vulnerabilities can severely limit a country's ability to plan adaptation measures and adapt effectively.

Cross-sectoral measures can include:

1. Improvements to systematic observation and communication systems;
2. Improvements in science, research and development and technological innovations such as the development of drought-resistant crop varieties or new technologies to combat saltwater intrusion;
3. Education and training to help build capacity among stakeholders;
4. Public awareness campaigns and measures to improve understanding on climate change and adaptation;
5. Strengthening or making changes in the fiscal sector such as new insurance options; and increased involvement of the private sector
6. Convergence of DRR and CCA is an obvious way forward and is already reflected in a growing body of emerging plans and projects, with promising prospects for better development outcomes
7. Climate Smart Disaster Risk Management measures such as emergency plans.

References

1. Aerts, J. & Droogers, P. 2009: Adapting to Climate Change in the Water Sector. In: Ludwig, F.; Kabat, P.; van Schaik, H.; van der Valk, M. 2009: Climate Change Adaptation in the Water Sector.
2. Global Water Partnership (GWP). 2000. Integrated Water Resources Management. GWP Technical Committee Background Paper 4. Stockholm: GWP.
3. GFDRR (2009) Stockholm Policy Forum on Climate Smart Disaster Risk Reduction, Summary Report, Global Facility for Disaster Reduction and Recovery online at http://
4. gfdrr.org/gfdrr/sites/gfdrr.org/files/documents/Stockholm%20Policy%20Forum%20 summary%20final.pdf (accessed August 3, 2010)
5. IPCC – Intergovernmental Panel on Climate Change 2007: Summary for Policymakers. In: Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; van der Linden, P.J.; Hanson, C.E. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change.
6. IUCN – International Union for Conversation of Nature 2003: Change – Adaptation of water resources management to climate change.
7. Mitchell, T.; Ibrahim, M.; Harris, K.; Hedger, M.; Polack, E.; Ahmed, A.; Hall, N.;
8. Hawrylyshyn, K.; Nightingale, K.; Onyango, M.; Adow, M., & Sajjad Mohammed, S. (2010), Climate Smart Disaster Risk Management, Strengthening Climate Resilience,
9. Brighton: IDS accessed online at http://community.eldis.org/.59d5ba58/SCR%20DRM.pdf
10. Mitchell, T.; van Aalst, M., and Villanueva, P.S. 2010, Assessing Progress on Integrating Disaster Risk Reduction and Climate Change Adaptation in Development Processes, Strengthening Climate Resilience Discussion Paper
11. UNISDR, 2009, Global Assessment Report on Disaster Risk Reduction
12. www.preventionweb.net/english/hyogo/gar/report/index.php?id=9413

13. www.moef.gov.bd/climate_change_strategy2009.pdf
14. Frank Thomalla, Tom Downing, Erika Spanger-Siegfried, Guoyi Han and Johan Rockström 2006. Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. Disaster, 30 (I): 39-48.
15. TERI (Tata Energy Research Institute). 1996, Impact Assessment Study -- Report No. 93/GW/52, New Delhi: TERI
16. Twigg J (2004) Good Practice Review 9. Disaster risk reduction: mitigation and preparedness in development and emergency programming. Overseas Development Institute Humanitarian Practice Network, London
17. United Nations International Strategy for Disaster Reduction (UNISDR). 2004. Terminology: Basic Terms of Disaster Risk Reduction. UNISDR: Geneva.
18. United Nations Framework Convention on Climate Change (UNFCCC). 2006. Technologies for Adaptation to Climate Change. UNFCCC: Bonn.
19. McGray H, Hammill A, Bradley R. 2007. Weathering the Storm: Options for Framing Adaptation and Development. World Resources Institute. Washington D.C.
20. Lewis J. 1999. Development in Disaster-prone Places: Studies of Vulnerability. Intermediate
21. Technology Publications: London.
22. Wilk, J. and Wittgren, H.B. (eds). 2009. Adapting Water Management to Climate Change. Swedish Water House Policy Brief Nr. 7. SIWI.
23. Wisner B, Blaikie P, Cannon T, Davis I. 2004. At Risk: Natural Hazards, People’s Vulnerability and Disasters. (2nd edn). Routledge: London.
24. Tran P, Shaw R. 2007. Towards an integrated approach of disaster and environmental management: a case study of Thua Thien Hue province in Central Vietnam. Environmental Hazards 7(4): 271–282.

10

Environmental-health Disasters: Disease outbreak related to water and wastes

Jugal Kishore and Indu Grewal

World Health Organization (WHO) defines disaster as any occurrence that causes damage, ecological disruption, loss of human life, deterioration of health and health services, on a scale sufficient to warrant extra-ordinary response from outside the affected community or area.[1] Disasters are of two types: Natural Disasters (e.g. Earthquakes, Floods, Volcanoes etc.) and Manmade Disasters (e.g. Famine, Epidemics, Fire, Microbial warfare, etc.). Environmental health disaster are mainly manmade but in some situations geophysical processes can result in environmental health diseases such as arsenic poisoning of water in West Bengal, Bangladesh. Irrespective of the nature of hazard, all disasters exert "7Ds effect": Death, Disability, Disease, Distress, Damage to health services, Damage to the economy of the country, and Damage to the environment.[2] Concept of 'hazard' and 'vulnerability' emerged out recently for prevention of disaster. Hazard is the dangerous condition or event, that threat or has the potential for causing injury to life or damage to property or environment. In case of water which is part of environment can be polluted to such a level that it can become hazard to environment and human health. One of the major causes of water pollution is waste. Although nothing is called as *waste* but for practical purpose, it can be define as a resource that is not safely recycled back into the environment or the marketplace. *Vulnerability* is the extent to which a community, structure, services or a geographic area is likely to be damaged/ disrupted by the impact of a particular hazard on account of their nature, proximity to hazardous terrain, or a disaster prone area.[2,3] The probability that a particular population will be affected by the hazards is known as 'Risk', which is depended on vulnerability and hazard.[2]

Majority of outbreaks if not managed on time then they have a potential to become epidemic and if epidemic not controlled then they can turn out to disasters. Therefore a clear cut definition has to be charted out for water and waste related outbreaks and epidemics. Water is a potential vehicle and any water pollutant can spread to a wider geographical area via water bodies like canals, rivers or seep into underground water table. A waterborne outbreak is defined as a cluster of two or more infections caused by the same agent(s) and linked to the same water exposure. Waterborne diseases can be caused by water contaminated with pathogens, chemicals, or toxins which can be spread through ingestion, contact with, or breathing contaminated water.

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Burden of Water related Disease outbreaks

In past, there were 2,200 water-related disasters from 1990 to 2001. (CRED 2002) [4] Their distribution were as follows: a) Floods: 50%, b) Water-borne and vector disease outbreaks: 28%, c) Droughts: 11%, d) Landslide and avalanche events: 9%, and e) Famine: 2%. The geographical distribution indicated that they had affected all regions of the world but more so in Asia (35%) and Africa (29%). In American region they were 20%, and in Europe 13%, and in Oceania only 3%.

The largest waterborne disease outbreak in United States history occurred in 1993 in Milwaukee, when over 400,000 people became ill with diarrhea when the parasite Cryptosporidium was found in the city's drinking water supply.[5] Similarly, Legionnaire's disease had caused severe outbreak in USA.[6]

Katrina and other Hurricanes exposed the truth that no country can take water related disasters lightly which directly and indirectly after the environment and human health.[7] These disasters had huge economic loss also. The American Insurance Services Group (AISG) estimates that Katrina is responsible for $41.1 billion of insured losses in the United States. An estimate of the total damage cost of Katrina in the United States is obtained by doubling the AISG figure to account for uninsured losses and adding the insured losses from NFIP. This yields a total damage estimate of $108 billion in the United States for Katrina.

In India, the 1999 Odisha cyclone, also known as *Cyclone 05B*, and *Paradip cyclone*, was the deadliest since the 1991 Bangladesh cyclone and deadliest Indian storm since 1971. The Odisha cyclone Approximately 275,000 homes were destroyed, leaving 1.67 million people homeless. A total of 19.5 million people were affected by that cyclone to some degree. A total of 9,803 people officially died from the storm, with 40 others still missing, though it is believed that 15,000 people died.[8]

Another example is Cloud burst in Leh region of Laddak where 400 families were badly affected due to flush flood and sub subsequently massive landslide made the situation worst for relief measures. Indian Red Cross Society provided clean drinking water to the affected population. In flood the drinking water is a major challenge to prevent waterborne disease epidemics.

Causes of Water related Disease outbreaks

Water related disease outbreaks occur due to pollution. Water pollution refers to the state of water in which undesirable and sufficiently large amount of pollutants (soluble, insoluble, toxin and pathogens) are present which may cause damage to the health of human being or environment. Natural disasters directly and indirectly affect the water leading to disease outbreaks and epidemics. As water is essential commodity of life, any damage to its quality and quantity may have serious effect on human health and environment. Similarly manmade conditions are also damaging the water. Following are the important causes for water related disease outbreaks:

1. **Geographical characteristics:** Arsenic concentrations in ground waters in Bengal, Southeast Asia, and elsewhere constitute a major hazard to the health of people using these waters for drinking, cooking, or irrigation. A comparison of occurrences in the Ganges-Brahmaputra, Mekong, and Red River basins indicates various reasons: (1) river drainage

from the rapidly weathering Himalayas, (2) rapidly buried organic-bearing and relatively young sediments, and (3) very low, basin-wide hydraulic gradients. Anaerobic microbial respiration, utilizing either sedimentary or surface-derived organic carbon, is one important process contributing to the mobilization of arsenic from host minerals, notably hydrous iron oxides. The extensive groundwater pumping in these areas could be another reason for change. However, there is sufficient evidence to make a prima facie case that human activity might exacerbate arsenic release into these groundwaters.[9]

Excessive level of arsenic in drinking water is a major public health disaster in those areas. Several viable approaches to mitigation could drastically reduce arsenic exposure, but they all require periodic testing. Similarly developing treatment technologies for alternative surface-water supplies need to be urgently required.[10]

2. ***Water supply and sanitation problem:*** Deficiencies in established norms and quality of potable water and difficulties in the disposal of excreta and other wastes result in the deterioration of sanitation, contributing to conditions favorable to the spread of enteric and other diseases. For example, immediately after the devastating earthquake in Turkey in August 1999, an infectious disease surveillance system mainly focused on diarrheal diseases analyzed 1,468 stool cultures and found main cause of diarrheal outbreak was Shigella species. This study has emphasized the necessity to set up infectious disease surveillance systems after such events[11] and also development of alternate mechanism of water supply and sanitation.

   Water-Borne Infection is a range of syndromes, including acute dehydrating diarrhea (cholera), prolonged febrile illness with abdominal symptoms (typhoid fever), acute bloody diarrhea (dysentery), and chronic diarrhea (Brainerd diarrhea). Common viral infections are hepatitis A and E, poliomyelitis,

   Common bacterial agents for diarrhea include Vibrio cholerae, Campylobacter, Salmonella, Shigella, and the diarrheogenic Escherichia coli. Each year, estimated 3-5 billion episodes of diarrhea result in an estimated 3 million deaths, mostly among children. Waterborne bacterial infections may account for as many as half of these episodes and deaths. Many deaths among infants and young children are due to dehydration, diarrhea associated malnutrition, or other complications of waterborne bacterial infections.

   Contaminated surface water sources and large poorly functioning municipal water distribution systems contribute to transmission of waterborne bacterial diseases. Chlorination and safe water handling can eliminate the risk of waterborne bacterial diseases. Over 2 billion persons living in poverty in the developing world are at high risk. Despite global efforts during the water and sanitation decade, improvements in water and sanitation infrastructure have barely kept pace with population increases and migrations in the developing world.

3. ***Food and nutrition problems:*** Food shortages in the immediate aftermath are very common. Food stock destruction within the disaster area may reduce the absolute amount

of food available, or disruption of distribution systems may curtail access to food, even if there is no absolute shortage. Flooding and sea surges often damage household food stocks and crops, disrupt distribution, and cause major local shortages. Contaminated water and improper waste disposal can be source of food and nutrition problems.

4. ***Damage to health infrastructure:*** Health systems are also among the most vulnerable to natural disasters. For example, after the 2004 Indian Ocean tsunami, a large number of health institutions were damaged. These included hospitals, drug stores, cold rooms, preventive health care offices, health staff accommodation facilities and district health offices. In addition, a large number of vehicles (ambulances, vans, motorbikes) and most of the medical equipment and office equipment in the affected areas were totally destroyed. The loss of health personnel included medical officers, nurses, midwives and support staff. Furthermore, a large number of health staff were injured, traumatized or displaced by the event, hence were unable to assist the affected.[12] Therefore, health care physical infrastructure and personnel are affected by the disasters like any other individual in the affected area. This damage occurs at the most in opportune time, just when the need for provision of emergency care is the most. Besides, non-structural damage also alters the ability of a health care system to provide adequate care at the time of catastrophe. The destruction of equipment and supplies, especially the loss of laboratory functions and pharmaceuticals places an additional burden on a health care agency trying to provide services to increased number of patients.[3] Beside this, natural disasters may seriously inflict damage on the services considered vital for smooth functioning of a health care system such as electricity, water supply, transportation etc. Transportation and tele-communications may seriously be jeopardized during a catastrophic event which may impede public health sector's ability to respond to disaster. The potential health risks of different disasters[13] can be summarized as shown in table 1. This is evident that risk of water related outbreaks is always there in almost all disasters.

Table 1: Risk of Water related diseases in various disasters

Health (related) effects	Earthquake	Floods	Land-slides	Epidemics	Conflict situation
Damage to water systems	Severe	Light	Severe (but localized)	None	Limited (depends on the factions fighting)
Damage to health facilities	Severe (structural & equipment)	Severe (equipment usually)	Severe (but localized)	None	Limited (depends on the factions fighting)
Damage to health services	High	High	Low	Moderate	High
Increased risk of epidemics	Yes	Yes	Yes	------	Yes

5. ***Waste:*** waste is a material that may be discarded as unwanted but which may have value or purpose in other content. Waste came to be viewed as discarded materials, however much of which can be reused or recycled (cardboard, paper, plastic, etc.) or generate fertilizer by composting waste.

Following are various categories of wastes which potential to contaminate water bodies:

a) Biomedical waste is generated in the diagnosis, treatment or immunization of human beings or animals, in research or in the production or testing of biological products including all categories of infected, blood products, dated/expired pharmaceutical drugs and toxic waste that is potential threat to human beings and environment. Such wastes if not managed carefully may have potential to contaminate water bodies.

b) Chemical waste: Inorganic: Nitrates, phosphates, chloride and fluoride, *Organic:* Pesticides, dyes, chloro-compounds, phenols, paints and plastics. *Heavy metals:* soluble heavy metal ions such as mercury, lead, cadmium, copper, zinc and their organometallic compounds. Products of industry and agriculture, such as dioxins and dioxin-like compounds (PCBs) are potential cause of health and environment effects.

