Integrating Environmental Safeguards into Disaster Management: a field manual

Volume 1: Reference material

Sriyanie Miththapala

Ecosystems and Livelihoods Group, Asia, IUCN

Integrating Environmental Safeguards into Disaster Management: a field manual

Volume 1: Reference material

Integrating Environmental Safeguards into Disaster Management: a field manual

Volume 1: Reference material

Sriyanie Miththapala

Ecosystems and Livelihoods Group, Asia, IUCN

This document was produced under the project 'Rehabilitating coastal ecosystems in a post-tsunami context: Consolidation Phase' carried out with financial support from the Autonomous Organisation for National Parks (*Organismo Autónomo Parques Nacionales* - OAPN) of the Ministry of Environment of Spain.

Published by: Ecosystems and Livelihoods Group Asia, IUCN, International Union for Conservation of Nature and Natural Resources.

Citation: Miththapala. S (2008). Incorporating environmental safeguards into disaster risk management. Volume 1: Reference material. Colombo: Ecosystems and Livelihoods Group, Asia, IUCN. viii + 130 pp.

ISBN: 978-955-8177-86-0

Cover Photo: © Earthquake damage in Pakistan, 2005 © Karl Schuler/IUCN

Design: Sriyanie Miththapala

Produced by: Ecosystems and Livelihoods Group Asia, IUCN.

Printed by: Karunaratne & Sons (Pvt) Ltd.
67 UDA Industrial Estate
Katuwana Road
Homagama
karusons@sltnet.lk

Available from: Ecosystems and Livelihoods Group, Asia
IUCN
4/1, Adams Avenue
Colombo 4
Sri Lanka
Phone: +(9411) 255 9634-5
Fax: +(9411) 255 9637
email: coastalinfo@iucnsl.org
website: http://data.iucn.org/places/asia/coastalinfo/

Contents

Acknowledgments

Many people assisted with the preparation and production of this manual. The author expresses her grateful thanks to Saima Baig, Channa Bambaradeniya, Lucy Emerton, Janaki Galappatti, Ranjit Galappatti, Usman Ifthikar, Mikkel Kallesøe, Sanjeewa Lellwala, Maeve Nightingale, Thushara Ranasinghe, Ali Raza Rizvi, Rebecca Roberts and Devaka Weerakoon for content inputs and comments.

Yvanka de Soysa prepared most of the annexes in Volume 1 and Eric Wikramanayake generated some GIS maps used for illustration in Volume 2. Anouchka Wijenaike and Irushnie Wedage proof-read the document.

Many people generously provided photographs for use. They are credited individually at the end of each volume.

This document was produced and published with financial support through a grant made from the Autonomous Organisation for National Parks (*Organismo Autónomo Parques Nacionales* - OAPN) of the Ministry of Environment of Spain to IUCN.

List of Figures

List of Tables

Executive summary

Environmental facets are essential components of human well-being and contribute positively to human security, providing basic materials for good life, good health and good social relations. Yet, these are being damaged and overexploited, ultimately to the detriment of humans. In addition, increasing incidence and intensity of natural disasters and climate change are having over-arching impacts on the environment. Sustainable development, often of the most vulnerable sectors of society, is thus being undermined.

One of the key reasons why this damage continues is that an integrated approach is adopted rarely in disaster risk management. For example, relief organisations may focus on damage to life and property while others examine impacts on livelihoods. Very often, ecological services and their indirect economic values are omitted completely from assessments. Adaptation to climate change is ignored.

Mainstreaming ecosystem concerns – both ecological and economical – into the development agenda and integrating them into disaster management, therefore, becomes essential. This manual attempts to provide background information and guidance for integrating environmental concerns into disaster management.

Volume 1 of the manual describes briefly the framework of the Millennium Ecosystem Assessment (MA). The MA links clearly ecosystem well-being to human well-being, and presents the major threats imposed by human activities to the services that ecosystems provide. Volume 1 also gives snapshot views of ecosystem well-being and human well-being in Asia and a brief overview of selected ecosystems in the region. Clarification of the difference between natural hazards and natural disasters and a discussion on risk and vulnerability are presented. Climate change and its impacts on natural disasters is also discussed. At the end of Volume 1 is a series of annexes that detail ecosystem services of and threats to ecosystems described in the text.

Volume 2 describes the disaster management cycle and its phases: prevention, mitigation, preparedness, relief, recovery and rebuilding. It introduces an integrated approach to assessments that examines biodiversity, ecosystem services, economic valuation and livelihoods. Volume 2 deals with each of the phases of the disaster management cycle, lists steps and introduces questions that must be raised during each phase in order to integrate environmental concerns into disaster management. These steps and questions are designed around the framework of the Millennium Ecosystem Assessment and its identified threats.

Finally, in the third volume, an integrated summary worksheet is presented as a tool for use. Details of the techniques for each component of assessment are also presented in this volume, as well as a list of available web resources.

The Indian Ocean tsunami of December 2004 served to focus the world's attention on the fatalities, the damage and the destruction that natural disasters cause. Much is being done and said about the development of early warning systems, disaster management and emergency preparedness planning.

Less is being said about integrating environmental safeguards into disaster management and preparedness planning. Even less is understood about why environmental safeguards are so vital for disaster management and, indeed, for sustainable living.

Why is the environment necessary for sustainable living?

The benefits that we amass from the Earth are enormous. The natural environment (ecosystems[1] in a narrower sense) provides us with many services.

These ecosystem services[2] can be categorised broadly as:
- Provisioning services,
- Regulating services,
- Supporting services, and
- Cultural services (see figure on following page).

Provisioning services:
These services cover the natural resources and products – goods – obtained from ecosystems. Such goods include food, wood, medicines, fuel and fuelwood, fibre and non-timber forest products. Ecosystems, therefore, provide, the basis for many industries: agriculture, livestock, fisheries, lumber, and pharmaceuticals, to name a few. They also provide the basis for a multitude of livelihoods.

Regulating Services:
These are the benefits obtained from the regulation of ecosystem processes, such as, for example, climate and flood regulation.

Supporting services:
These are ecosystem services that are necessary for the production of all other ecosystem services. For example, the production of biomass, balancing gases in the atmosphere, formation of soil, degradation of waste, nutrient and water cycling and pollination.

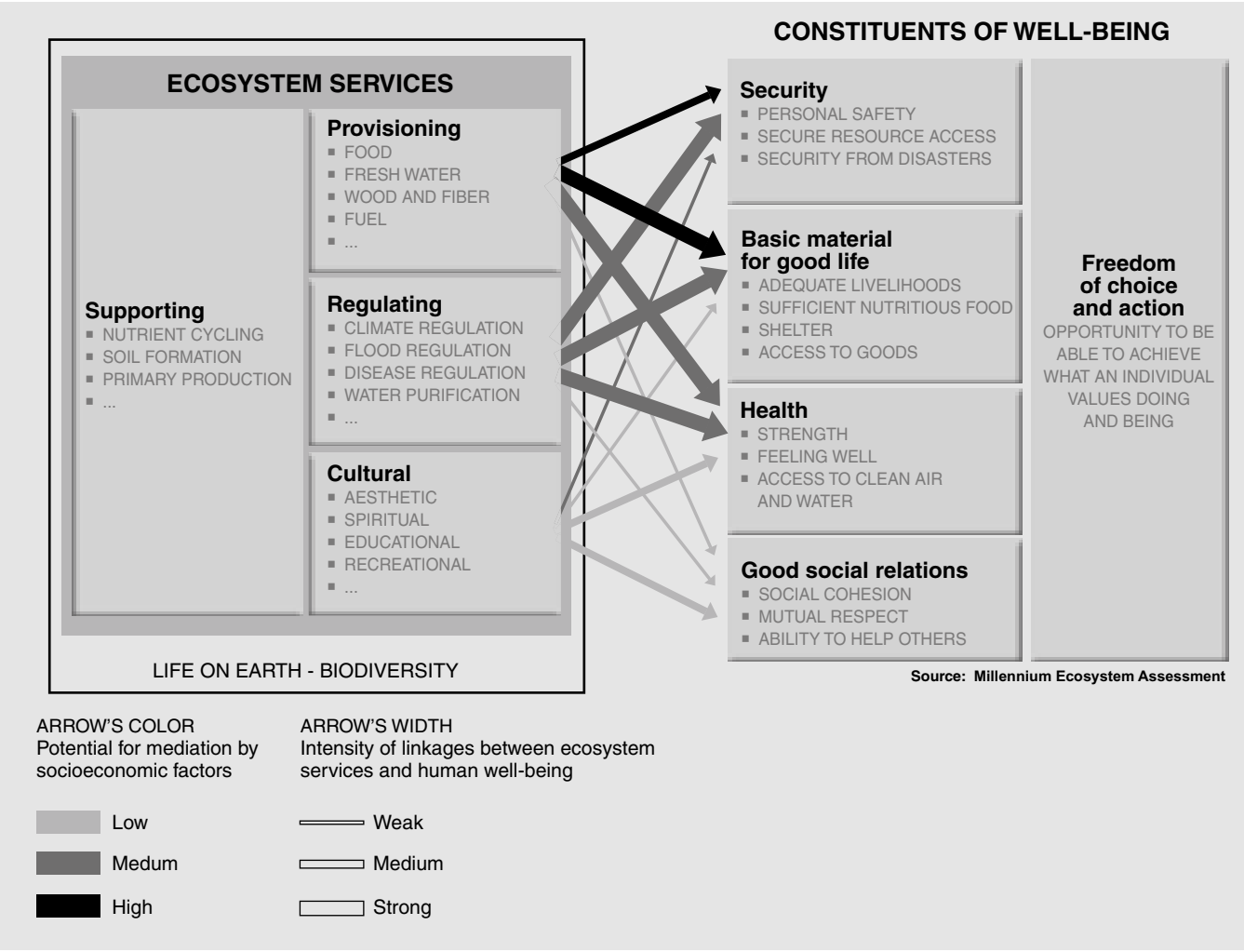
Cultural services:
These are non-material benefits people obtain from ecosystems through spiritual enrichment, development of learning, recreation and aesthetic experience.