Organic mercury and heavy metals, such as lead and cadmium are well known water contaminants leading to disaster like situations. One of the examples of worst sea water contamination is Minimata disease that was first discovered in Minimata city in Kumamoto prefecture Japan in 1956. It was caused by the release of methyl-mercury industrial waste water from the Chisso Corporation's chemical factory in the Minimata sea, which continued from 1932 to 1968. This toxic chemical accumulated in shellfish and fish in Minimata Bay and the Shiranui Sea, which when eaten by the local people resulted in mercury poisoning. While cat, dog, pig, and human deaths continued over more than 30 years from the disease. As of March 2001, 2,265 victims had been officially recognized (1,784 of whom had died) and many more times were disabled had received financial compensation. By 2004, Chisso Corporation had paid $86 million in compensation, and in the same year was ordered to clean up its contamination. On March 29, 2010, a settlement was reached to compensate as-yet uncertified victims.[14-15]

Another example is *Itai-itai disease* which was caused by Cadmium poisoning due to mining in Toyama Prefecture. In various mining processes for gold, silver, lead, copper, zinc, the cadmium was released in significant quantities. This subsequently increased the pollution of the Jinzu River and its tributaries. The river was used mainly for irrigation of rice fields, but also for drinking water, washing, fishing, and other uses by downstream populations.[16] The cadmium accumulated in the people eating contaminated rice lead to kidney diseases and bone deformities.

c) Dioxins and dioxin-like compounds (Polychlorinated biphenyls, PCBs) are by-products of various industrial processes, and are commonly regarded as highly toxic compounds that are persistent organic pollutants. The acute exposure to PCBs has been reported in Japan following the ingestion of rice oil contaminated by PCBs. In Sweden birth weight has been found to be reduced and the perinatal mortality rate higher than expected in regions with high consumption of fatty fish from the Baltic Sea. In addition, from studies around Lake Michigan, it has been shown that children who had been exposed to PCBs in *utero* have retarded cognitive development. [17]

d) *Liquid Wastes* are usually wastewaters, generated from municipalities, laboratories and industries, which contain less than 1% suspended solids. Because it contained bacteria, viruses, chemicals, metals, etc., if disposed off in water bodies without treatment it can be dangerous to human health and environment.

e) *Radioactive waste and accidental release in water body:* liquid, solid and gaseous wastes, contaminated with radionuclides from nuclear medical diagnostic, therapeutic procedures or power generation. Recently tsunami caused havoc in Japan by destroying three nuclear power plants. These effects have to be estimated yet.

f) *Solid Wastes* are waste materials having less than approximately 70% water. This class includes municipal solid wastes such as household garbage, industrial waste, mining wastes, and oil field wastes. They are also potential sources of water contamination if directly dumped in water bodies.

g) *Physical waste:* waste heat from industrial plants, turbidity etc. also causes water pollution which affect the aquatic life and make the water unfit for human consumption.

6. ***Aral Sea Disaster:*** Aral Sea is an example of manmade environmental water related disaster. Until 1960 the Aral Sea was considered the 4th largest lake in the world by surface area. From early 1960s because of extensive water use--unreturned withdrawal of water for irrigation and consequent drying up of many tributaries before reaching the main rivers--the water level in the Aral Sea began falling very rapidly. By 1990 the level of the Aral Sea water fell by more than 17 m, the volume of water decreased by 75%, the salinity of seawater increased up to 30 g/l, and the surface area of the sea reduced from 66,400 sq. km to 31,500 sq. km. Irrigated soils become deserts, deterioration of underground and surface water quality, reduction of available water for domestic and agricultural needs, loss of Aral Sea fishing and finally human activities put the health of present and future generations under threat.[18] Children are more prone to poverty and exposure of chemicals and pesticides which were heavily used for agriculture and industries near the Aral Sea resulted congenital defects and malnutrition in them.[17]

7. ***Pesticides:*** are used for many purposes for example to gain agricultural productivity and to keep homes free from mosquitoes and other pests. But pesticides are toxic substances to human and environment. The World Health Organization and the United Nation Environment Program estimate that each year, 3 million workers in agriculture in the developing world experience severe poisoning from pesticides, about 18,000 of whom die.[19] In India, water was found contaminated with pesticides. Even the bottled water which is considered to be safe was also had all types of pesticides such as HCH (Lindane), DDT and its metabolites, Endosulfan, Malathion and Chlorpyrifos.[20-21] Pesticides are also linked with the rising incidence of cancers in Punjab.[22]

8. ***Water-Based Disease (non-fecal contamination)*** refers to the infections transmitted through an aquatic invertebrate animal e.g. schistosomiasis and dracunculiasis. Dracunculus medinensis is the causative organism of Guinea worm disease, and is unique in being the only pathogen of non-fecal origin and ingested through water.

9. ***"Water-Breeding" diseases*** are those which are transmitted by mosquitoes or flies living near aquatic conditions. They are the part of water-related diseases which refer to the infections spread by insects that depend on water. Insect vectors breeding in water transmit malaria, filariasis, onchocerciasis, sleeping sickness, yellow fever and dengue fever. The infection may also occur by inhalation through microbes on water droplets, such as those produced by showers, air conditioning systems or the irrigation of agriculture land. All these diseases have potential to cause epidemic in a wide geographical areas.

Current status of management of water related outbreaks in India

The ferocity and impact of catastrophic events have increased in recent times in the country. Traditionally, disasters have been looked upon as aberrations or interruption in normal day to day activity of the society to be responded primarily with relief. But, there was growing realization that development cannot be sustained unless all the phases of Disaster Management Cycle continuum are comprehensively addressed considering the large number of casualties and economic losses which the country has experienced in the recent past.[23] The Government of India thereupon adopted a more pro-active multidisciplinary and holistic approach for prevention, mitigation and preparedness. This paradigm shift in the national approach to disaster management led to enactment of Disaster Management Act, on 23rd Dec, 2005, which envisaged the creation of an apex body National Disaster Management Authority with Prime Minister as a chairperson and likewise constitution of State Disaster Management Authorities (SDMA) and District Disaster Management Authorities (DDMA).[23,24,3]

With the backdrop that the common denominator of all disasters is human suffering, there is a need of concerted actions from SDMA/DDMA and medical fraternity for prevention and management of mass casualty inflicted due to disasters.

The Indian Red Cross Society is implementing Disaster Risk Reduction program in 3 states-Maharashtra, Andhra Pradesh and Odisha which is supported by Hong Kong and Canadian red Cross.

Medical preparedness of Disasters in India

The pro-active approach adopted by Government of India (GOI) and Naitonal Disaster Management Authority (NDMA) culminated into formulation of the National Guidelines on Medical Preparedness and Mass Casualty Management.[25] These guidelines encompasses medical management in four phases, that is, initially at the Incident site by the Medical First Responders within the 'golden hour' preferably a critical period between injury and life/limb saving surgery that decides the patient's outcome; then evacuation in the ambulances fitted with critical care equipment; followed by prompt treatment in the hospitals and sequelae of resultant disease/disability; and lastly, prevention of epidemics, management of chronic health effects and provisioning psychosocial care (medical preparedness).

Disease surveillance can predict outbreaks and epidemic in the community after disaster. For that fully furnished laboratories network with peripheral units are required. Bio-safety laboratories with few BSL-3 and BSL-4 are being established at designated nodal institutions.

Integrated Disease Surveillance Project along with upgraded laboratories has proved very useful in the management of water related epidemic control. Most of the deaths due to shock can be prevented by intravenous fluid infusion and blood transfusion. Licensed blood banks critical for management of shock have been networked to cater for surge requirement during disasters.

Transportation for casualty evacuation by the Integrated Ambulance Network having basic medical equipment for resuscitation, essential drugs, and two way communication vis-à-vis the hitherto before Ambulances which functioned only ferried patients. Of late, casualty evacuations by air, especially by helicopters ambulances, have greatly improved patient care management capabilities.

Additional thrust is on telemedicine which entails putting diagnostic equipment and Information Communication Technology for connectivity between the disaster site and advanced medical institutes where such linkup have been installed. Training in First Aid of the community to improve their response to disaster is also useful.

Water related outbreaks and epidemics are investigated at the district and state level by District or State Rapid Response Team under Integrated Disease Surveillance Program (IDSP) under the umbrella of National Rural Health Mission. The major objectives of the IDSP are: **a)** to establish a decentralized state based system of surveillance for communicable and noncommunicable diseases, so that timely and effective public health actions can be initiated in response to health challenges in the country at the state and national level; and b) to improve the efficiency of the existing surveillance activities of disease control programs and facilitate sharing of relevant information with the health administration, community and other stakeholders so as to detect disease trends over time and evaluate control strategies.[3]

The program has three types of surveillances:

1. ***Syndromic Surveillance:*** Health workers in the field do the surveillance on the basis of syndrome which they can identify for example, increase number of loose stools with or without blood.
2. ***Clinical Surveillance:*** This is carried out by medical officers and based on his/her clinical skills, they diagnose the diarrhea or water related disease case clinically and report.
3. ***Laboratory Surveillance:*** This is based on the laboratory diagnosis which is more confirmed about the disease pathology or etiology. For all practical purpose such diagnoses are not required for an epidemic response. However laboratory confirmation is always required to determine the cause.

Under IDSP data is collected on a weekly basis (Monday-Sunday). The data is collected on 3 specified reporting formats, namely ‘S’, ‘P’ & ‘L’ filled by health worker, clinician and clinical laboratory staff respectively. The weekly data gives the time trends. Whenever a rising trend of illness in any area is noticed, it is investigated by the Medical Officer/Rapid Response Team to diagnose and control the outbreak. Data analysis is carried out by their respected units. Emphasis is laid on reporting of surveillance data from major hospitals both from private and public sector and also from infectious Disease Hospital.

Functions of National Surveillance Unit (NSU)

NSU execute the approved annual plan of action for IDSP and also monitor progress of implementation of the project. It is its duty to obtain physical reports and expenditure statements from states and report regularly to National Disease Surveillance Committee. The unit provides prototype guidelines, manuals and modules. Procurement of goods, training and IEC, analysis of data from the states and provide feedback on trends observed and coordinating with National Center for Disease Control, ICMR and others bodies.

Functions of State Surveillance Unit

Chairperson of the State Surveillance Committee is State Secretary Health. He is supported by Joint Director (State Surveillance Officer). There are 2 consultants (for Technical & Training and Finance & Procurement) and one data manager, two data entry operators, one office assistant and class IV employees. State Surveillance Unit collates and analyses the data received from district and transmitting to Central Surveillance Unit. It coordinates activities of rapid response teams and deputing them to the field. Monitoring and reviewing the activities of the district surveillance units including checks on validity of data, responsiveness, functioning of the laboratories, training are also its functions.

Functions of District Surveillance Unit

Chairperson District Surveillance Committee is District Collector or District Magistrate. Deputy Chief Medical Officer acts as District Surveillance Officer. District surveillance unit collates and analyses data received from all reporting units and transmitting to state, constitutes rapid response teams and deputing them to the field whenever needed.

In rural areas primary health centers /community health centers, Sub-divisional and district hospitals including sentinel private practitioners or private hospitals are responsible for data collection and response the outbreak. In urban areas hospitals, ESI, Railway, CGHS hospitals and dispensaries, other hospitals medical collages, Municipal Corporation hospitals and dispensaries, including some sentinel private nursing homes, sentinel Hospitals, medical Colleges, NGOs, and private laboratories are also collected the data and reported to the authorities for rapid action.

Epidemic Response

Epidemiological response include following actions:

1. Verification of diagnosis
2. Definition of outbreak;
3. To confirm that an epidemic actually exists;
4. To assess the magnitude of problem in terms of morbidity and mortality and its geographical spread using working case definition;
5. To identify the source of infection and mode of transmission by developing hypothesis and testing of hypothesis; and
6. To institute area and situation specific control measures and communication.

Preventive Measures

1. Provision of safe drinking water: Safety of drinking water can be ensured either at the point of storage or distribution. Prescribing boiling of water or use of chlorine tablets for chlorination at household level is one of the most important preventable steps. Chlorinometer is used to measures chlorine content in water regularly.
2. Disposal of waste and human excreta needs special attention.
3. Fly proofing is done by regular bleaching powder spray in the areas.
4. Health education: Use of mass media like radio, TV, Newspapers, pamphlets, leaflets containing small repeated message on:
   a) Personal hygiene
   b) Water consumption
   c) Use of boiled water and use of chlorine tablets
   d) Food consumption: Food should be safe, fresh and less costly.
5. Surveillance: a close watch should be kept every day on disease occurrence and trends should be instituted.
6. Immunization against diseases for high risk group population.
7. Preparedness for occurrence of disease epidemic based on the community's coping capabilities and required institutional capacities.
8. Administrative arrangements need to ensure following:
   a) Identification of target groups/communities.
   b) Continuous and adequate procurement from medical stores: It is expected that 10% of the affected population may require medical treatment. Most common diseases are diarrheal diseases including gastroenteritis, dysenteries, cholera, typhoid, infective hepatitis and poliomyelitis, respiratory infections, skin infections, malaria, insect bites, and snakebites.
   c) Disinfection of drinking water sources and frequent monitoring at distribution point like households. Centralized water treatm ent and distribution systems are expensive and take years to complete. To provide the underserved with potable water in the short term requires innovative practical solutions such as point-of-use disinfection and safe water storage vessels. Electrolytic generators that produce sodium hypochlorite from salt water are now affordable and available for use in the developing world. Use of homemade ORS and other safe rehydration solutions can markedly reduce diarrheal deaths.
   d) Availability of vaccine for immunization with quality service.
   e) Establishment of medical and health camps.
   f) Setting up of epidemiological surveillance.

g) Publicity and need based health education.

h) Involvement of other departments for handling veterinary problems, transport problems, water and sanitation problems, etc.

i) More Involvement of community groups, NGOs and other voluntary groups in relief activities.

j) Monitoring and review.

Water related outbreaks and epidemics are real threats to the human health. Environmental degradation is one of the major causes of such disasters. A comprehensive strategy for the prevention of environment pollution not only decreases environment health but also water related disasters. Medical preparedness for early response to such outbreaks decreases human losses to a great extent. So, all stakeholders of public health must work in coordinated manner in prevention and control of environmental disasters.