All these ecosystem services are not only of direct value to humans, but they also offer indirect benefits by supporting and promoting the natural resource base upon which livelihood and economic activities are based. The Millennium Ecosystem Assessment framework examines and shows the relationships among biodiversity, ecosystems and ecosystem services, and also details the relationship between ecosystem services and human well-being (MA, 2005). (See Figure 1 on following page.)

At the turn of this century, the then secretary of the United Nations, Kofi Anan, called for a global assessment of the state of the Earth. One thousand three hundred and sixty scientists from 95 countries participated in this assessment that was carried out between 2001 and 2005. It focussed on developing and presenting a framework that linked clearly all the services that ecosystems provided to human well-being. It examined relatively untouched ecosystems as well as intensively managed and highly modified systems. It examined how ecosystem well-being affects the services it provides and therefore, affects human well-being. This framework links clearly ecosystem well-being to human well-being, and shows explicitly that humans are integral parts of ecosystems. In its review, the Millennium Ecosystem Assessment (hereafter called the MA) also identifies major anthropogenic threats to ecosystems or drivers of ecosystem change (MA, 2005).

[1] Ecosystems are defined as dynamic complexes of flora, fauna and other living communities and their nonliving environment interacting as functional units (MA, 2005).
[2] Defined as the benefits that ecosystems provide for human well-being (MA, 2005).

Figure 1: The Millennium Ecosystem Assessment (MA) framework (Source MA, 2005)



The MA framework shows clearly that through different ecosystem services, biodiversity is an essential component of human well-being and contributes positively to human security, providing basic materials for good life, good health and good social relations.

The bottom line is that without ecosystems, humans can not live. In short, in order to achieve human well-being, it is essential that we also have ecosystem well-being.

This is the link that underpins sustainability of livelihoods and of development.

Yet this link is being threatened by various actions of humans and ecosystems and the services that are obtained from them are being damaged and degraded.

The five major drivers of biodiversity loss and change in ecosystem services are

- Over-exploitation,
- Habitat change,
- Climate change,
- Invasive Alien Species and
- Pollution.

Over-exploitation:

Humans are, simply, taking too much out of ecosystems, for food, medicines, as pets, as ornamentals and for other purposes. The demand for fish as food for people is increasing, resulting in major collapses of some fisheries industries. About 75% of the world's commercial marine fisheries are either exploited fully (50%) or over-exploited (25%) (MA, 2005).

Habitat Change:

Almost all of the world's ecosystems have been changed by humans. Changes in the last 50 years have been more than in any other time in recorded history.

More land was converted to cropland between 1950-1980 than in the 150 years between 1700 and 1850.

Twenty percent of coral reefs all over the world are already destroyed and another 20% are degraded.

Tropical rain forests are lost at the rate of one hectare per second (equivalent to the extent of two U.S. football fields).

Up to 80% of original mangrove ecosystems and 50% of the world's wetlands are already degraded and lost (MA, 2005).

Climate Change:

The result of excessive greenhouse gas emissions and an increased greenhouse effect is a distinct warming of the earth. This global warming is causing climate change: melting ice caps, changing weather patterns and ocean currents, increasing extreme weather events and spreading disease. Climate change, therefore, is causing overwhelming changes to ecosystems and their services. (See later section on climate change for a more detailed description.)

Invasive Alien Species:

Invasive Alien Species are introduced species that do not stay confined to the area into which they were introduced, compete vigorously with native species, become established in natural ecosystems, threaten native species and have the potential of eradicating them. When they eradicate native species and disrupt ecosystem interactions, they damage ecosystem services and cause severe economic damage (IUCN, 2000).

Pollution:

Ecosystem degradation and loss have had serious impacts on human well-being in the Asian region.

Since 1950, increases in nitrogen, phosphorus, sulphur, and other nutrient-associated pollutants (often fertilisers) have become one of the most important drivers of ecosystem change.

Other forms of water pollution such as domestic, industrial and marine pollution are further degrading ecosystems and damaging their services. The accumulation of non-degradable solid waste (which attracts disease carriers, pollutes groundwater and rivers and generates methane) is also adding considerably to the problem of ecosystem degradation.

In all, the Millennium Ecosystem Assessment reveals that 15 ecosystem services - including provisioning services such as fisheries, timber production and regulating services such as water supply, waste treatment and detoxification, water purification, natural hazard protection, regulation of air quality, regulation of regional and local climate, regulation of erosion, and many cultural benefits - have been degraded.

Asia contains some of the richest ecosystems and livelihoods. More than half the world's biodiversity is found in the region (Sodhi et al., 2004). South and Southeast Asia house about 15.5 % of the world's fauna and 12% of the world's flora. Five out of 17 mega diverse countries (which contain, within their borders, more than two thirds of the world's biodiversity) of the world are Asian (China, India, Indonesia, Malaysia and the Philippines) (Mittermeier et al., 1997). Of the 25 'biodiversity hotspots' (areas richest in biodiversity but also the most highly threatened) identified in the world, six hotspots (Indo-Malaya, the Philippines, the Himalayan region, the mountains of southwest China, the Sundalands, and the Western Ghats and Sri Lanka) are found in this region (Conservation International, 2008). Together, the region has a biological diversity that is not found elsewhere in the world, and this biodiversity sustains human life by providing essential provisioning services such as food, medicines, wood and firewood and regulating and supporting services such as storm protection, climate regulation, balancing gases in the atmosphere, water regulation, soil engineering, nutrient cycling, degradation of wastes and pollination.