References

1. Kishore J. A Dictionary of Public Health. 2nd Edition. New Delhi: Century Publications 2007.
2. Kishore J, Anand T. Epidemiological Disaster: Role of Environmental Knowledge. In Anil Gupta, Sreeja Nair (Ed). Environmental Knowledge for Disaster Risk Management. New Delhi: ekDRM Secretariat and NIDM 2011; pp. 28-41.
3. Kishore J. National Health Programs of India: National Policies and Legislation related to health. 10th Edition. New Delhi: Century Publication 2012.
4. CRED (Centre for Research on the Epidemiology of Disasters). Executive Summary of the World Water Development report 2002. The OFDA/CRED International Disaster Database. Brussels, Université Catholique de Louvain.
5. Centers for Disease Control and Prevention. Surveillance for Waterborne Disease Outbreaks – United States, 1993-1994. MMWR 1996:45(No. SS-1). Available at http://www.cdc.gov/mmwr/preview/mmwrhtml/00040818.htm.
6. Centers for Disease Control and Prevention. Patient Facts: Learn More about Legionnaires' disease. Available athttp://www.cdc.gov/legionella/patient_facts.htm.
7. National Weather Service. 2005 Atlantic Hurricane Season. Available at http://www.nhc.noaa.gov/2005atlan.shtml
8. http://news.bbc.co.uk/onthisday/hi/dates/stories/october/29/newsid_3691000/3691573.stm.
9. Charlet L, Polya DA. Arsenic in Shallow, Reducing Groundwaters in Southern Asia: An Environmental Health Disaster. ELEMENTS April 2006 v. 2 no. 2 p. 91-96)
10. Ahmed MF, Ahuja S, Alauddin M, Lloyd JR, Pfaff A, Pichler A et al. Ensuring Safe Drinking Water in Bangladesh Science 2006: 314 (5806) :1687-1688.
11. Norris FH, Friedman MJ, Watson PJ, et al. 60,000 disaster victims speak: part I. An empirical review of the empirical literature, 1981–2001. Psychiatry 2002;65:207–39.
12. Inui A, Kitaoka H, Majima M, Takamiya S, Uemeto M, Yonenaga C, et al. Effect of the Kobe Earthquake on Stress and Glycemic Control in Patients With Diabetes Mellitus. Arch Intern Med 1998;9:274-78.
13. Hendrickson LA, Vogt R. Mortality of Kauai Residents in the 12-Month Period following Hurricane Iniki. Amer J Epidemio 1996;144(2):188-91.
14. Saito, Hisashi. (2009). Niigata Minamata Disease: Methyl Mercury Poisoning in Niigata, Japan. Niigata Nippo.
15. Walker B. "Toxic Archipelago: A History of Industrial Disease in Japan." University of Washington Press 2010.
16. ICETT. Itai-itai disease (1998) available from: http://www.icett.or.jp/lpca_jp.nsf /a21a0d8b94740f bd492567ca000d5879/b30e2e489f4b4ff1492567ca0011ff90?).

17. Zetterstrom R. Child health and environmental pollution in the Aral Sea region in Kazakhstan. Acta Paediatr Suppl 1999 May;88(429):49-54.

18. Usmanova RM. Aral Sea and sustainable development. Water Sci Technol. 2003;47(7-8):41-7.

19. Miller GT (2004), Sustaining the Earth, 6th edition. Thompson Learning, Inc. Pacific Grove, California. Chapter 9, Pages 211-216.)

20. Mathur H B, Johnson S, Mishra R, Kumar A, Singh B. Analysis of pesticide residues in bottled water [Delhi region]. CSE 2003. http://www.cseindia.org/userfiles/Delhi_uploadfinal_sn.pdf

21. Agrawal A, Pandey RS, Sharma B. Water Pollution wit special reference to pesticide contamination in India. Journal of Water Resource and Protection 2010; 2(5): 432-448.

22. Yadav Sandeep. Green revolution's cancer train. http://www.hardnewsmedia.com/2006/11/648

23. Health impact of Disasters presented at 1st regional Conference on Emergency and Humanitarian Action, Dhaka, Bangladesh on 17th-22nd Dec, 1996.

24. Medical preparedness aspect of Disasters. Available from: http://ndma.gov.in/ndma/guidelines/MedicalPreparedness.pdf.

25. NDMA. National Guidelines on Medical Preparedness and Mass Casualty Management. New Delhi: NDMA 2009.

11

Environmental Impact Assessment: Elucidating Policy-Planning for Natural Disaster Management

Anil K. Gupta and Sreeja S. Nair

Environment Based DRR: An Overview

Environmental approach to disaster risk reduction (DRR) is widely advocated as 2nd paradigm shift in disaster management, as it directly links with the livelihood of the people and sustainability of their resources. This calls for emphasis on natural resource management, ecosystem services, land-use and adaptation to climate-change within the strategies of disaster prevention, preparedness and post-disaster relief and recovery process. Drought, cyclone, flood, landslide, tsunami, vegetation fire, pests and epidemics, etc. are major disasters associated with environmental processes and natural resource systems. Strategic management of disasters depends on prudent decisions, planning and enforcement of mitigation provisions. Policy instruments are the 'tools' useful in formulation of policies and strategies and those in implementing policy decisions. Environmental impact assessments (EIAs) and Environmental Law are key instruments, with potential of significant role in different phases of disaster management. EIA tools broadly covers strategic and project EIA, Life-cycle Assessment, Audit, Risk Analysis and Resource Accounting.

In view of the Hyogo Framework of Action (HFA), the UN-ISDR Global Joint Work programme for 2008-2009 sought to ensure that *"national and local authorities are better equipped to protect environmental services in coastal areas, flood and fire-sensitive basins and mountain ecosystems"*. Hazards and disasters are two sides of the same coin; neither can be fully understood or explained from the standpoint of either physical science or social science alone; and are inextricably linked to the ongoing environmental changes – global, regional and local levels, including factors that interact to determine prospects of sustainable development **(figure 1)** (Dynes, 2004).

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

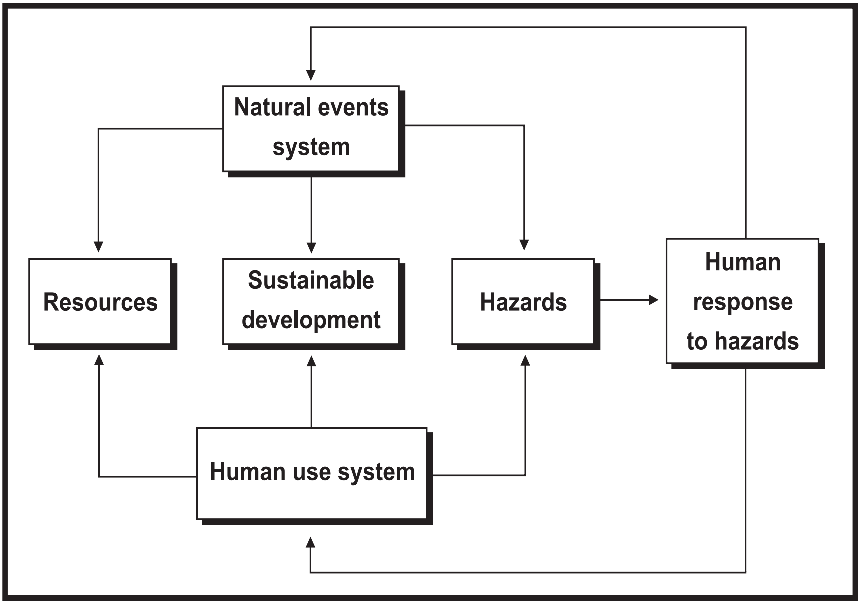

Figure 1. Environmental hazards and interface of natural events system with human use system (Burton et al., 1993).

Environmental degradation is defined as any change or disturbance to the environment perceived to be deleterious or undesirable, be it quantitative or qualitative, whereas the disasters are the events of environmental extremes which are inevitable entities of this living world. Major environmental changes driving hazards and vulnerabilities of disasters are – climate-change, land-use changes and natural resource degradation (Gupta and Nair, 2011).

Environmental approach: Paradigm Shift in DRR

Globally, disaster management has voiced of a paradigm shift from 'response & relief' centric in approach to 'mitigation and preparedness', a lesson drawn from UN-IDNDR. A 2nd paradigm shift is on-way as driven by climate-change awareness and sustainability concerns in disaster management (Gupta, 2010). This has resulted in wider acceptance of 'Disaster Risk Reduction (DRR) concept over 'Disaster Management' and greater recognition of 'Environmental approach to disaster risk reduction and management' is now a prime concern in disaster management strategies worldwide. Environmental management for disaster risk reduction did not exist as a formal field of practice. Instead, its scope is largely defined by the goals set by organizations working on related issues, namely: ecosystems conservation, sustainable development, disaster risk reduction and climate change adaptation / mitigation, etc.

Environmental approach to disaster risk management aims at utilizing environmental knowledge and practices in all stages of risk-cycle so as to reduce disaster's risk, impact and ensure sustainability in reconstruction and recovery. It starts with the understanding of the environmental basis of disasters, or in other words – recognizing disasters as 'environmental events' **(Box 1)**.

BOX 1. Environmental classification of disasters

DISASTER TYPES: RE-CLASSIFIED…*

1) **Environmental disasters**
   Hydro-meteorological, Vegetation fire, Geophysical, Geo-chemical, Biological, Epidemics…., etc.

2) **Technological disasters**
   Industrial (chemical), Electrical, Mechanical, Nuclear/radiological, Aviation, Dam break, Mining, Structural collapse …., etc.

3) **Civil disasters and conflicts**
   Civil unrest, Strike, War, Sabotage, Mass poisoning, Bomb blast, Stampede, Transport accidents.... etc.

* *An environmental disasters may be of natural origin or human-induced / man-made and can also trigger a technological disasters or civil conflicts. On other hand, a technological mishap or civil disaster may trigger environmental calamity.*

"Human societies cannot be dissociated from the environment that they shape and which in turn influence their development and livelihoods. Together they form a comprehensive system with intrinsic levels of vulnerability and inherent coping mechanisms. The less degraded the environmental component of this system, the lower its overall vulnerability and the higher its coping capacity.' – the principles set out in the Hyogo Framework (HFA) are acknowledged by the UN-ISDR, which defines ten Opportunities for Environment in the context of disaster prevention or reduction (UNEP, 2010):

1. Engage environmental managers fully in natural disaster risk management mechanisms;
2. Include risk reduction criteria in environmental regulatory frameworks;
3. Assess environmental change as a parameter of risk;
4. Utilize local knowledge in community-based disaster risk management;
5. Engage the scientific community to promote environmental research and innovation;
6. Protect and value ecosystem services;
7. Consider environmental technologies and designs for structural defenses;
8. Integrate environmental and disaster risk considerations in spatial planning;
9. Prepare for environmental emergencies; and,
10. Strengthen capacities for environmental recovery.

In addressing the relationship between social and environmental vulnerability and the occurrence of disasters, Wilches-Chaux (1993) states: *"There is no doubt those natural forces play an important role in the initiation of several disasters, however it is no longer the case that they can be considered the main cause of such disasters. There seem to be three fundamentals causes that dominate the disaster processes in the developing world, which is precisely where their incidence is the largest (IADB, 1999)". Environmental and natural resource management is the other key element in vulnerability reduction; it is essential to place continuous emphasis on implementing long-term environmental measures (IADB, 1999).* Environmental approaches envisaged in the national disaster management guidelines for floods, drought and cyclone (NDMA, India) are given in **Box 2**.

BOX 4: National Disaster Management Guidelines: Environmental Approaches

Government of India has developed specific guidelines for management of different disasters. Many approaches based on environmental knowledge and management of natural resources and ecosystems are manifested in their contents. A pilot assessment of the three guidelines*, viz. Flood, Cyclone and Drought, has been undertaken to identify ecosystem and environmental based approaches referred therein:

Reference	**Flood Management Guidelines**	**Cyclone Management Guidelines**	**Drought Management Guidelines**
Environmental rights	Lives and livelihoods, Livelihood systems	Livelihood	Livelihoods, Alternative livelihood
Climate-change	Snow melt, GLOF, LLOF	Climate-change and sea level rise	Climate-change impact on drought and agriculture
Natural Resource Management	Catchment area treatment, Anti-erosion measures, Coastal protection, Carrying capacity of rivers and drainage, River-bank erosion, Sediment load from river catchments, Drainage congestion, Wetlands, Integrated water resource management, Environmental-health, Encroachment of waterways, Waste management	Coastal afforestation, Aquaculture, Coastal resources, Bio-shields, Mangroves, Shelterbelt plantations, Coastal flood plain management, Coastal erosion, Crop and livestock protection, Environmental-health responses, Shelterbelt plantation monitoring	Agriculture, Land resource management - Soil-moisture, Soil amendment, Integrated Nutrient and Pest management Water scarcity and management, Reservoirs and wetlands, Groundwater, Streams, Drought prone area programme, Desert development programme, Alternative cropping, In-situ conservation, Horticulture, Ecosystems, Forest management, Crop phenology, Coastal & marine resources, Pollution control

Land-use / land-cover	Afforestation, Watershed management,	Alternative developmental scenario, preferred scenario, Land-use	Afforestation, Alternative land-use, Agroforestry, Biofuel cultivation
Environmental Impacts / Risk Analysis, Environmental statistics	Ecofriendly structural & non-structural mitigation, Environmental database for forecasting & damage assessment, Dam safety	Coastal zone management, EIA, Assimilative capacity estimation, Regional Environmental Management Plans	Environmental impacts of drought – environmental health risks, livelihood impacts, Environmental indicators for risk and impact assessments including databases, Environmental planning,
Environmental regulations	River regulation zone, Flood-plain zoning	National environmental policy, Coastal zone management, EIA	Environmental law
Date of release	January 2008	April 2008	September 2010

Environmental Policy Instruments and DRR

Instruments useful in the formulation of policy and/or implementation of policy are called 'policy instruments'. There are many instruments that are relevant for environmental policy, like tools for analysis, checklists, and plans. More generally, instruments for environmental policy can be seen as the means for executing environmental objectives in project & policy design. More restrictively defined *"Instruments for environmental policy are structured activities aimed at changing other activities in society towards environmental goals"* (Huppes and Simonis, 2003). The prime role of environmental policy instruments (EPIs) is in reducing the risk to manageable proportions. Common and important environmental policy instruments of recent times for their potential of use in disaster risk management are grouped in three major classes **(Box 3).**

Policy Statements are regulatory tools that define and focus the political agenda

BOX 3: Common Environmental Policy Instruments

(1) Regulatory Instruments

a. Command & Control Strategies
   1. Policy statements
   2. Environmental laws (acts and rules therein)
   3. Regulatory notifications

b. Market Based Instruments
   4. Environmental taxes, levy and cess
   5. Environmental clearance
   6. Discharge & Liability permits

(2) Socio-commercial Instruments

a. Environmental economics and resource accounting
b. ISO/EMS Certification
c. Environmental auditing
d. Ecomark and ecolabelling

(3) Ecological-Planning Instruments

a. Environmental Impact Assessment (EIA) (Including Disaster Management Plan, DMP and Emergency Preparedness Plan, EPP)
b. Environmental Risk Assessment
   1) Safety Risk Assessment
   2) Public Health / (Environmental) Health Risk Assessment
   3) Ecological / (Ecosystem-health) Risk Analysis (RA)
c. Life Cycle Assessment (LCA) and Industrial Ecology
d. Ecological Footprints
e. Environmental Vulnerability Indicators (EVI)
f. Strategic Environmental Assessments (SEA)

of a government to initiate a decision cycle to conduct its affairs and act in specific circumstances (http://en.wikipedia.org/wiki/Policy) (examples are: National Conservation Strategy and the Policy Statement on Environment and Development, 1993; Policy statement for Abatement of pollution 1992). Unlike Specifications and Codes that guide engineers as they create designs, policy statements are more concerned with specific procedures and operating decisions.