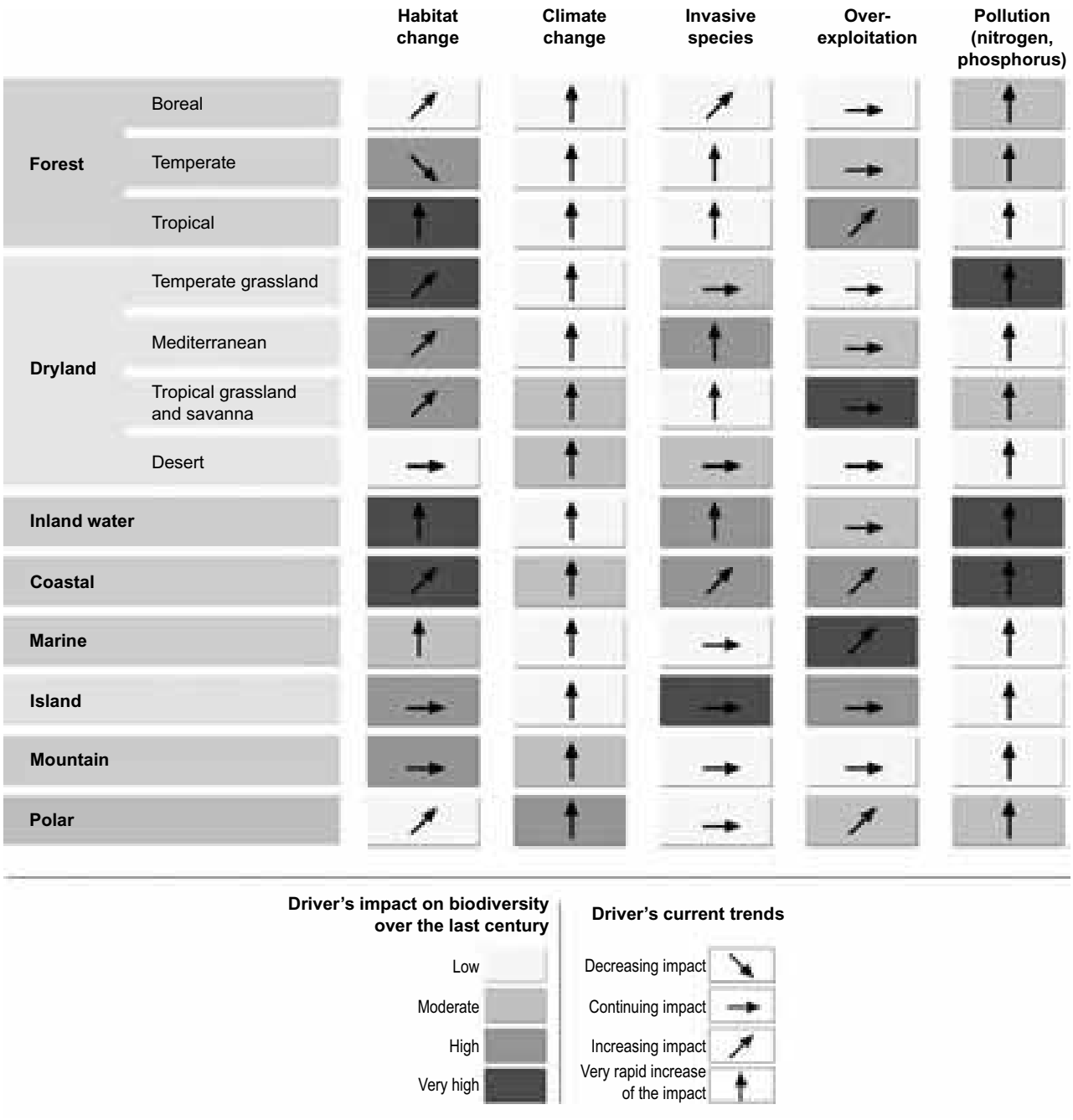
The results of the Millennium Ecosystem Assessment released in 2005 were alarming.

- Of 24 evaluated ecosystems, 15 are being damaged. Twenty percent of the world's coral reefs (the centre of diversity of which is in Asia) were lost and 20% degraded in the last several decades. Thirty five percent of mangroves have been lost in the last several decades. (Forty percent of the world's mangroves are found in Asia).
- Other significant changes include the conversion of forests and grasslands for agriculture, diversion and storage (through dams) of freshwater.
- Other ecosystems affected seriously by human activity include temperate broad-leaved forests, temperate grasslands, Mediterranean forests, and tropical dry forests.
- The most rapid changes are taking place currently in developing countries, 17 of which are in Asia (BMBF 2002).
- Sixty percent of the world's ecosystem services have been degraded.
- The most important change in the world has been the conversion of natural ecosystems to cultivated land - 24% of the terrestrial extent of the earth is now agricultural.

(Source MA, 2005).

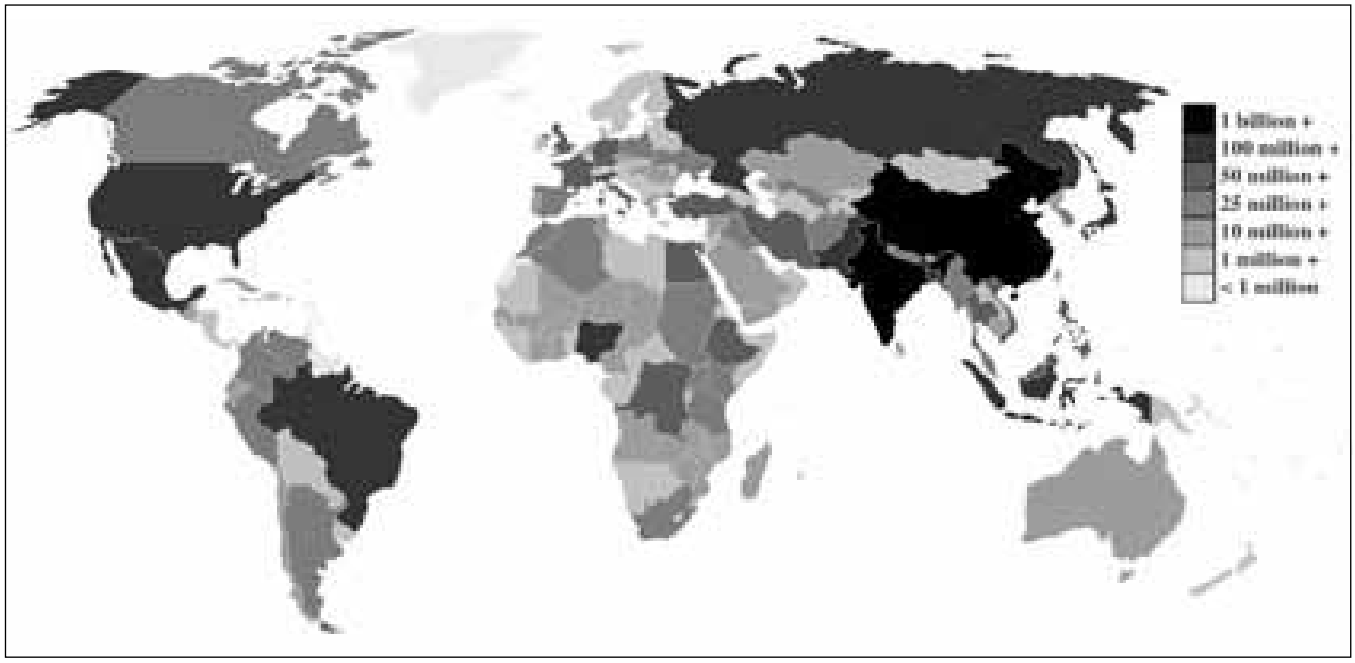
This ecosystem degradation and loss has had serious impacts on human well-being in the Asian region. 'These include reduced availability of goods and services to local communities, increased spread of diseases and reduced economic opportunities. This, in turn, is leading to issues associated with environmental security through the loss of livelihoods and food security. Declining ecosystems have also increased the vulnerability of the people to natural disasters and their inability to absorb related shocks and stresses' (Emerton, 2006).

Figure 2: Impacts of the main drivers of ecosystem change (Source: MA, 2005)



The current world population stands at just over 6,660,000,000 (U.S. Census Bureau, 2008). Of this, the Asian region accounts for 56.5% or 3,733,783,474 people (U.S. Census Bureau, 2008).

Figure 3: Current world population
(Source: http://upload.wikimedia.org/wikipedia/commons/b/b1/World_population.PNG)



The two most populous countries in the world – China and India - are found in the Asian region. In addition, of the top ten most populous countries in the world in 2002, six (China, India, Indonesia, Pakistan, Bangladesh and Japan) are Asian (U.S. Census Bureau, 2008).