'Environmental Impact Assessment' is an anticipatory mechanism for assigning quantitative values to the parameters indicating the quality of environment before, during and after a major activity, project or incident, thus allowing measures to ensure ecological compatibility and economic efficiency in decision making". Concept of Regional EIA, sometimes known as Country EIA or Cumulative EIA, facilitate the environmental assessment of activities in a defined administrative or ecological region, whereas EIA of policies, plans and programmes are called as 'Strategic Environmental Assessment (SEA)'. EIA, in pre-disaster prevention and mitigation phase, helps in precise decisions regarding planning risk reduction and choices of mitigation methods, technology and locations for activities, whereas Rapid EIA of disasters (REIA) help ensure sustainability concerns in relief, reconstruction and recovery process (Gupta et al., 2002a). Risk analysis and/or a disaster management plan is often a part of EIA process, besides the information generated by EIA of direct use to the disaster management system and in Cost-benefit Analysis (CBA) of a developmental project.

Table 1. Modern Environmental-policy Instruments and their Role in DRR

INSTRUMENT	BRIEF DESCRIPTION/ EXAMPLES	ROLE IN DISASTER RISK REDUCTION
• Strategic Environmental Assessment (SEA)	EIA of policies, plans and programmes	Mainstreaming DRR towards sustainable development with ecosystem approach, climate-risk mitigation and post-conflict recovery context (OECD, 2011).
• Environmental Impact Assessment (EIA(s)	Regional EIA, Country EIA, Cumulative EIA, Carrying Capacity Based Planning Process	Anticipation of hazards, risk hotspots, vulnerability – spatial contexts; Projected mitigation and capacities; Residual risks for emergency response/plan
• Life Cycle Assessment (LCA)	Environmental impacts during different stages of life-cycle of a material or a major project	Prediction and forecasting of changing patterns of hazards and risk profiles over time to cause a disaster
• Ecological-footprint	Human demand of natural resources and ecosystem services bearing to regeneration capacity	Anticipation of ecosystem fragility or biotic pressure on land & water resources that lead to hazards and aggravate disaster risks
• Environmental Legislation	Policy Statements, Acts & Rules, Ordinances, Notifications, Standards and Codes, Treaties	Provides legal support for reducing hazard precursors, vulnerability causes; offers capacity and recovery potentials, health, livelihood and sustainability.

• Auditing / Environmental Management System (EMS)	Environment audit, Water-balance audit, Safety & Health audit, Eco-auditing	Impact of a strategy or activities of an organization/facility, person or business on environment leading to hazards, vulnerability or mitigation, and related data/documentation
• Cess / Levees	Charges for natural resource exploitation, environmental services - water & clean-up, etc.	Reduces pressure on landscape and ecosystems; facilitates conservation – reduces hazard intensities, susceptibility and improves response resources
• Natural Resource Accounting (NRA)	Transformation of data on environmental features for use in economic decisions	Assessment of prevailing and anticipation of vulnerability; resilience and recovery potentials
• Eco-labelling / Eco-mark	Public information on eco-friendly production and product	Promoting peoples contribution and concern to reducing hazards in nature and culture of disaster prevention
• Environmental Taxes	Polluter pays principle; payments to curb the ill-effects on environment	Curbing environmental precursors of hazards and vulnerability; financing mitigation and sustainability

Environmental regulations provide for the application of environmental assessment and evaluation tools help reduce the risk of disasters by generating knowledge of the hazards and underlying causes of vulnerability within the process of planning itself. EIA became a regulatory provision with National Environmental Protection Act in 1969 (USA). Environmental clearance of major developmental and industrial in India as per EIA notification (1994, 2006) under the Environmental Protection Act, 1986, specifically requires (a) Environment Impact Assessment Report, (b) Environment Management Plan including a disaster Management plan, and (c) Rehabilitation plans (where ever necessary) for assessing the case. Environmental Impact Assessment Act 2001 of the Federal Republic of Germany, Article 2 of the Act envisages for identification, description and assessment of the direct and indirect impacts of a project on the (1) human beings, animals and plants, (2) soil, water, air, climate and landscape, (3) cultural heritage and other material assets, and (4) the interactions between the foregoing protected assets. EIA Act 2001 provides a useful tool in identification and assessment of futuristic impact on the drivers of disaster risks and is a reference within the related regulations (Federal Nature Conservation Act, 2002, Federal Water Act, 2002, Federal Building Code to EU Directives 2004). EIA Act also envisages for the planning procedure as an environmental assessment pursuant to the provisions of the Building Code applicable.

Role of Environmental Impact Assessment (EIA)

Disasters generate in the environment and cause environmental impacts either direct or indirect, and thereby, hamper socio-economic and health wellbeing of affected community. Environmental carrying capacity, conceptualized as an assemblage of (a) supportive capacity

Figure 2. EIA applications in DRR phases

(b) assimilative capacity and (c) regenerative capacity, offers limits to economic development in an ecological region (Gupta et al, 2002b). Environmental Assessments (EAs), therefore, of any kind and any levels are known to provide scientific and strategic insights on potential risks and vulnerabilities in the defined region, and thus, help in approach to disaster risk reduction. Millennium Ecosystem Assessment (MA), an exercise of global significance, itself is an extended application of EIA, and is known as a milestone in disaster risk reduction worldwide **(Box 4).**

BOX 4: Global Ecosystem Assessment: A Milestone in DRR

The Millennium Ecosystem Assessment (MA) is a landmark report because of its comprehensive and global scope. Initiated in 2001, the MA contains scientific assessments of the world's ecosystems—their condition, trends, and utility for human well-being if used sustainably. It is also a milestone in the field of disaster risk reduction, paying special attention to the full value of ecosystem services, including their role in mitigating disaster risks – particularly flood and fire hazards. The report presents options for ecosystem conservation, enhancement and restoration, recognizing their important function in disaster risk reduction and livelihood protection. Follow-up activities from the MA include the recommendation to line up with other global agendas, for instance those affecting disaster risk reduction and climate change. One specific recommendation of the Advisory Group for MA Follow Up states that "any follow up exercise on biodiversity and ecosystem services should as much as possible interact with other key processes including the IPCC for climate change and the Potsdam initiative on the macroeconomics of biodiversity." The MA has already made international headway, currently considered by many as the "foundation" for linking biodiversity, changes in ecosystems and livelihoods, and can be an excellent tool for disaster risk management around the world, especially when follow-up activities collaborate with the climate change and disaster risk reduction communities.

EIA takes into account all positive and negative impacts, and thus, provides a basis for the Cost-benefit Analysis of proposed change or activity or a strategic proposal. EIA as a proactive approach and an anticipatory mechanism facilitates a 'culture of safety and prevention' throughout the project cycle or a developmental process. Potential of 'EIA tool' to transform and adapt to the needs of assessment, information and decision-support during different phases of disaster risk management are now widely recognized **(figure 2)**. Strategic Environmental Assessments (SEAs) determine potential environmental consequences of development plans and policies.

BOX 5: Environmental Clearance in India

Projects Requiring Environmental Clearance in India (Select list):

- River Valley projects including hydel power, major Irrigation & their combination including flood control.
- Ports, Harbors, Airports
- Exploration for oil and gas and their production, transportation and storage.
- Tourism projects
- Mining projects
- Highway Projects
- Tarred Roads in the Himalayas and or Forest areas.
- Nuclear Power and related projects such as Heavy Water Plants, nuclear fuel complex, Rare Earths.
- Thermal Power Plants.
- Petroleum Refineries including crude and product pipelines.
- Other major industries/chemical units as specified in the list.

Category-wise EIA Committees in India are constituted by the Ministry of Environment & Forests (as per EIA Notification) to screen the environmental clearance proposals, and consist of experts in the following disciplines:

- Eco-system Management
- Air/Water Pollution Control
- Water Resource Management
- Flora / Fauna conservation and management
- Land Use Planning
- Social Sciences/Rehabilitation
- Project Appraisal
- Ecology
- Environmental Health
- Subject Area Specialists
- Representatives of NGOs/persons concerned with environmental issues.

(Source: EIA Notification, Govt. of India, Ministry of Environment & Forests)

(a) Role of EIA in Developmental Planning and Disaster Risk Reduction

The frequency with which some countries experience natural disaster should certainly place disaster risk at the forefront of development planners' minds. For example, Mozambique faces a regular cycle of droughts and floods: 1976-1978 (floods), 1981-1984 (drought), 1991-1993 (drought), 1996-1998 (floods), 1999-2000 (floods). It has been widely accepted now that it is not only the geography or ecology that generates disaster risk but developmental processes have shaped human vulnerability and hazards paving the way for disaster. The influence of past development on present disaster risk underlines the significance of contemporary decision making for the disaster risk that might be experienced by future generations. EIAs offer potential of bringing together disaster risk reduction and development concerns within environmental-management framework by facilitating the following:

- The collection of basic data on risk and the development of planning tools to track the changing relationship between development policy and disaster risk levels.
- The collation and dissemination of best practice in development planning and policy that reduce disaster risk.
- The galvanizing of political will to reorient both the development and disaster management sectors.

'Present is the key to the past' (James Hutton, 1785) in knowing the patterns of disasters, and of the future probabilities, as human activities decrease and increase the magnitude and frequency of natural process, for example flooding, landslide, desertification, driven by the changes in hydrological regime, environmental pollution, habitat fragmentation, species extension, etc. Maintaining the ecosystems is crucial to the sustainability of life, and EIA is a tool for decision making towards sound environmental management practices (NEPA 1969). EIA is a decision-support system and an information tool to help precise planning for almost all the stages of disaster risk management (Figure 4). Primarily EIA's are designed to be 'anticipatory mechanism' and to be exercised well-before the actual actions and, thus, are while conceptualizing an action plan. There may be many types and forms of EIA into practice, for example:

- Strategic Environmental Assessment (EIA of Policies, Plans and Programmes)
- EIA of Projects (developmental projects like water resources, highway, airport, tourism, housing complex, railway, etc. or an industrial project like manufacturing, mining, food, dairy, etc.)
- Regional EIA (also known as Country EIA or Cumulative Impact Assessment)
- Carrying Capacity (Assessment) based developmental planning process (Gupta *et al*., 2004).
- Environmental Risk Mapping Based Developmental Planning (Gupta *et al.*, 2002c)
- Environmental-health Impact Assessment (as part of EIA or Risk Analysis) (Gupta *et al*., 1999).

Environmental assessments produce targeted environmental analyses by reporting on current and anticipated future environmental conditions and identifying drivers of change. Information generated by environmental assessments is routinely included in early warning systems for all hazards. EIA methodology has options like matrices, network, weighted ranking and computer aided modular approach, which helps in identifying and defining the relationship between different actions, environmental changes, impacts at primary, secondary and their consequence, and thereby, assess the conditions of hazards and patterns of vulnerability in the context of developmental process. EIAs, legally, are meant for environmental scrutiny of a proposed developmental and industrial project, and is, therefore, notified often as part

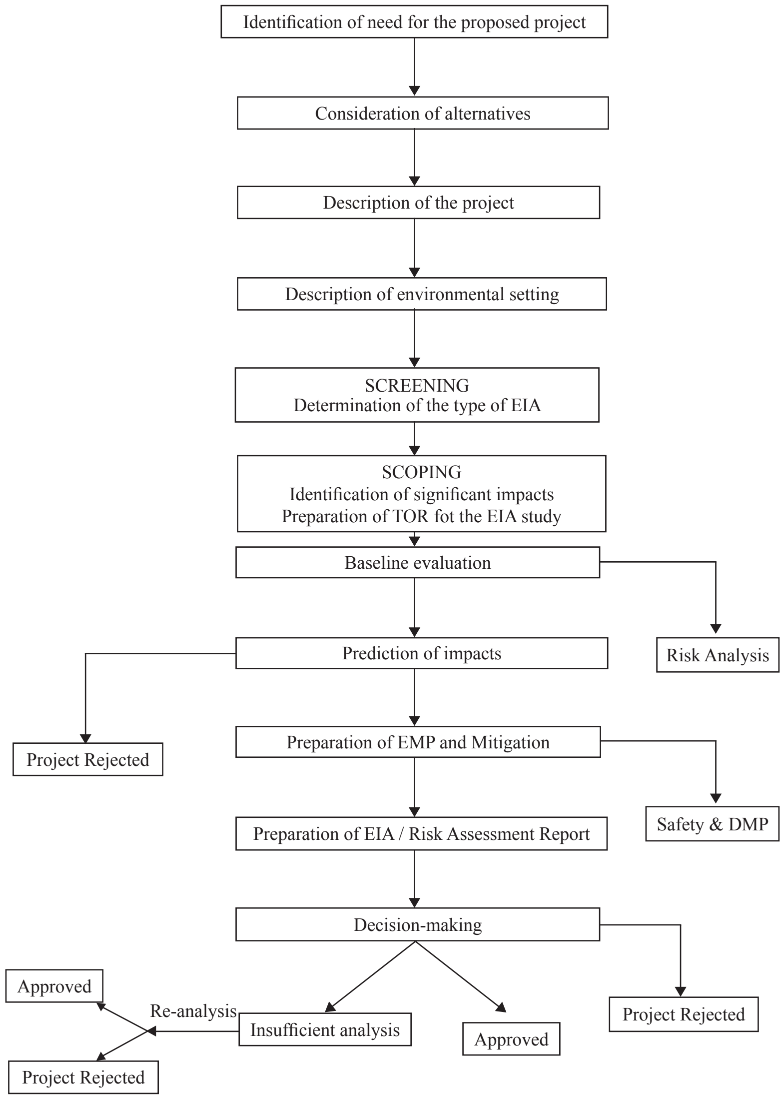

Figure 5: Basic components of EIA study (Source: Preliminary Draft of Guidelines on EIA of Water Resources Projects, Bureau of India Standards, 2011).

of 'environmental clearance procedure' **(Box 5)**. EIA addresses residual risk of disasters and emergencies by requiring a disaster management plan along with an emergency response plan, environmental monitoring plan and auditing scheme to assess the implementation of the mitigation plan. A procedural framework of EIA is given in the **figure 5**.

China's new Law on Environmental Impact Assessment (2003) focuses on multi-disciplinary assessment of impact of developmental or industrial project on all aspects of environment – including public safety, health, livelihood, and economics, and incorporates the information on threats of natural hazards or technological and chemical risks. Most EIA provisions call for a component of risk assessment, and a 'Disaster Management Plan' as part of the environmental risk mitigation and management plan.

(b) Hazard-risk and Vulnerability Assessment within EIA

Early EIAs focused only or primarily on impacts on the natural or biophysical environment (such as effects on air and water quality, flora and fauna, noise levels, climate and hydrological systems). However, over time, increased consideration has been given to social, health and economic impacts. This trend has been driven partly by public involvement in the EIA process. It is reflected by the evolving definition of the term 'environment' in EIA legislation, guidance and practice. In many EIA systems, a broad definition of 'environment' is adopted. This can include effects on (Bhatt and Khanal, 2009):

- Human health and safety,
- Flora, fauna, ecosystems and biological diversity,
- Soil, water, air, climate and landscape,
- Use of land, natural resources and raw materials,
- Protected areas and designated sites of scientific, historical and cultural significance,
- Heritage, recreation and amenity assets, and
- Livelihood, lifestyle and well being of those affected by a proposal.

It is essential that these environmental assessments cover natural hazards and related risk. The state of the environment is a major state of EIA process determining vulnerability to natural hazards. Environmental degradation is widely recognized as one of the key factors contributing to increasing human, physical and financial hazard-related losses. For instance, in many countries deforestation has disrupted watersheds and resulted in siltation of riverbeds, leading to more severe droughts and floods. Increased siltation of river deltas, bays and gulfs, together with the destruction of mangroves, reefs and other natural breakwaters, has also increased the exposure to storm surges and seawater intrusion. Poor land use management, unsustainable agricultural practices and more general land degradation have further contributed to increasing flood losses and the rising incidence of drought (Benson, 2007). Environmental assessments should measure potential risk reduction benefits of the envisaged environmental management within the proposed major activity of developmental project.

Natural hazards are themselves environmental phenomena which, as demonstrated time and time again, can potentially damage and disrupt projects and jeopardize the achievement of their aims and objectives. As such, the environmental assessment is also the natural place in the project appraisal process to collate data on natural hazards – that is, on types of hazard faced, magnitudes and probabilities of occurrence – in the project area to feed into other forms of appraisal and engineering design as relevant. Spatial planning recommendations are common outcome of recent EIAs and are of significance in pre-disaster risk reduction as well as post-disaster reconstruction sustainability **(Box 6)**.

BOX 6: Indonesia – Indian Ocean Tsunami 2004

Assessment of land environment and land-use recommendations are one of the key outcomes of EIA exercises. Consequent upon the Rapid EIA of Disaster (Indian Ocean Tsunami) in Indonesia, spatial planning was assigned an important role in reducing the risks of future disasters. Environmentally fragile zones were designated along the coastline so that no new construction would be permitted, in order to protect mangrove regeneration. Special consideration however was provided for the fishing communities in recognition of their particular requirements, which were economically important to the overall recovery process of the area and which helped to restore individual livelihoods. The layout of towns and cities was designed to avoid the fragile coastal belt while also being able to conform with avoidance of likely tsunami risks. Similarly, road alignments were planned with obvious evacuation routes indicated and the provision of higher ground locations for escape and refuge in the time of an emergency.

ProVention Consortium Guidance note 7 for mainstreaming DRR focuses on Environmental Assessments as the natural starting point in the design of a project to explore natural hazards and related risk. It provides guidance in analyzing the disaster risk-related consequences of potential projects via their impact on the environment and also the potential threat to projects posed by natural hazards, both for development projects in hazard-prone areas and, more briefly, for post-disaster relief and rehabilitation operations. This guidance note has been jointly prepared by the ProVention Consortium and the Caribbean Development Bank (CDB).

In India, the environmental concerns of the major developmental projects were considered with the 4th five year plan (1969-1978) the Dept of Environment established in 1980. This marked a beginning of EIA regime in India and concerns of catastrophic risks, displacement and mitigation issues were flagged for certain mega-dams and river valley projects. The guidelines required various studies such as impacts on forests and wild life in the submergence zone, water logging potential, upstream and downstream aquatic ecosystems and fisheries, water related diseases, climatic changes and seismicity. The Ministry of Environment & Forests is the nodal agency for environmental clearance. 'Site clearance' from the State Government including district administration is the first step towards implementation of EIA and 'environmental clearance' procedure (ECT, 2005). Environmental clearance requires following documents:

- Environment Impact Assessment Report.
- Environment Management Plan and disaster Management plan
- Rehabilitation plans (where ever necessary)

BOX 16: Activities in Water Resource Management Projects for EIA

Provisions of EIA Act of FR Germany are applicable to a number of major activities likely to cause significant impact on environment and can generate new hazards (or aggravate) hazards causing disasters, besides creating background vulnerability of environment, communities and their properties to the impact of any disasters. For example, the EIA requirement is envisages for category "water management projects' enlists many activities as following:

- Deep well for water supply purposes;
  Water management project in agriculture, including soil irrigation or drainage;
- Construction of a dam or other installation for retaining or permanently storing water, by means of which River canalisation and watercourse correction work;
- Construction of an inland waterway port, if the port can be accessed by vessels of;
- Construction of an inland port for sea-going vessels; Construction of a pier for loading and unloading vessels (excluding ferries) that is connected with an inland port for sea-going vessels, which can accommodate;
- Construction of any other port, including fishing harbours or yacht harbours, or an infrastructural port facility;
- Construction of a dyke or embankment which influences flood water drainage;
- Construction of a hydroelectric power station;
- Dredging in rivers or lakes to obtain minerals;
- Other development measures.

Environmental Impact Assessment Act 2001 of the Federal Republic of Germany, Article 2 of the Act envisages for identification, description and assessment of the direct and indirect impacts of a project on the following:

(1) human beings, animals and plants,

(2) soil, water, air, climate and landscape,

(3) cultural heritage and other material assets, and

(4) the interactions between the foregoing protected assets.

EIA Act 2001 of the EU which provides a useful tool in identification and assessment of futuristic impact on the drivers of disaster risks as well has reference within the related regulations (Federal Nature Conservation Act, 2002, Federal Water Act, 2002, Federal Building Code to EU Directives 2004). Act also provides for the trans-boundary participation of authorities and public in the case of foreign projects planned in another state and is capable of having significant impacts on the country's environment and safety. EIA Act also envisages the provisions related with environmental aspects of line determination and airport development consent, and prescribes for the development plans, regional planning procedure and approval procedure. EIA Act also envisages for the planning procedure as an environmental assessment pursuant to the provisions of the Building Code applicable. Broad categories of projects/ activities covered under EIA Act of Federal Republic of Germany are following:

1. Water management projects involving the use or development of a body of water (Box 7)
2. Transport projects:
3. Mining:
4. Land consolidation
5. Forestry projects:
6. Building projects
7. Utility lines and other installations
8. Utilisation and disposal of waste and other materials:
9. Landfill sites:
10. Nonmetallic minerals, glass, ceramics, building materials:
11. Food, confectionery and animal feeds, agricultural produce
12. Heat generation, mining and energy:
13. Wood, cellulose
14. Iron, steel and other metals including processing:
15. Chemical products, pharmaceuticals, petroleum refining and processing:
16. Surface treatment of plastics:
17. Storage of substances and preparations:
18. Miscellaneous industrial installations:
19. Nuclear energy:

(c) Strategic Environmental Assessment (SEA)

HFA's recommendation on tools for mainstreaming DRR in development cooperation triggered many initiatives. SEA is one important tool for mainstreaming Disaster Risk Reduction in policies, plans and programs at national and sectoral levels. As a tool for strategic participatory analysis of the ways that communities and their development are vulnerable to disasters, it offers an approach of analyzing different development choices for their implications on altering community resilience and broader yardsticks of environmental sustainability (OECD, 2008).

SEA is the '*formalized, systematic and comprehensive process of identifying and evaluating the environmental consequences of proposed policies, plans or programmes to ensure that they are fully included and appropriately addressed at the earliest possible stage of decision-making on a par with economic and social considerations'*. Strategic environmental assessment covers a wider range of activities than the environmental impact assessment of projects. SEA might be applied to an entire sector, (such as a national policy on energy for example), or to a geographical area, (for example in the context of a national, state or regional development scheme). The basic steps of strategic environmental assessment are similar to the steps in environmental impact assessment.

An Advisory Notes on 'Strategic Environmental Assessment and Disaster Risk Reduction' intended to the following objectives (OECD, 2010):

1. applying SEA in particular situations or circumstances that will require unique sensitivity and awareness (e.g. post-conflict environments);
2. providing further perspective, information and guidance on emerging issues that may need to be more adequately integrated into an SEA (e.g. climate risk or ecosystem services);
3. undertaking an SEA that focuses specifically on a key emerging issue or policy area that was not sufficiently addressed when the DAC SEA Guidance was prepared (e.g. biofuel development strategies, post-conflict reconstruction plans).

This document is closely related to the advisory note on SEA and Climate Change Adaptation and recognizes the inter-linkages between DRR and Climate Change. There are however, certain geological events and human induced disasters that are unrelated to climate change. Other SEA Advisory Notes available in this series are focusing on the following topics, and are of significant use in DRR strategies:

- SEA and Adaptation to Climate Change;
- SEA and Ecosystem Service;
- SEA and Post-Conflict Development.

Country environmental analysis (CEA) is a relatively new analytical tool now in use by international agencies as an option of strategic environmental assessment in regional/country context. CEA provides systematic analysis of key environmental issues most critical to the sustained development of a country and opportunities for overcoming constraints in reference to the environmental impact of a development policy; country's environmental management proficiency. CEA aims to focus on mainstreaming environmental issues into development planning and provides an important opportunity to highlight disaster risks, where significant, and helps ensure that they are adequately addressed.

The Asian Development Bank's CEA for Tajikistan, for instance, identifies natural hazards, including drought, landslides and earthquakes, as one of the country's key environmental problems and highlights a related reduction in vulnerability as a major element in promoting environmental interventions to reduce poverty. In order to enhance resilience, it recommends support for activities that contribute to greater physical stability (e.g., prevention of soil erosion); the exploitation of opportunities for simultaneously reducing vulnerability and supporting livelihoods (e.g., drainage of lands prone to mudslides and use of the water collected for irrigation); careful attention to zoning of economic activities; and, more generally, a policy that favours risk reduction over emergency response and reconstruction (ADB, Tajikistan, 2005). All CEAs should include collation of basic hazard data and background information on past disaster losses to give a preliminary overview of the significance of disaster risk in a country and to provide information that can be drawn upon both in undertaking environmental assessment of individual projects and in country programming. United Nations Development Programme (UNDP) environmental guidelines, for instance, already indicate that country environmental reviews should include baseline data on rainfall, climate, temperatures, seismic faults, cyclones and droughts. SEA are policy focused whereas Cumulative EIA (C-EIA) are the EIA expertise taking into account the synergistic impact of multiple impact sources in a regional context. EIAs have direct input to various aspects of disaster risk management **(figure 4)**.

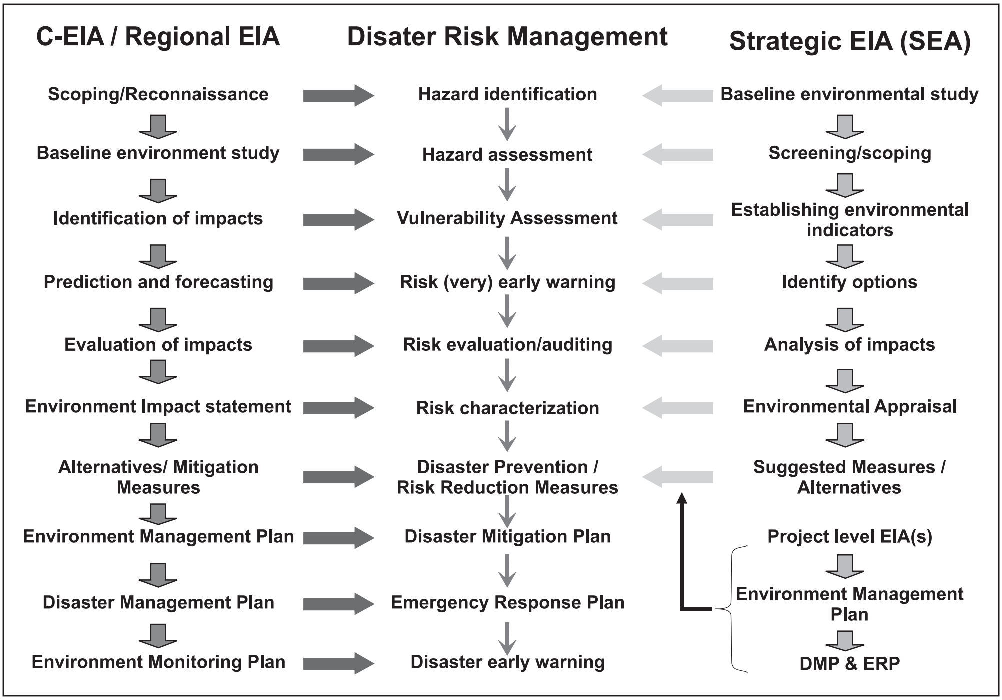

Figure 4. Inputs of EIA and SEA to DRR, (C-EIA – Cumulative EIA)

(d) Rapid EIA of Disasters (REIA)

Disaster events, be of the environmental, technological or industrial, or civil origin, they cause significant effects on the ecology, infrastructure, people and properties. People and their properties are affected either directly in the form of death, injuries or damages, or due to disaster's impact on ecosystem-productivity, environmental services & supplies, and the natural resources. Effects of disasters on the environment, thus, finally manifest in the form of their deleterious consequence on people's health, livelihood, economy and overall-wellbeing. Our understanding for categorizing the impacts of common disasters is following:

- Physical (effects on infrastructure, buildings, physical property, industry, roads, bridges, monuments, etc.)
- Environmental (effects on water, land/soil, land-use, landscape, crops, lake/rivers / estuaries, aquaculture, forests, animals/livestock, wildlife, atmosphere/climate, energy, etc.)
- Social (effects on life, health, livelihoods, employment, relations, security, peace, etc.)

- Economic (effects on assets, deposits, reserves, income, commerce, production, guarantee/ insurance, etc.)
- Ecological (effects on ecosystem integrity and ecosystem-health, structure & functions, productivity, succession, carrying capacity, etc.)

However, as experienced from the past, environmental impacts of the disasters are rarely given a consideration in damage and loss assessment process following a disaster, or the components with direct computable economic value are incorporated within the economic loss category. Despite of our improved understanding and recognition of the environmental impacts of disasters, it could at least get annexed as 'add-on' at the end in the recent guidelines and procedures.