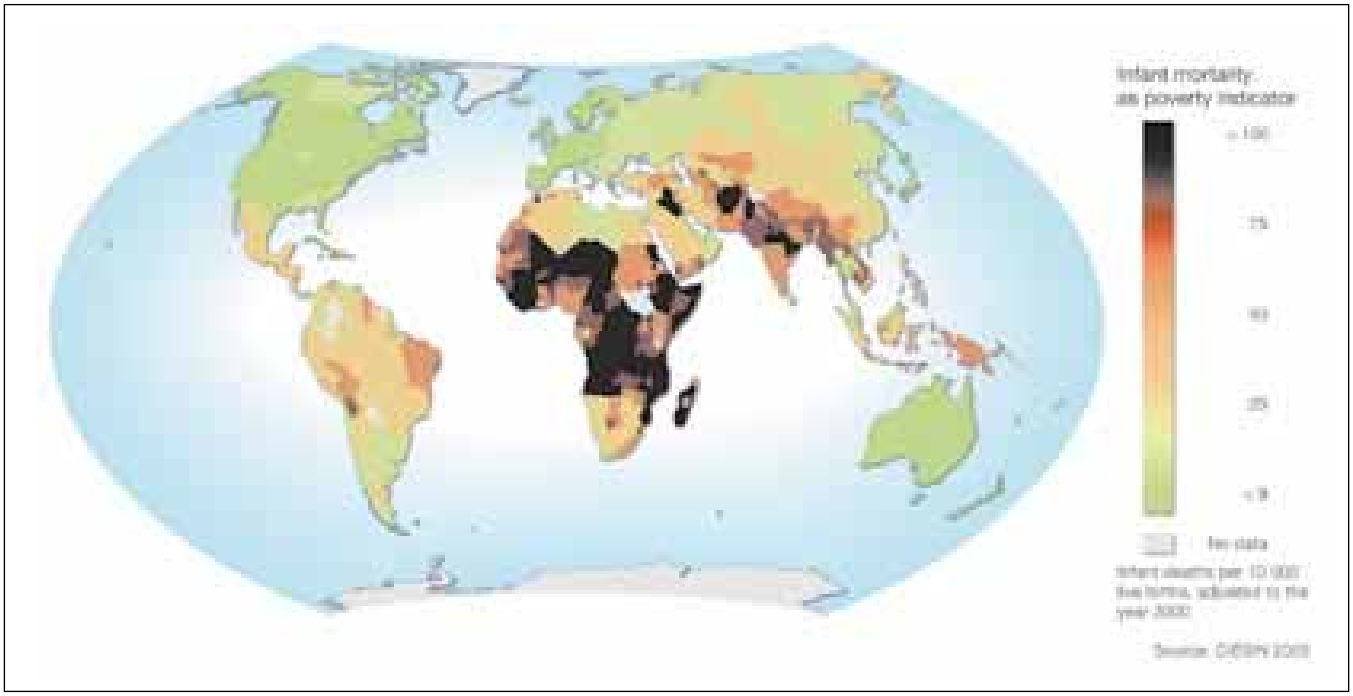
Asia is also the home to over 70% of the world's poor, most of whom live in rural areas and many of whom live in coastal areas and depend on an easily disturbed natural resource base for their survival.

Table 1. Population and poverty in Asia (Sources: as listed individually)

Country	Population 2005 (millions)[3]	Population living on less than 2 USD/day[4]	GNI[5] per capita 2005 (Atlas method, USD)[3]
Bangladesh	141.8	83.0%	470
Cambodia	141.0	77.7%	430
China	1,300.0	47.0%	1,740
India	1,100.0	80.0%	730
Indonesia	220.6	52.0%	1,280
Lao PDR	5.9	74.0%	430
Malaysia	25.3	9.3%	4,970
Maldives	0.3	NA	2,320
Nepal	27.1	69.0%	270
Pakistan	141.5	74.0%	690
Sri Lanka	19.6	41.6%	1,160
Thailand	64.2	25.2%	2,720
Vietnam	83.1	NA	620

[3] World Bank Country tables, 2005.
[4] Poverty Database World Bank.
[5] GNI is Gross National Income - the sum of all income earned in a county within one year.

Figure 4: World poverty distribution - using infant mortality as a poverty indicator
(Source: UNEP/GRID-Arendal, 2008)

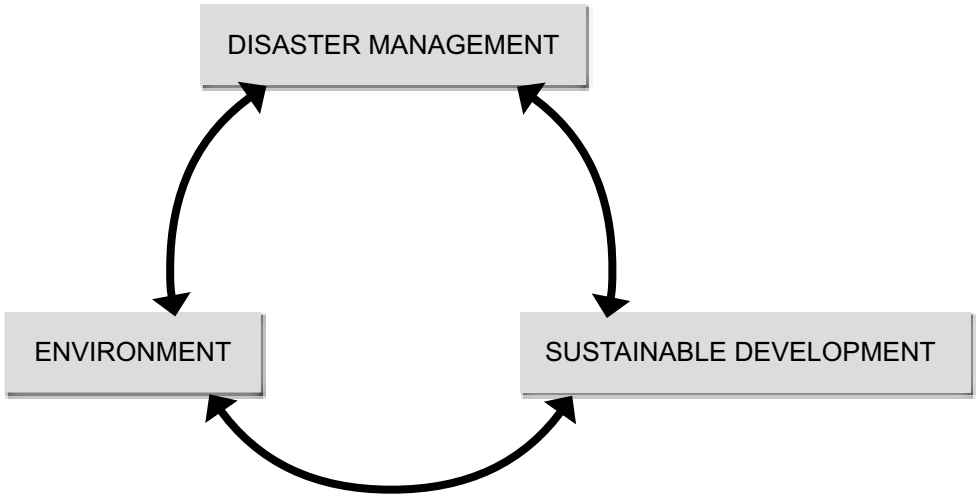


Along with rapid urbanisation and growth, a great proportion of the population in Asia remains vulnerable, and faces uncertain and insecure livelihoods. In many countries, there have been worsening levels of corruption, ethnic and religious tensions, gender inequalities, excessive consumption by the rich, and trafficking in drugs and people.

What should be done?

One of the key reasons why biodiversity and ecosystems continue to be degraded and lost is that the impacts of their loss are not assessed together. Assessments are often made in a fragmented manner, with the result that only part of the true picture is revealed. For example, relief organisations may focus on damage to life and property while others examine impacts on livelihoods. Very often, ecological and their indirect economic values are omitted completely from assessments.

Mainstreaming ecosystem concerns – both ecological and economical – into disaster management and integrating them into development agendas, therefore, becomes essential. It is only then that, in the long term, disaster management becomes effective and development sustainable. In turn, good practices in disaster management and development will protect the environment.



This manual attempts to provide background information and guidance for integrating environmental concerns into disaster management and to provide direction for carrying out integrated assessments.

The manual is structured in three parts. Volume 1 gives background information on ecosystems and their value, and also clarifies the difference between natural hazards and natural disasters. It discusses risk and vulnerability. Climate change and its impacts on natural disasters are also discussed. Volume 1 also presents a series of annexes detailing ecosystem services of and threats to ecosystems described in the text.

Volume 2 describes the disaster management cycle and its phases: prevention, mitigation, preparedness, relief, recovery and rebuilding. It deals with each of the components of the disaster management cycle, lists steps and raises questions that must be asked at each step in order to integrate environmental concerns into disaster management. The steps and questions are designed round the framework of the Millennium Ecosystem Assessment and its identified threats.

Finally, in the third volume, an integrated summary worksheet is presented as a tool for use. Details of the techniques for each component of assessment are also presented in this volume, as well as a list of available web resources.

An overview of main Asian ecosystems and their status

The World Wide Fund (WWF) for Nature recognises 142 terrestrial, 53 freshwater, and 43 marine ecoregions (WWF, 2007). A detailed description of each of these ecoregions is beyond the scope of this manual, but a broad-brush overview of a select cross-section of ecosystems found in the Asian region is presented here.

Terrestrial inland ecosystems

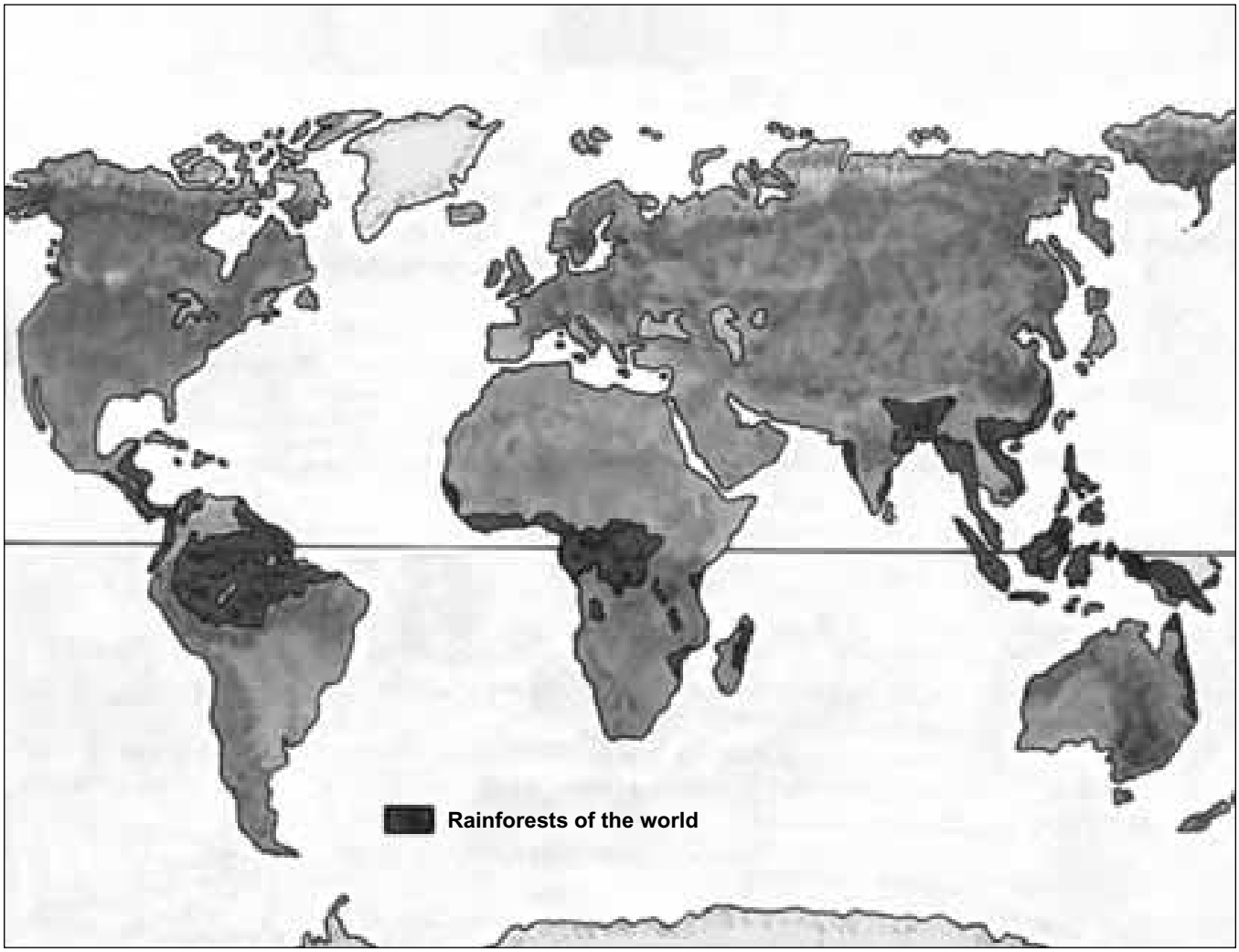
Tropical lowland rain forests (Moist broad-leaved forests)

Tropical lowland rain forests are found at elevations below 1000m near the equator between the Tropic of Cancer and the Tropic of Capricorn. This means that the temperature in tropical lowland rain forests does not vary and ranges only between about 20-28°C. Tropical lowland rain forests, as their name implies, receive high annual rainfall - at least 254cm and, on average, between 1.25 – 6.5m of rain annually, distributed evenly through the year. The soils of lowland rain forests are impoverished.

These forests are concentrated in Africa, Asia, Australia and Central and South America.

The Amazon is the world's largest rainforest. It covers areas in Brazil, Peru, Venezuela, Colombia and Ecuador and is estimated to represent half of the world's remaining rainforests (UNEP, 2001).

Figure 5: Global distribution of tropical rainforests
(Source: http://en.wikipedia.org/wiki/Rainforests)



Tropical lowland rainforests are famous for their incredible diversity and species richness. It is reported that one square kilometre of Amazonian forest may contain over 75,000 types of trees and 150,000 species of higher plants (Lewinsohn et al., 2005).

Tropical lowland rainforests are extremely important as they provide many goods to humans. Many fruits consumed today (such as bananas, papayas, citrus fruits), vegetables (such as legumes, cassava, peppers, okra) flavourings (such as cocoa, vanilla, sugar), spices (such as nutmeg, cinnamon), nuts (such as peanuts and cashew nuts) originated in the rainforest. It is reported that a staggering 80% of the foods eaten in the developed world originated in rainforests (http://www.andrew.com).

Over a quarter of the world's allopathic medicines also originated in rainforests. The US National Cancer institute has identified over 3,000 plants that have chemicals active against cancer cells; of these 70% are found in rainforests. Many familiar medications - such as quinine (used to treat malaria), curare (used as a muscle relaxant) vincristine and vinblastine (used to treat some forms of leukaemia) - had their origins in rainforest plants (http://www.andrew.com).

Apart from their amazing provisioning services, lowland tropical rainforests provide a wide range of other services, such as climate and flood regulation, water purification, nutrient cycling, primary production, carbon sequestration as well as aesthetic and educational services – all essential for human well-being (Condit et al, 1996; Ross et al., 1990).

Tropical rain forests are being threatened very rapidly by habitat destruction and climate change, increasingly by invasive alien species and have continued over-exploitation of species. (See Annexe 1 for a detailed description of the services provided by and threats to tropical lowland rainforests.)

Tropical montane and submontane rain forests

Tropical montane rainforests, as their name suggests, grow in the tropics above 2,500-3,000m. The temperatures in tropical montane forests are generally cooler than that of lowland rainforests. A particular type of montane forests are cloud forests in which clouds hang low near the tree canopy and provide plentiful moisture. Typically, trees in montane and cloud forests are shorter as an adaptation to high winds at high elevations. Submontane forests are found at intermediate elevations - lower than montane forests, but higher than lowland forests. Their structure is in-between that of montane and lowland rain forests (WWF, 2007).

Like tropical lowland rain forests, montane, cloud and submontane forests support a high diversity of species, often with a high degree of endemicity. Montane and cloud forests, in particular, support a rich diversity of epiphytes such as orchids. Many montane and sumontane forests provide watershed protection and prevent soil erosion.

These forests are subject to many of the same threats as lowland rain forests. (See Annexe 2 for details.)

Cloud forests are found at lower elevations of the Andes in Ecuador, Peru, Colombia, and Venezuela, Costa Rica, Borneo and Africa.

Monsoon forests (Dry/semi evergreen broad-leaved forests)

Monsoon forests are found in tropical areas that have a long dry season followed by a season of heavy rainfall. The seasonal dry season has a huge impact on these forests, whose species are adapted to deal with times of water stress. For example, many trees shed their leaves during the dry season. Hence, these forests are also called tropical deciduous forests.

Monsoon forests provide a range of ecosystem services but are under threat from selective over-exploitation, habitat destruction – for example, from shifting cultivation - pollution, climate change and invasive alien species. (See Annexe 3 for details.)

Monsoon forests are found just north and south of the rainforest belt. The most diverse dry forests in the world are found in southern Mexico. There are also monsoon forests in India, Sri Lanka and Indochina, and these forests support many large vertebrates (WWF, 2007).

Scrub forests

Scrub forests also grow in areas that are water stressed, but tend to be found in more arid regions than monsoon forests, where the dry season is prolonged. Here, plants show xeromorphic[6] adaptations to conserve water. Animals too are able to survive water stress and many are vagile[7].

When monsoon forests are destroyed, often, thorn scrubs regenerate in their place.

Scrub forests are threatened particularly by slash and burn cultivation and invasive alien species, such as Prickly Pear (*Opuntia dillenii*) and Mesquite (*Prosopis juliflora*). (See Annexe 4 for details.)

In Asia, scrub forests are found in India and Sri Lanka (the Deccan thorn forests) and in north western India.

[6] Xeromorphic characters are adaptations that allow plants to conserve water.
[7] Vagile animals range widely.

Tropical coniferous forests

Tropical coniferous forests experience low rainfall and moderate temperature variability. Vegetation is adapted to deal with this variability, and leaves are needle-shaped to reduce water loss during cold periods. Animals migrate to warmer areas during the cold season.

These forests are characterised by many species of conifers and large ungulates.

Because these forests are found in Asia on mountain slopes they provide regulating services in flood and erosion prevention. Their streams provide fresh water for humans at lower elevations.

Tropical coniferous forests are threatened by habitat destruction through wildfires and logging, forest fragmentation and over-exploitation by hunting. (See Annexe 5 for details.)