WWF and Red-Cross have developed a environmental guide for humanitarian response managers **(Box 8)**. A Guidelines on Rapid Environmental Assessment (REIA) of Disaster has been developed by Benfield Hazard Research Centre and CARE International's (Charles Kelly, Version 4.4, 2005), so as to help a decision-maker to consider the environmental conditions of a particular location during a specific period of time to identify any existing or potential problems or concerns with regards to the use of natural resources, but also considering broad social and economic impacts. These guidelines focus on: assessment of the general context of a disaster; disaster-related factors that may have an immediate impact on the environment; possible immediate environmental impacts of disaster agents; unmet basic needs of disaster survivors that could lead to adverse impacts on the environment; and potential negative environmental consequences of relief operations. The EIA following of a Disaster can be undertaken by gathering information from a range of sources, completing a series of short descriptions, checklists and ranking matricies and by analysis, discussing and synthesizing the findings. The methodology is based on qualitative assessment, drawing heavily on perceptions and often incomplete data, helping to facilitate rapid assessment under difficult circumstances.

BOX 8: Green-Guide to Humanitarian Response

WWF and the American Red Cross, two leading institutions in the fields of environmental conservation and humanitarian aid, developed a toolkit and training to equip field staff working in humanitarian aid, government, and conservation with practical, solution-oriented techniques for integrating environmental sustainability into international disaster recovery and reconstruction. ***The Green Recovery and Reconstruction: Training Toolkit for Humanitarian Aid (GRRT)*** helps make communities stronger and more resilient by making environmental issues an integral part of the recovery process.

Module 3 builds upon Module 2, focusing specifically on assessment tools that can be used to determine the environmental impact of humanitarian projects regardless of project type or sector. This module explains the value of conducting ***Environmental Impact Assessments***, and answers the questions how, when and why an assessment should be conducted. A case study using the Environmental Stewardship Review for Humanitarian Aid (ESR) is presented.

Module 7: Green ***Guide to Water and Sanitation***

Module 7 addresses innovative water and sanitation programs that can make communities more resilient to future disasters and reduce long-term impacts on ecosystems.

(Urban *et al.*, 2010; http://www.worldwildlife.org/humanitarian)

The Benfield Hazard Research Centre and CARE International's REA guidelines on Rapid EIA of Disasters have been applied a number of times, including in several REAs undertaken by United Nations (UN) agencies. For instance, an REA carried out by UNEP and the UN Office for the Coordination of Humanitarian Affairs (OCHA) of Sri Lanka following the December 2004 Indian Ocean tsunami highlighted urgent environmental concerns relating to the management of tsunami debris and to sewage and sanitation issues in emergency shelter locations (UNEP/UN-OCHA, 2005). Recommendations of a UNEP/OCHA REA of the impact of Hurricanes Ivan and Jeanne in Haiti, Grenada and the Dominican Republic in 2004 included the need to address risks to surface- and groundwater in Grenada and immediate and longer-term increased flooding and landslide risks in all three countries (UNEP & UN-OCHA, 2005).

The Joint UNEP/OCHA Environment Unit (Joint Environment Unit) is the United Nations mechanism to mobilize and coordinate emergency assistance to countries affected by environmental emergencies and natural disasters with significant environmental impacts. Environment Unit has also developed a Guidelines for Environmental Assessment Following Chemical Emergencies, with the purpose to be able to move quickly and identify the key problems following an emergency.

BOX 9: Post Tsunami Environmental Needs Assessment

Samoa Tsunami Rapid Environmental Impact Assessment (EIA) Recommendations (October 2009) contributed in quick mode a section on Post-disaster Environmental Needs Assessment conducted jointly by the Government of Samoa Ministry of Natural Resources and Environment, Pacific Islands Programme Conservation International, Secretariat for the Pacific Regional Environment Programme, UNESCO, UNDP, UNEP Cluster for Early Recovery (Head Georgina Bonin, UNDP Apia, Samoa), etc. Aerial photography was of critical help in the rapid assessment process (Full report with detailed observations is available at the Apia office of UNEP: Dr Greg Sherley care of UNDP). Salient features of the overview findings are following:

- Significant environmental damage was sustained on the south and east coast of Upolu and Manono island including coastal erosion, salinisation of coastal areas, damage from building debris and pollution from solid waste and sewage in village areas
- Sensitive marine ecosystems including coral reefs and sea grass beds are expected to have sustained significant damage
- Environmental damage was greatest at the far eastern and southern facing coast of Aleipata and generally diminished westwards
- Coastal morphology, including distance of reef from shore and the location of channels had a major influence on the damage sustained
- More detailed environmental assessments are needed especially for sensitive marine ecosystems such as coral reefs and sea grass beds and terrestrial ecosystems such as coastal marshes and mangrove areas and offshore islands.

(e) Role of EIA during Relief and Green Recovery

Post-disaster environmental assessments similarly need to explore whether proposed relief, reconstruction and rehabilitation efforts will have acceptable environmental impacts (e.g., environmentally sound selection of sites for refugee camps and sourcing of reconstruction materials) and whether they will strengthen resilience to future natural hazards. In addition, they need to ensure that the response and recovery process addresses environmental problems caused by the disaster (e.g., contamination of water and soil).

Blaikie et al. (2005), in the aftermath of the Indian Ocean tsunami, suggested that effective recovery and reduction of future vulnerability for local people depended on:

- Recognizing that ecosystem services provide the basis for sustainable reconstruction and reduction of future vulnerability;
- Long-term monitoring of both ecological and socioeconomic parameters and a management strategy that encourages adaptation to changing circumstances;
- Addressing issues of governance and politics at all levels, local to international;
- Providing a clear articulation of the rationale for including biodiversity conservation concerns in reconstruction planning;
- Resolving resource tenure issues with all involved stakeholders;
- Ensuring full participation of all stakeholders affected by the disaster in the recovery process;
- Including local solutions and “ways of doing things” and local institutions in recovery planning and implementation.

Environmental Guidelines (UNHCR) (2005) was developed to incorporate environmental factors into specific UNHCR procedures and provide a framework for identifying and evaluating environmental impacts, opportunities to undertake positive environmental interventions of the key stakeholders. Guidelines focus on the natural resource deterioration, ecosystem services impairment and their consequences on health and socio-economic well-being of the people.

Some donor organisation guidelines include checklists on environmental assessment of disaster relief and humanitarian assistance operations (e.g., ADB, DFID and SIDA, the Swedish International Development Cooperation Agency) whilst UNHCR has developed a set of guidelines aimed specifically at building environmental considerations into refugee and returnee operations, including assessment of any potentially adverse environmental impacts of particular refugee and returnee situations. The Benfield Hazard Research Centre and CARE International have developed a more detailed and comprehensive set of guidelines on rapid environmental assessment (REA) in disasters. These guidelines focus on assessment of the general context of a disaster; disaster-related factors that may have an immediate impact on the environment; possible immediate environmental impacts of disaster agents; unmet basic needs of disaster survivors that could lead to adverse impacts on the environment; and potential negative environmental consequences of relief operations. The methodology is based on qualitative assessment, drawing heavily on perceptions and often incomplete data, helping to facilitate rapid assessment under difficult circumstances. Salient features of EIA of Tsunami 2009 have been presented in **Box 9** and **Box 10** (Post-disaster environmental needs assessment and early recovery framework).

BOX 10: EIA of Tsunami 2009 for Early Recovery Framework

A rapid assessment of the environmental impacts of the 29 September tsunami was conducted by a multi-agency team from 3 to 14 October, 2009 and submitted to the Prime Minister of Samoa. Fourteen "green" and 10 "brown" environmental variables were selected and measured based on the experience of the survey team and similar reports from elsewhere. Ministry of Enviornment and Natural Resources, UNEP, WHO, Conservation International and FAO, were key players in the team for conducting early recovery needs assessment and framework drafting. It aimed to address the issues like resettlement, livelihoods and disaster risk reduction in relation climate change and environment, so as to assist in the transition from relief phase to the recovery phase and minimize the impact of future disasters.

Among the most obvious indicators of the tsunami's impact were: solid waste (sometimes resulting from the complete destruction of a village), erosion of the beach and fore-shore and the (expected) impact on marine resources. Impacts on a wharf/dry dock facility are also described (including lost fuel drums) as are the possible environmental implications of new settlements created by displaced persons (mainly revolving around sanitation, drainage and water supply).

Strategically the key recommendation for marine habitats is to implement actions that foster the natural recovery and resilience of these areas, and for terrestrial habitats - to implement actions that focus on restoration based on ecological and resilience principles, such as replanting affected coastlines with native wave resistant species and ensuring that all developments, rebuilding and associated infrastructure (e.g. villages, tourism) are undertaken cognizant of both the ongoing risk from tsunami, cyclones, sea level rise and other coastal hazards and follow appropriate planning processes and codes of environmental practice to minimize environmental impact to sensitive terrestrial and marine habitats.

Relevant National Policies and Strategic Plans referred in the assessment report were the following:

- National Biodiversity Strategic Action Plan
- Biodiversity Policy
- Waste Management Policy
- National Adaptation Programme of Action (NAPA)
- National Disaster Management Plan
- Coastal Infrastructure Management Plan (CIM Plan)
- National Implementation Plan (NIP) for Persistent Organic Pollutants
- Land, Surveys and Environment Act 1989

Conclusion & Recommendations

Integration of environment and disaster management framework holds the key for promoting the environmental approach for DRR. It shall require reforms and adaptation on legal, institutional and implementation framework of both – environmental governance, and disaster management, at different levels of planning and action. Knowledge building and perception holds the key of attitudinal change. Environmental education provides communities with the necessary skills to make informed decisions as well as the motivation to participate in and take responsibility for environmental management (IADB, 1999). The Inter-American Development Bank has adopted a strategy that stipulates that all projects financed by the Bank include an analysis of natural hazard risks. A central aspect of this strategy is cooperation with Member Countries to ensure that projects are designed to improve or preserve the environment, and to reduce vulnerability to natural disasters (IADB, 1999).

Introduction of Regional EIA (District level, and preferably National & State level as well) is identified as a pre-requisite to medium and long-term planning. For example, 5 yearly planning is common in India and Regional EIA can facilitate for preparation of an 'Environment Management and Action Plan' at District/State level as an strategic Umbrella Approach on sustainable development **(figure 6).**

Figure 6: Integration of environment and natural disaster management at district level

Disaster Risk Reduction and Post-disaster Relief and Recovery needs to be introduced as a compulsory module within the higher education, research and awareness courses in the Universities, colleges and school curriculum in particular within the courses on environmental sciences and natural resources. On the other hand, the module on ecosystem-approach to DRR within disaster management training and sensitization framework needs to emphasize the role of legislation and in particular of environmental/ natural resource law and EIAs. Environmentally sustainabile mitigation option and the concept of 'greening disaster-response' and 'sustainable-recovery' need to be promoted within the framework of sustainable development, by integrating SEA to the developmental planning process. SEA and EIA scope need to necessarily include hazard-risk and vulnerability assessment within the assessment framework.

References and Further Readings

1. ADB. *Tajikistan: Country Environmental Analysis.* Manila: Asian Development *Bank, 2004*. Available at: http://www.adb.org/Documents/Reports/CEA/taj-july-2004.pdf
2. AfDB/ADF (2004). *African Development Bank Group's Policy on the Environment*. Abijan: African Development Bank and African Development Fund, Available at:
3. Benson, C. (2007). Tools for Mainstreaming Disaster Risk Reduction (EIA, Guidance Note 7). For - International Federation of Red Cross and Red Crescent Societies / the ProVention Consortium, Geneva, Switzerland, and Caribbean Development Bank.

4. Bhatt, R. P. and S. K. Khanal (2009). Environmental impact assessment system in Nepal – An overview of policy, legal instruments and process. *Kathmandu University Journal of Science, Engineering and Technology,* 5 (2), 2009: 160- 170.

5. Blaikie, P., S. Mainka, and J. McNeely (2005). The Indian Ocean tsunami: reducing risk and vulnerability to future natural disasters and loss of ecosystems services. International Union for Conservation of Nature Information Paper, February 2005. International Union for Conservation of Nature, Gland, Switzerland. [online] URL: http://data.iucn.org/dbtw-wpd/edocs/Rep-2005-006.pdf.

6. Burton, I., R. W. Kates and G. F. White (1993). Environmental Hazards. The Guildford Press, London.

7. CDB and CARICOM Secretariat. Sourcebook on the Integration of Natural Hazards into Environmental Impact Assessment (EIA): NHIA-EIA Sourcebook. Bridgetown, Barbados: Caribbean Development Bank, 2004. Available at: http://www.caribank.org/Projects.nsf/NHIA/$File/NHIA-EIA_Newsletter.pdf?OpenElement

8. Dynes, R. (2004). Expanding the Horizon of Disaster Research. *Natural Hazards Observer,* 28(4): 1-2.

9. Environment Programme/Office for the Coordination of Humanitarian Affairs Environment Unit, 2004. Available at: http://www.benfieldhrc.org/disaster_studies/rea/Caribbean_REA.pdf

10. Environmental Conservation Team (2005). Environment Impact Assessment Process In India And The Drawbacks. September 2005. Vasundhara, 15, Sahid Nagar, Bhubaneshwar – 751 007 (on website)

11. Gupta, A. K. (2010). Policies, Strategies and Options for Disaster Risk Reduction interventions in India. In: Proceedings of Int. Workshop on Risk to Resilience: Strategic Tools for Disaster Risk Management (eds: A.K. Gupta, S. S. Nair, S. Chopde and P.K. Singh), NIDM New Delhi and ISET, Colarado, US (with Winrock International, DFID and US-NOAA).

12. Gupta, A. K. and M. Yunus (2004). India and WSSD (Rio+10) Johannesburg: Issues of National Concern and International Strategies. Curr. Sci., 87(1): 37-43.

13. Gupta, A. K. and S. S. Nair (eds.) (2011). Environmental Knowledge for Disaster Risk Management – Concept Note. In: Abstract Book of the International Conference 9-10 May 2011, New Delhi. National Institute of Disaster Management, New Delhi and GIZ Germanry. P 117.

14. Gupta, A. K., I. V. Suresh, J. Misra and M. Yunus (2002c). Environmental Risk Mapping Approach – risk minimizing tool in developing countries. J. Cleaner Prod., 10: 271-281.

15. Gupta, A. K., J. Misra and M. Yunus (1999). Environmental-health Assessment of Thermal Power Project within the Scope of EIA and Risk Analysis: Guideview. In: Proc. Nat. Semin. Energy & Environment, Lucknow, July 1999, P 86-95.