The most diverse tropical coniferous forests are found in Mexico. In Asia, they are found at high elevations where the temperature is lower, in Lao PDR, Vietnam, the Philippines and the lower ranges of the Himalayas (WWF, 2007).

Temperate broad-leaved and mixed forests

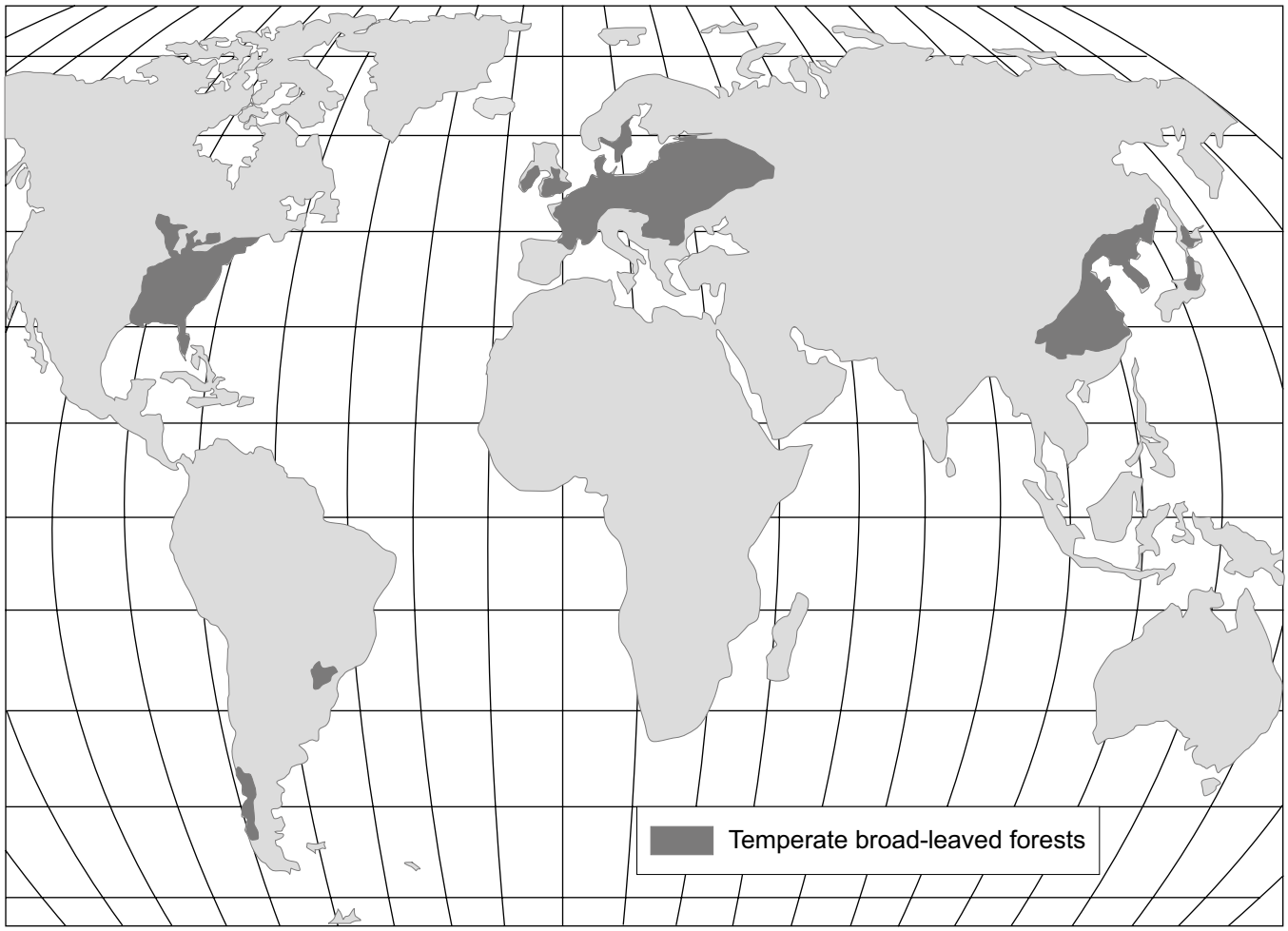
Temperate broad-leaved forests have marked seasonal changes in temperatures: with distinct seasons of moderately cold winters, springs, warm summers and autumns. Throughout the year, they also have marked changes in the length of day: during the summer, daylight hours are long; while during the winter, they are short. There is good precipitation throughout the year but some of it becomes unavailable when it is too cold. The soils of rain forests are nutrient rich.

These forests are characterised by a mix of deciduous vegetation with evergreen species. Both flora and fauna are adapted to survive changes in temperature and daylight hours, and many animals migrate to warmer areas to feed during winter months.

Because soils are nutrient rich, much of these forests have been cleared for agriculture. They are affected by habitat fragmentation and invasive alien species. (See Annexe 6 for details.)

Temperate broad-leaved and mixed forests are found at varying elevations. In Asia, they are found in the Himalayas - above elevations that support tropical coniferous forests and in south west China.

Figure 6: Global distribution of temperate broad-leaved forests
(Source: http://www.runet.edu/~swoodwar/CLASSES/GEOG235/biomes/rainforest/rainfrst.html)



Tropical grasslands

Tropical grasslands are found in both wet and dry areas at low altitudes.

Savannahs

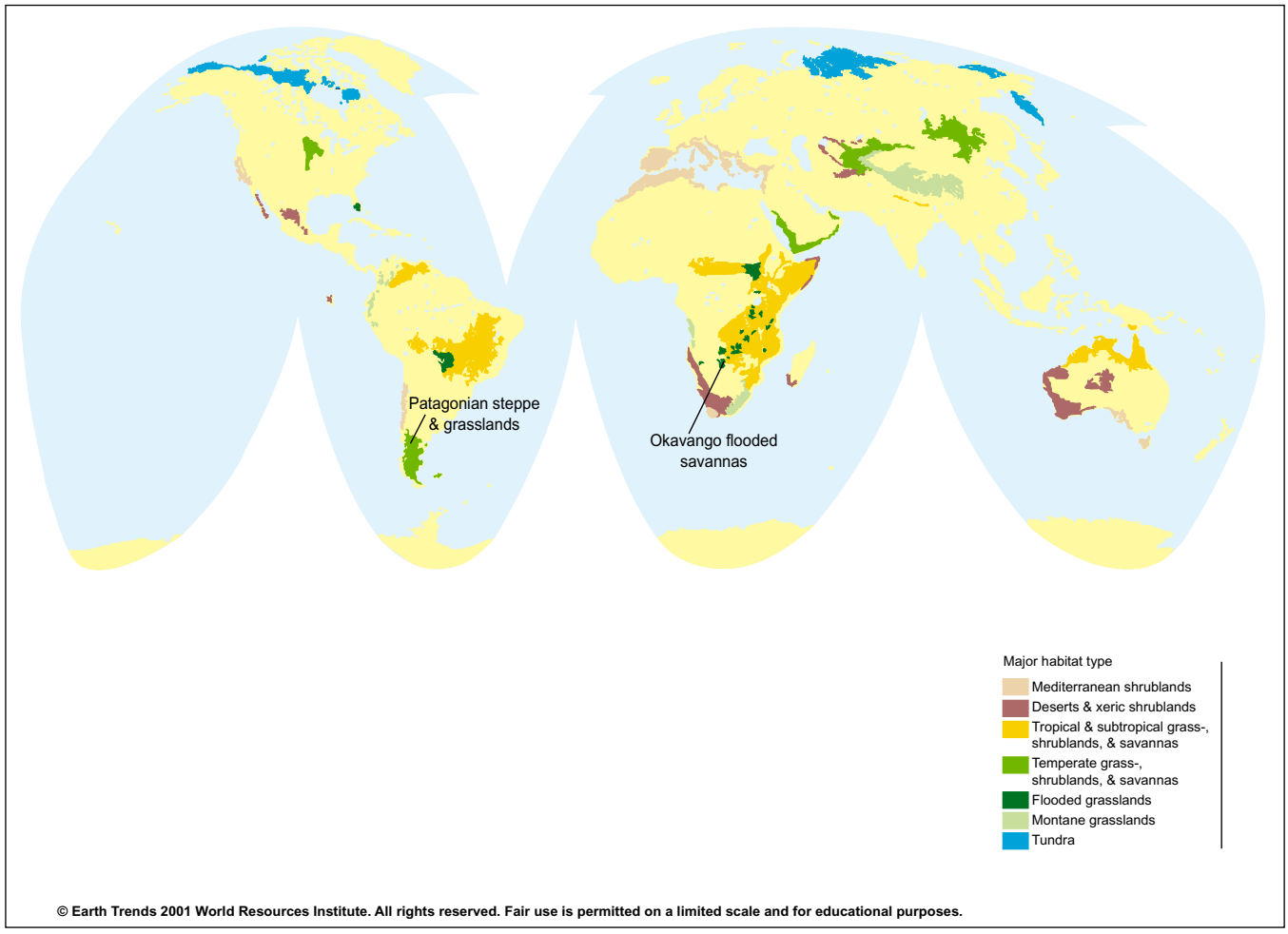
Tropical dry grasslands of low altitude are called savannahs and are characterised by so little rainfall per annum that there is insufficient moisture to sustain much tree life. Instead, savannahs support a multitude of grasses, some shrubs and a few scattered trees, all adapted to conserving precious water. Because of the diversity of grass species, the fauna of savannahs is dominated by grazing herbivores, as well as many carnivores who feed on the herbivores (WWF, 2007).

Grasslands, therefore, support high species richness. In addition, they sequester carbon, prevent soil erosion, provide fertile soils and regulate floods.

Although seasonal fires - when conditions become very dry - play a vital role in the savannah's biodiversity, grasslands are threatened as a result of excessive burning by humans and also by over-grazing by domestic livestock that alters the ecosystem balance as well as water balance, leading to desertification. (See Annexe 7 for details.)

Savannahs are found in east and central Africa and in India.

Figure 7: Global distribution of grasslands (Source WRI, 2002)



Flooded grasslands

Tropical wet grasslands (flooded grasslands) are flooded either during a particular season or the whole year round and are found in nutrient rich soils. These are found on all the continents.

These grasslands are threatened by water diversion schemes, pollution and eutrophication[8].

Montane grasslands

Montane grasslands are found, as their name implies, at high elevations, in both temperate and tropical regions in all continents. Flora and fauna are adapted to wet, cold conditions and strong sunlight.

These grasslands are threatened by ploughing, extensive burning and over-grazing. (See Annex 7 for details.)

Montane grasslands are found in the Andes Mountains, east and central Africa, in Borneo, in the Western Ghats of South India, Sri Lanka and the central highlands of New Guinea.

In Asia, temperate grasslands (Alpine meadows) are found in Malaysia and the eastern Himalayan slopes.

[8] Eutrophication is a process whereby water bodies - such as lakes, estuaries, or slow-moving streams - receive excess nutrients that stimulate excessive plant growth (algae and weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die.

Deserts

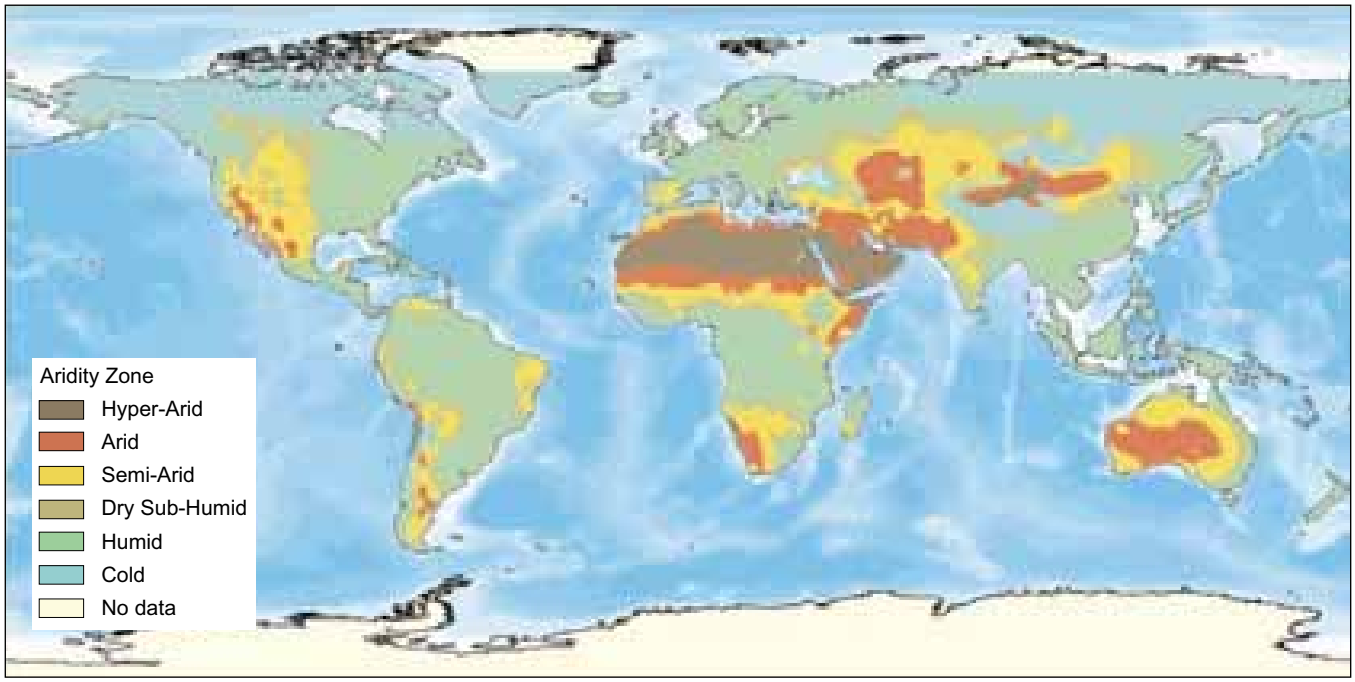
Deserts are characterised by very little rainfall throughout the year – in fact, evaporation in deserts exceeds precipitation. Temperature, however, varies: in some deserts, such as hot deserts, it is hot all year round, while in others – in cold deserts – it becomes cold in the winter. A characteristic of both hot and cold deserts is that temperature varies within a twenty four hour period: it is extremely hot during the day and cold at night. Both flora and fauna are adapted to harsh conditions. Plants have xerophytic characteristics (adaptations to conserve water) and animals also exhibit a wide range of behavioural and physiological adaptations to prevent water loss. The landscape is generally bare, with sparse vegetation.

Deserts are the home to many nomadic cultures, hunter-gathering and pastoral livelihoods. Mineral and oil deposits are found in some deserts. Desert fauna and flora are thought to have provided the base for present day pastoral and agricultural societies.

Over-grazing, mining, pollution of fragile water bodies with heavy metals are threatening deserts. Oil extraction leads not only to water pollution but also to air pollution. Over-extraction of precious water is also a threat in deserts. The increase of desert areas – desertification - is a consequence of over-use of arid scrublands. Desertification is predicted to increase as a result of climate change. (See Annexe 8 for details.)

Deserts are found on all the continents. Major hot deserts include the Sahara (9,000,000km^2) and the Kalahari in Africa, and the Thar in India. Cold deserts include the Gobi in Asia (1,125,000km^2).

Figure 8: Global distribution of deserts (Source: WRI, 2002)



Aquatic inland ecosystems

Inland aquatic ecosystems are freshwater systems that include rivers and streams (created when water runs off in terrestrial habitats), as well as ponds and lakes (where this runoff accumulates in a land locked area).

Streams and rivers

These are bodies of water that move continuously in one direction. At the headwaters of a stream (the beginning) the channel is narrow and the water is pure and carries less sediment than downstream, as well as only a few minerals. Many such streams (tributaries of a river) join together to form a larger river. The river slopes become gentler and slow moving as they flow downstream except where there are steep, rocky and rapidly flowing reaches. Rivers carry sediments down with the water. The coarser particles (sand and gravel) move along the river bed and the finer particles (clay, silt and fine sand) move in suspension. Suspended sediment makes the water turbid. Turbidity is more pronounced soon after it rains.

At the mouths of rivers (where they run into the sea), sometimes deltas form. River deltas are landforms of river-borne sediment, which the river unloads in that area. (Deltas are formed when the amount of sediment accumulating far exceeds sediment that can be carried out by currents into the sea.)

Figure 9: Major river basins of the world (Source: Global Runoff Data Centre 2008)

The terrain in rivers varies with location as does temperature, which varies with altitude and latitude. The amount of water varies seasonally with rainfall or with melting snow.