16. Gupta, A.K., A. Kumar, J. Misra and M. Yunus (2002a). Environmental Impact Assessment and Disaster Management: Emerging Disciplines of Higher Education and Practice. In: Environmental Education (eds: P. Srivastava and D. P. Singh), Anmol Publishers, New Delhi. Pp 7-23.

17. Gupta, A.K., A. Kumar, J. Misra and M. Yunus (2002b). EIA & Disaster Management: Principles, Methodological Approach & Application. In: Bioresources & Environment (eds: Y C Tripathi & G Tripathi), Campus Books International, New Delhi. PP.

18. http://www.benfieldhrc.org/disaster_studies/rea/environmental_assessment_rapid_ocha_unep_sri_lanka_indian_ocean_tsunami_disaster_december2004.pdf

19. Huppes, G. and U.E. Simonis (2001). Environmental Policy Instruments is a New Era. Research Professorship Environmental Policy, FSII 01-404, Science Center Berlin (http://www.wz=berlin.de/uta).

20. Inter-American Development Bank (1999), Working paper on Reducing Vulnerability to Natural Hazards: Lessons Learned from Hurricane Mitch A Strategy Paper on Environmental Management. Stockholm, Sweden.

21. Joint United Nations Environment Programme/Office for the Coordination of Humanitarian Affairs Environment Unit, 2005.

22. Judges & Environmental Law: A Handbook for the Sri Lankan Judiciary 2009 United Nations Environment Programme (UNEP), Environmental Foundation Limited, Colombo 5, Sri Lanka

23. OCED (2010). Organisation for Economic Co-operation and Development 2 Rue Andre Pascal, 75775 Paris, France: Website www.oecd.org

24. OECD (2008). Strategic Environmental Assessment (SEA) and disaster risk reduction (DDR), OECD 2008. DAC Network on Environment and Development Co-operation (ENVIRONET) at their 8th Meeting on 30 October 2008.

25. UNEP and UN-ISDR (2010). Environment and Disaster Risk: Emerging Perspective. United Nations Environment Programme, Post-Conflict and Disaster Management Branch, Geneva, Switzerland, Web: http://postconflict.unep.ch

26. UNEP, UNISDR-PEDRR (2010). Opportunities in Environmental Management for Disaster Risk Reduction: Recent Progress - A Practice Area Review. In: Contribution to the Global Assessment Report on Disaster Risk Reduction. Special circulation.

27. UNEP/OCHA (2005). *Indian Ocean Tsunami Disaster of December 2004: UNDAC Rapid Environmental Assessment in the Democratic Socialist Republic of Sri Lanka.* Geneva:

28. UN-ISDR (2005). Hyogo Framework for Action 2005-2015; Building the Resilience of Nations and Communities to Disasters, 2005.

29. Wilches-Chaux, Gustavo (1993) "La vulnerabilidad global" in Los Desastres no son Naturales, Andrew Maskrey (ed.) Bogotá: La Red/ITDG.

30. Websites of UNEP, UN-OCHA, UN-ISDR, National Governments, Ministries, Academic Institutions, and unpublished literature and reports.

12

Ecological Approach for Post-Disaster Recovery and Mitigating Future Risk

Ram Boojh

Introduction

Ecological aspects of disaster risk reduction and post-disaster recovery planning, have received little attention in development planning. Preservation and use of nature's protective shield against disasters are relatively low on public agenda, while relief and rehabilitation constitute the primary form of disaster risk management. Further, there are very few research and policy studies available on the inherent link between disaster reduction and environmental management. Also the concept of using environmental tools for disaster reduction has not yet been widely applied by many practitioners (ISDR 2002). Ecological approaches to disaster risk reduction make use of ecosystem's protec¬tive elements such as mangrove forests, coastal wetlands, sand dunes etc to provide safety shield against disasters. These are also used for ensuring sustainable livelihood to disaster affected communities by helping them in alleviating poverty and achieving economic growth. This approach is a conceptual shift in thinking away from post-disaster reaction to pre-disaster action and stresses the merit of mitigative and preventive measures through scientific understanding and technological know-how. This also makes effective use of information and communication technologies, community involvement and disaster prevention education and awareness of the public (UNESCO.2007).

Ecological degradation has been identified as the main factor behind devastation triggered by natural disasters in a large number of incidents around the world (ADPC 2004). Destruction of complex ecological safety net such as forests, wetlands, corals, mangroves and sand dunes along with climate change deteriorates the resilience of ecosystems making them ineffective to provide their protective services against disasters. Well managed productive ecosystems not only mitigate the impact of natural hazards but also support sustainable income-generating activities in the aftermath of a disaster. It is therefore essential to factor contributions of ecosystem services into relief and rebuilding efforts in the post-disaster response phase so as to ensure long term sustainability of these systems. In particular, regeneration of critical ecosystems should be carefully integrated in the post disaster planning to avoid significant economic and environmental losses and hardships to vulnerable communities.

Ecosystem Approach to Disaster Risk Reduction. Edited by Anil K. Gupta and Sreeja S. Nair,

Protective values of ecosystems

The Millennium Ecosystem Assessment (2005) provided clear evidence that ecosystems such as coral reefs, mangroves, wetlands and mountain forests, not only support people's livelihoods, but are also important in mitigating the impact of natural hazards **(Table 1)**.

Table 1: Ecosystem Functions for Disaster Risk Reduction *(ISDR 2002)*

Wetlands	Important wetland functions include water storage, storm protection, flood mitigation, shoreline stabilization and erosion control. These functions are also essential for sustainable development.
Forests	Forests play an important role in protecting against landslides, erosion, floods and avalanches. They also safeguard against drought.
Coastal Zones	Barrier reefs, barrier islands and mangroves contribute significantly to the mitigation of hurricane risk, storms and tidal surges

The value of ecosystem services was clearly demonstrated during the Indian Ocean Tsunami of December 2004 where natural protective shields helped in decreasing impacts of the extreme event in majority of situations. Mangrove forest reduced the impact of the tsunami by reducing the velocity of the storm after it entered into the mangroves

Due to friction created by thick mangrove forest. In case of Sunderbans during the Alia cyclone of 2009 mangrove forests could withstand the wind speed of 100-150 kms/ hr. unfortunately, these factors are often ignored while planning for disaster recovery and management leading to increased vulnerability to future hazards and loss of biodiversity. Ecosystems provide valuable protective services such as forest cover reduces soil erosion and landslides; sand dunes and mangrove forests protect against wave surges; and wetlands mitigate the impacts of flooding. In addition to being insurance against natural disasters, which particularly benefits poor populations, ecosystems can bring a significant return on investment (Sudmeier-Rieux et al 2006):

- Sri Lanka's Muthurajawela marsh, a coastal peat bog cover¬ing some 3,100 hectares, is an important part of local flood control. The marsh significantly buffers floodwaters from the Dandugam Oya, Kala Oya and Kelani Ganga rivers and discharges them slowly into the sea. The annual value of these services was estimated at more than $5 million, or $1,750 per hectare of wetland area (Emerton and Bos 2004).
- In Malaysia the value of intact mangrove swamps for storm protection and flood control has been estimated at US$ 300,000 per km, which is the cost of replacing them with rock walls (Ramsar Convention on Wetlands 2005).

- The 40,000 hectares of managed mangrove forest in Matang, West Malaysia yield $10 million in timber and charcoal and over $100 million in fish and prawns every year (Talbot and Wilkinson 2001).
- Damage assessments from the 2004 Indian Ocean tsunami concluded that there was significantly more damage to human lives and livelihoods where ecosystems had been disturbed, especially sand dunes, mangroves and coral reefs. (Boojh 2005, Dah¬douh-Guebas et al. 2005; Dan¬ielsen et al. 2005).
- In Thailand, poorly planned tourist develop¬ments and fishing communities built close to the shore on flat, low-lying land and in wide, ex¬posed bays with no coral reefs were the worst hit (UNEP 2005).
- In Banda Aceh, Indonesia, one of the areas most devastated by the tsunami, large areas of mangroves had been converted to shrimp ponds. It is unclear, how¬ever, whether intact mangroves would have saved more lives. Before the tsunami, it has been estimated that there were 36,597 hectares of fish/shrimp ponds (UNEP 2005).

Disaster recovery planning and the environment

Post disaster recovery planning often provides opportunities for creating sustainable livelihoods and resilient ecosystems which may decrease vulnerability to future disasters. Sustainable livelihoods are dependent upon healthy ecosystems. Efforts should be made to allow and support ecosystem recovery without putting further stresses on already damaged ecology of the area. The hasty decisions taken for rapid response during the initial rescue and relief phase without taking care of environment may bring adverse impacts on the ecosystem services. An Asian Development Bank (ADB 2005) study found that post-tsunami clean up actions around the Andaman Sea such as dumping of the waste into wetlands resulted in disruption of drainage systems and flood retention areas, increasing the potential for waterborne diseases. The ecologically unplanned or badly planned resettlement sites might threaten biodiversity-rich areas, therefore ADB recommended that resettlement sites should be located with an adequate buffer between them and the biologically sensitive sites, and ensure that the number of households relocated were within the carrying capacity of the area.

Another important consideration in the post disaster recovery planning is the problem of waste and invasive alien species. The giant waves of the Indian Ocean tsunami carried invasive alien species such as prickly-pears (Opuntia sp.) and salt-tolerant mesquite (Prosopis sp.) to protected areas such as Yala National Park in Sri Lanka. These non-native species are replacing the native species that are more palatable to Sri Lanka's livestock and wildlife (UNEP 2005). The disaster recovery should therefore be guided by several key elements: understanding the status and trends of biodiversity, capacity to integrate conservation into disaster recovery, and policy support for integrating environmental conservation (Mainka & McNeely 2011) such as:

- Ecosystem policies that foster spatial and biological heterogeneity when choosing sites and improve ecological resilience by re-establishing key ecological processes upon which agricultural and natural communities depend, e.g., hydrological cycles, nutrient cycles and flows;

- A socioeconomic policy that supports infrastructure development that minimizes impact on ecosystems, creates new and potentially sustainable resources, and adds to the diversity of economic resources available.

Further, the post disaster recovery planning should consider the landscape approach on a scale broad enough to recognize the role of all critical influencing factors and of stakeholders that shape land use decisions (McNeely and Scherr 2003, Scherr and McNeely 2007). Good landscape management will fulfill societal needs by equitably balancing trade-offs between the productive, social and environmental requirements of current land use.

Blaikie et al. (2005), in the aftermath of the Indian Ocean tsunami, suggested that effective recovery and reduction of future vulnerability for local people depended on:

- Recognizing that ecosystem services provide the basis for sustainable reconstruction and reduction of future vulnerability;
- Long-term monitoring of both ecological and socioeconomic parameters and a management strategy that encourages adaptation to changing circumstances;
- Addressing issues of governance and politics at all levels, local to international;
- Providing a clear articulation of the rationale for including biodiversity conservation concerns in reconstruction planning;
- Resolving resource tenure issues with all involved stakeholders;
- Ensuring full participation of all stakeholders affected by the disaster in the recovery process;
- Including local solutions and “ways of doing things” and local institutions in recovery planning and implementation.

The influence of climate change on recovery planning

The Fourth Assessment Report of the IPCC (IPCC 2007) while reporting about the increased frequency and intensity of disasters due to climate uncertainties, suggested for strengthening ecological systems as part of adaptation and mitigation strategies. It has suggested several possible adaptation responses such as building ecological infrastructure, changing food or recreation choices, altering agricultural practices, and integration of adaptation into planning policy. As climate change is an extremely dynamic process and uncertainties remain, adaptation measures will need to be flexible and responsive to changing situations (Fankhauser et al. 1999).

The adaptation responses such as physical infrastructure are permanent inflexible structures as compared with ecosystem which can adapt much more quickly to changing environments. Therefore, physical infrastructure based adaptation measures should be complemented by more responsive adaptation strategies such as ecosystem-based approaches. Ecosystems provide support services to the economy and society and should therefore be considered as integral elements of the infrastructure for post disaster recovery and development (Emerton 2006). Ecosystem-based adaptation is not ‘new technology’ but forms part of traditional coping strategy of communities for millennia. Finally, ecosystem-based adaptation are cost-effective compared with many types of infrastructure, and can be implemented immediately. Therefore, they are of particular importance for the rural poor, who often do not have access to alternative adaptation responses (Secretariat of the CBD 2009).

The time frame for including ecosystem recovery in reconstruction efforts is long, and yet it is absolutely worth including in these plans because, as demonstrated throughout this review: sustainable livelihoods, both immediately and in the long term, will depend on ecosystem services; and restoring habitats will improve the capacity of both ecosystems and people to withstand future extreme natural events. Making wiser use of ecosystems could both decrease risk to people and support delivery of ecosystem services. However, use of ecosystems as 'bioshields' is not a panacea for decreasing people's vulnerability to natural disasters and should be accompanied by other measures such as early warning systems and disaster preparedness (Feagin et al. 2010). The opportunities that effective ecosystem management provides in terms of decreasing vulnerability of both people and ecosystems to future extreme events should be given high priority in disaster management planning.

The 2004 Asian Tsunami showed that social-ecological resilience is an important factor in post disaster planning. A key lesson is that resilient social-ecological systems reduced vulnerability to the impacts of the tsunami and encouraged a rapid, positive response. Resilient social-ecological systems incorporate diverse mechanisms for living with, and learning from, change and unexpected shocks. Disaster management requires multilevel governance systems that can enhance the capacity to cope with uncertainty and surprise by mobilizing diverse sources of resilience **(Table 2)**.

Table 2. Examples of local- and regional-scale actions to enhance resilience in social-ecological systems exposed to abrupt change (Adger et al 2005).

Elements of vulnerability	Local action	National and international action
Exposure and sensitivity to hazard	Maintenance and enhancement of ecosystem functions through sustainable use Maintenance of local memory of resource use, learning processes for responding to environmental feedback and social cohesion	Mitigation of human-induced causes of hazard Avoidance of perverse incentives for ecosystem degradation that increase sensitivity to hazards Promotion of early warning networks and structures Enhancement of disaster recovery through appropriate donor response
Adaptive capacity	Diversity in ecological systems Diversity in economic livelihood portfolio Legitimate and inclusive governance structures and social capital	Bridging organizations for integrative responses Horizontal networks in civil society for social learning

Disaster Ecology and Risk Ecology

While ecology is the study of relationship between organisms and their environment, the disaster ecology by analogy, investigates the relationship between organisms or society and disaster. Disaster ecology analyzes the role of disaster in relationship between society and its environment. It applies not only to society's reactions following a disaster, but also to the influence of the threat of disaster on society's attitudes and decisions, which may lead to prevention, mitigation, and adaptation activities (Kelman 2007). Disaster ecology examines the interrelationships and interdependence of the social, psychological, anthropological, cultural, geographic, economic, and human context surrounding disasters and extreme public health events such as severe storms, earthquakes, acts of terrorism, industrial accidents, and disease epidemics (Kaplan, 1999).

Disasters from an ecological viewpoint present challenges to be overcome during evolution at various time scales, thereby potentially producing stronger species, communities, and ecosystems. Rapid environmental changes termed as "disturbances" or "perturbations" brought out by disasters increase number of niches available for ecological processes beneficial to biological diversity. Despite these benefits, risk-related and disaster-related actions often translate into misguided approaches of environmental hazard "reduction", "prevention", or "mitigation". An appropriate understanding of and interaction with risks and disasters can be achieved through analyzing the resources available from risk and disasters, the benefits which risks and disasters sometimes provide, and how these resources and benefits could best be harnessed. Ecosystem-based disaster risk reduction and post disaster recovery recognize that ecosystems are not isolated but connected through the biodiversity, water, land, air and people that they constitute and support (Shepherd, 2008). Sustainable ecosystem management is based on equitable stakeholder involvement in land management decisions, land-use trade-offs and long-term goal setting. These are central elements to reducing underlying risk factors for disasters and climate change impacts **(figure 1)**.

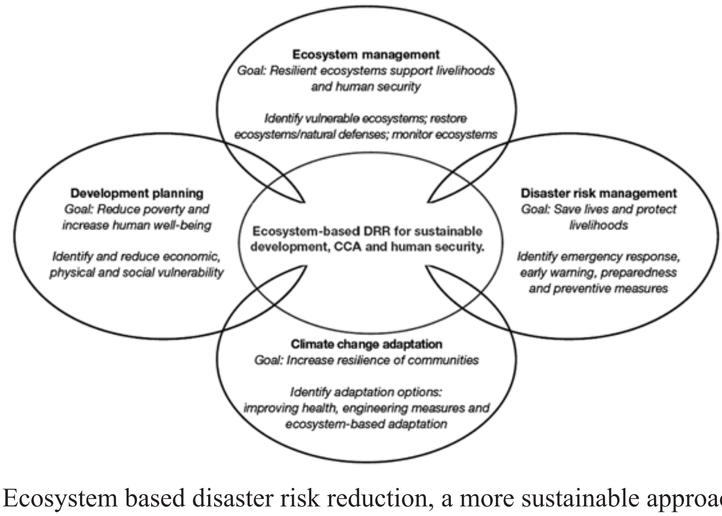

Figure 1: Ecosystem based disaster risk reduction, a more sustainable approach to DRR and climate change adaptation (from Sudmeier-Rieux and Ash 2009).

The Ecosystem Approach can make a valuable contribution to managing disaster risk and mitigat¬ing the impacts of disasters. An ecosystem approach to disaster risk reduction is one where ecosystems make a key contribution to enhancing people's livelihoods. The Ecosystem Approach is an effective strategy to manage or restore ecosystems and their services while focusing on human livelihood needs (Sudmeier-Rieux & Ash 2009).

Conclusions

The view that disasters can be managed by technical interventions only, has undergone a crucial change with recognition of the ecological approach to disaster management. The crucial role of environment in disaster risk reduction and post disaster recovery has also been recognized by several international conferences and deliberations. The International Decade of Natural Disaster Reduction (IDNDR, 1990s) concluded that "environmental protection, as a component of sustainable development and consistent with poverty alleviation, is imperative in the prevention and mitigation of natural disasters" (ISDR 2002). The UN decade of education for sustainable development (DESD- 2005-2014) and the World Conference on Disaster Reduction (WCDR- 2005) held in Kobe Japan also emphasized on the effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction. The Hyogo Framework for Action (2005-2014), a 10-year plan to make the world safer from natural hazards, adopted by 168 Member States at the WCDR, has also recognized that ecosystem management is central to building resilience of communities and nations against disasters.

The ecological model of disaster risk reduction and recovery emphasizes on the sustainability of ecological services and systems. The disasters bring deterioration in ecosystem services and sustainability of ecosystems thereby increasing the risk to people and their livelihood resource base. From an economic viewpoint, investments in preventive measures, including in maintaining healthy ecosystems, are seven-fold more cost effective than the costs incurred by disasters (World Bank, 2004). However, use of ecosystems as 'bioshields' is not a panacea for reducing people's vulnerability to natural disasters and should be accompanied by other measures such as early warning systems and disaster preparedness (Feagin et al. 2010). The opportunities that effective ecosystem management provides in terms of decreasing vulnerability of both people and ecosystems to future extreme events should be given high priority in disaster management planning.

References

1. Adger, W N, T P Hughes, C Folke, S R Carpenter and J Rockstrom (2005), Social-Ecological Resilience to Coastal Disasters; Science, 309, pp. 1036-1039. URL: http://www.sciencemag.org/content/309/5737/1036.full
2. ADPC – Asian Disaster Preparedness Centre (2004), Environmental Degradation and Disaster Risk, Prepared for the Embassy of Sweden/Sida Bangkok by Glenn Dolcemascolo, *Asian Disaster Preparedness Centre*. p 39.
3. Allison, E. H., A. L. Perry, M. C. Badjeck, W. N. Adger, K. Brown, D. Conway, A. S. Halls, G. M. Pilling, J. D. Reynolds, N. L. Andrew, and N. K. Dulvy (20090, Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries* 10(2):173-196.

4. ADB-Asian Development Bank (2005), *Assessment of tsunami recovery implementation in Hambantota district*. Asian Development Bank, Manila, Philippines. [Online] URL: http://www.adb.org/Documents/Reports/Rebuilding-Sri-Lanka/Hambantota-team.pdf.

5. Blaikie, P., S. Mainka, and J. McNeely (2005), The Indian Ocean tsunami: reducing risk and vulnerability to future natural disasters and loss of ecosystems services. IUCN Information Paper, February 2005. IUCN, Gland, Switzerland. URL: http://data.iucn.org/dbtw-wpd/edocs/Rep-2005-006.pdf.

6. Boojh, R. (2005), The effects of tsunami on fish stocks: planned intervention and recovery, Presentation at the *World Aquaculture 2005*, Bali, Indonesia.

7. Dahdouh-Guebas, F., L.P. Jayatissa, D. Di Nitto, J.O. Bosire, D. Lo Seen and N. Koedam. (2005), How effective were mangroves as a defence against the recent tsunami?, *Current Biology*, Vol. 15, No. 12: 443-447.

8. Danielsen, F., M.K. Serensen, M.F. Olwig, V. Seklvam, F. Parish, N.D. Burgess, T. Hiraishi, V.M. Karunagaran, M.S. Rasmussen, L.B. Hansen, A. Quarto and N. Suryadiputra (2005), The Asian Tsunami: a protective role for coastal vegetation, *Science*, 310: 643.

9. DESD- UN Decade of Education for Sustainable Development (2005), Education for disaster risk reduction, http://www.desd.org/efc/Education_for_Disaster.htm

10. Emerton, L.(2006), Counting coastal ecosystems as an economic part of development infrastructure, *Ecosystems and Livelihoods Group Asia,* International Union for Conservation of Nature, Colombo, Sri Lanka.

11. Emerton, L. and Bos, E. (2004), Value: Counting Ecosystems and Water Infrastructure, *Water and Nature Initiative.* IUCN, Gland, Switzerland.

12. Fankhauser, S., J. B. Smith, and R. S. J. Tol (1999). Weathering climate change: some simple rules to guide adaptation decisions, *Ecological Economics* 30(1):67-78.

13. Feagin, R. E., N. Mukherjee, K. Shanker, A. H. Baird, J. Cinner, A. M. Kerr, N. Koedam, A. Sridhar, R. Arthur, L.P. Jayatissa, D. L. Seen, M. Menon, S. Rodriguez, Md. Shamsuddoha, and F. Dahdouh-Guebas (2010), Shelter from the storm? Use and misuse of coastal vegetation bioshields for managing natural disasters, *Conservation Letters,* 3(1):1-11.

14. IPCC-Intergovernmental Panel on Climate Change (2007), Summary for policymakers. In *M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, editors. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, UK. [online] URL: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf.

15. IUCN-International Union for Conservation of Nature (2005). *Recovery from the Indian Ocean tsunami - guidance for ecosystem rehabilitation incorporating livelihoods concerns*. International Union for Conservation of Nature, Gland, Switzerland. [online] URL: http://data.iucn.org/dbtw-wpd/edocs/Rep-2005-007.pdf.

16. IUCN-International Union for Conservation of Nature (2010), *IUCN Red List of Threatened Species.* International Union for Conservation of Nature, Gland, Switzerland. [online] URL: www.iucnredlist.org.

17. Jackson, S. T., and R. J. Hobbs (2009), Ecological restoration in the light of ecological history. *Science* 325(5940):567-569.

18. ISDR- International Strategy for Disaster Reduction (2002), *Living with Risk: A global review of disaster reduction initiatives,* Prepared as an inter-agency effort coordinated by the ISDR (www.unisdr.org/wcdr) Secretariat with special support from the Government of Japan, the World Meteorological Organization and the Asian Disaster Reduction Center, Geneva.

19. Kaplan, G.A. (1999), What is the role of the social environment in understanding inequalities in health? *Annals of the New York Academy of Sciences,* 896, 116-119.

20. Kelman, I. (2007), *Disaster Ecology, Risk Ecology, the Risk Resource, and the Disaster Resource,* Version 7, 9 December 2007. URL, http://www.ilankelman.org/miscellany/EcologyResource.rtf

21. McNeely, J. A., and S. J. Scherr (2003), *Ecoagriculture: strategies for feeding the world and conserving wild biodiversity*. Island Press, Washington, D.C., USA.

22. Millennium Ecosystem Assessment (2005), *Ecosystems and human well-being: synthesis.* Island Press, Washington, D.C., USA. URL, http://www.maweb.org/documents/document.356.aspx.pdf

23. Mainka, S. A., and J. McNeely (2011), Ecosystem considerations for post disaster recovery: lessons from China, Pakistan, and elsewhere for recovery planning in Haiti. *Ecology and Society* **16**(1): 13. URL: http://www.ecologyandsociety.org/vol16/iss1/art13/

24. Ramsar Convention on Wetlands (2005), www.ramsar.org/values_shoreline_e.htm

25. Sudmeier-Rieux, K., H. Masundire, A. Rizvi and S. Rietbergen (2006). *Ecosystems, Livelihoods and Disasters: An integrated approach to disaster risk management*. IUCN, Gland, Switzerland and Cambridge, UK. x + 58 pp.

26. Sudmeier-Rieux, K. and Ash, N. (2009), *Environmental Guidance Note for Disaster Risk Reduction: Healthy Ecosystems for Human Security,* Revised Edition. Gland, Switzerland: IUCN, iii + 34 pp.

27. Scherr, S. J., and J. A. McNeely (2007), *Farming with nature: the science and practice of ecoagriculture*. Island Press, Washington, D.C., USA.

28. CBD- Convention on Biological Diversity (2009), *Connecting biodiversity and climate change mitigation and adaptation: report of the second ad hoc technical expert group on biodiversity and climate change*. Technical Series No. 41. Secretariat of the CBD, Montréal, Québec, Canada. Also available online: http://www.cbd.int/doc/publications/cbd-ts-41-en.pdf .

29. Shepherd, G. (2008). *The Ecosystem Approach:Learning from Experience*. Gland, Switzerland: IUCN. Also available online : www.iucn.org/about/union/commissions/cem/cem_resources/

30. UNEP-United Nations Environment Programme (2005), *After the tsunami: rapid environmental assessment*. United Nations Environment Programme, Nairobi, Kenya. Also available online : http://www.unep.org/tsunami/tsunami_rpt.asp.

31. Talbot, F. and C. Wilkinson (2001), *Coral Reefs, Mangroves and Seagrasses: A Sourcebook for Managers*, Australian Institute of Marine Science.

32. UNESCO-United Nations Educational, Scientific & Cultural Organization (2007), Disaster preparedness and mitigation: UNESCO's role. UNESCO, Paris, Also available online : http://www.unesco.org/science/disaster/index_disaster.shtml

33. WCDR- World Conference on Disaster Reduction (2005), World Conference on Disaster Reduction held in Kobe, Hyogo, Japan, Also available online, http://www.unisdr.org/2005/wcdr/

34. World Bank. (2004). "Natural Disasters: Counting the Cost". Press release, March 2, 2004. Also available online: http://www.worldbank.org

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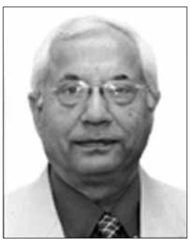

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M.Sc., Ph.D. in Botany (Ecology), Faculty Member of National Institute of Disaster Management, New Delhi, for last 15 years is currently associated with hydro-meteorological disaster management division. Actively involved in conducting training programmes particularly water and climate related disasters – floods, drought and forest fire, Dr. Kaushik is disaster management professional trained in India and abroad, contributed many research publications in Disaster Management & Environmental Ecology, to documentation on Mumbai flood and Meerut fire and development of a detailed training manual on floods disaster mitigation and management.

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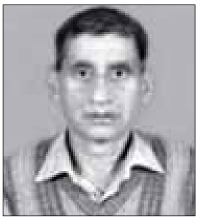
An ecologist by training, Dr. Ashish Rawat has extensively worked on the landslide risk mitigation and management using the ecological applications in the Himalayan Region. He attained his doctoral degree from the FRI University on"Bioengineering of Landslides in Garhwal Himalayas" Dr. Rawat has also worked on the ecological restoration of derelict mined lands, carbon sequestration, Climate Change mitigation and adaptation. Dr. Rawat's research interests include disaster management, rehabilitation/reclamation of degraded lands, natural resource management and Environmental Impact Assessment, Monitoring and Evaluation of Developmental Projects. Dr. Rawat has also published research papers and articles in journals of national and international repute.



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With more than two decades of research experience, Dr. H.B. Vasistha has extensively worked on several aspects of forest ecology such as ecological restoration, biodiversity conservation, natural resource management etc. His areas of research experience pertain to ecological impact assessment, ecological restoration, ecological investigations of invasive and alien species and natural resource management. He has published research papers in journals of national and international repute. Recent work related to application of ecological research in disaster risk management as well.

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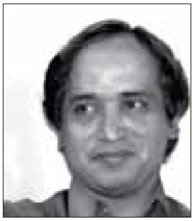

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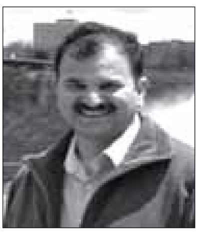

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Sanjay has contributed to the preparation of framework and supporting the preparation of State Action Plan on Climate Change in 16 states of India. He has also contributed to IISD's recent book entitled 'Creating Adaptive Policies: A Guide for Policymaking in an Uncertain World'

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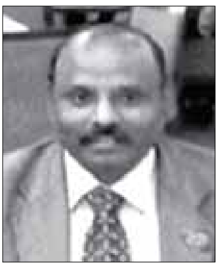

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