Flora and faunal communities are adapted to the above conditions but vary significantly between upstream and downstream.

The transport of water downstream to cultivated ecosystems and provision of freshwater are two main ecosystem services provided by streams and rivers. The transport of sand and other sediments and waste products downstream from the catchment is also a less recognised service provided by rivers. Fertile deltas, beaches etc. are products of these services. Navigation is also an important service provided by larger rivers for transport of people and goods. Riverine vegetation stabilises the soil and prevents erosion. Many rivers - such as the Mekong and Amazon rivers – provide fish stock that supports large communities. Floodplains along rivers and coasts provide flood protection. Many rivers and streams provide diverse recreational services such as fishing, boating and camping.

Rivers and streams are threatened seriously all over the world by water diversions schemes – dams. According to the MA large dams have probably done more harm to freshwater ecosystems than any other human intervention. The MA notes that the amount of water impounded behind dams has quadrupled since 1960, and that six times more water is held in reservoirs than flows in natural rivers. However, the hydropower generated by these dams is the largest contributor to renewable and non-carbon emitting generation of electricity (MA, 2005).

Pollution – from industries, farms and households – is poisoning rivers and streams. Invasive alien species – such as Water hyacinth (*Eichhornia crassipes*), *Salvinia* and Water lettuce (*Pistia spp.*) – are clogging up many major rivers in Asia. Eutrophication sometimes results from excessive pollution from fertilisers. (See Annexe 10 for details.)

Climate change is expected to change the quantity, intensity and spatial distribution of rainfall. These changes will have an impact on the hydrological cycle and river flow regime with long term consequences for each river.

In Asia, major rivers include the Mekong (which flows through China, Burma, Thailand, Lao PDR, Cambodia and Vietnam) and the Yangtze in China, while the Indus and Ganges/Brahmaputra in the Indian subcontinent form major deltas.

Ponds and lakes

Ponds and lakes are found where freshwater runoff accumulates in a land-locked area. Such water bodies are called ponds when they are small and lakes when they are large. In ponds and lakes, temperature and light changes along a vertical gradient and animal and plant communities are also stratified.

Ponds and lakes provide protection from floods, resources such as food fish, and recreation – such as angling, boating, camping.

Pollution – from industries, farms and households – is affecting ponds and lakes. Aquatic invasive alien species are clogging up many lakes all over Asia. Eutrophication sometimes results from excessive pollution from fertilisers. Climate change will change rainfall patterns as well as the quantity and intensity of rain. These changes will have an impact on the hydrological cycle and river flow regime with long term consequences on ponds and lakes, which are fed by rivers and streams. (See Annexe 11 for details.)

In Asia, Lake Inle is found in the Shan Plateau, in Myanmar and Tonle Sap lake, in Cambodia.

Coastal ecosystems

Coastal ecosystems include mangroves, coral reefs and sea grasses, but estuaries and marshes, lagoon and salt ponds, inter-tidal zones, kelp forests, rock and shell reefs and inner shelf are also part of a mosaic of interconnected environments and organisms found along the coastline (Kallesøe et al., 2008).

Coral Reefs

Corals are two-layered invertebrates that live in groups (i.e. they are colonial) and are related to jellyfish and sea anemones.

Corals are made up of tiny individuals called polyps. Each polyp is like a fluid-filled bag with a ring of tentacles surrounding its mouth, and looks like a tiny anemone. Polyps within a colony are linked by living tissues and can share their food (Allen & Steene, 1994). In some corals, the polyp extracts calcium carbonate from the sea and secretes it as a cup of calcium carbonate from the bottom half of its body. These cups provide anchorage for the polyps but when threatened, the polyp can retreat into the safety of the hard cup. When the calcium carbonate cups of many billions of these polyps fuse together, they form coral reefs (Veron, 2000).

Some corals obtain their nutrients from one-celled organisms called zooxanthellae. Zooxanthellae are single-celled organisms that use sunlight for photosynthesis and transfer 95% of the food they produce to coral polyps. Both coral and the zooxanthellae benefit from this association: the zooxanthellae receive protection from currents and

herbivores, while corals obtain their nutrients. This kind of association is called a mutualistic association. These corals are called hermatypic corals. Individual polyps of hermatypic corals secrete calcium carbonate (limestone) skeletons which, in time, form coral reefs. Hermatypic corals are also known, therefore, as reef building corals.

Because of this association with zooxanthellae that need sunlight to produce food, hermatypic corals are dependent on sunlight and only grow in shallow waters less than 60m deep, which have a temperature range between 25° and 30°C. To keep the balance of this association, hermatypic corals prefer narrow salinity and low turbidity ranges.

Therefore, coral reefs are found

- where the sea is shallow (less than 100m);
- where the sea is warm (between 25° and 30°C);
- And are, therefore, located within the latitude of 30°N to 30°S i.e., only in tropical seas.

Coral reefs are extremely important as they provide many services to humans. Coral reefs support human life and livelihoods and are important economically. Nearly 500 million people depend - directly and indirectly – on coral reefs for their livelihoods, food and other resources (Wilkinson, 2004). Further, it is estimated that nearly 30 million of the poorest human populations in the world depend entirely on coral reefs for their food (Wilkinson, 2004).

Despite their immense ecological, economical and aesthetic values, it is estimated that 20% of the world's coral reefs are destroyed with no hope of recovery (Wilkinson, 2004). Over-exploitation, habitat destruction, climate change, pollution and invasive alien species affect coral reefs. (See Annexe 12 for details.)

Mangroves

A mangrove is a woody plant or plant community which lives between the sea and the land in areas which are flooded by tides for part of the time. Mangrove forests make up one of the most unique ecosystems on earth in that they thrive where no other trees can survive – in the transition zone between the ocean and land. They are among the world's most productive ecosystems.

Because mangroves are found in this transition zone – where the tide rises and falls daily, where salinity changes with this rise and fall of the tide and where the oxygen content is less – both the flora and fauna of this ecosystem have developed very distinct morphological and physiological adaptations.

Mangroves are found in latitudes of 32ºN and 38ºS of the globe and also in the mouths of estuaries and in other inter tidal areas. Approximately one-fourth of the world's tropical coastline comprises mangrove ecosystems and they are estimated to

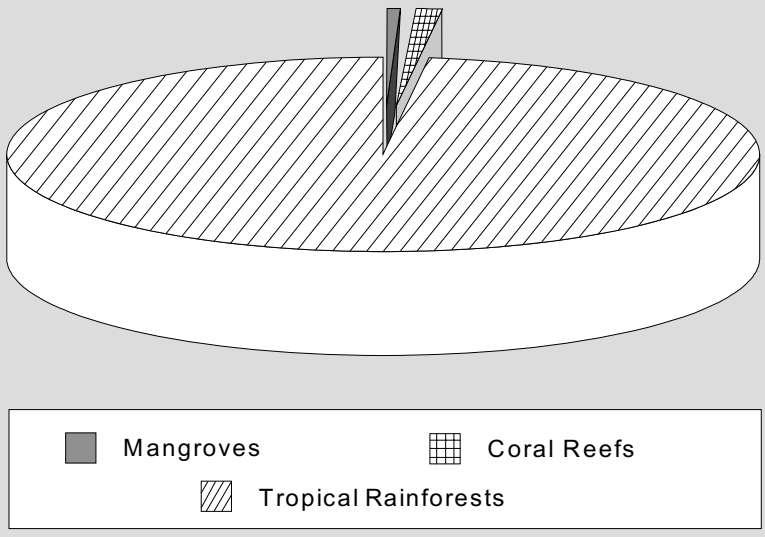
extend along an area of between 167,000 and 181,000km^2, in 112 countries (Spalding, 1997; Kathiresan and Bingham, 2001).

Mangroves are one of the most productive ecosystems in the world and provide humans with many goods such as food, firewood, fuelwood, timber and medicine, and protective, supporting and regulatory services.

However, they are among the world's rarest and most threatened ecosystems. Globally, coral reefs cover nearly twice the area of mangroves, and tropical and subtropical forests more than 125 times as much (EJF, 2005). They are threatened by habitat alteration, over-exploitation, pollution, IAS and climate change. (See Annexe 13 for details.)

Forty percent of mangroves occur in the South and Southeast Asia regions (Spalding, 1997) and the single largest area of mangroves in the world lies in Bangladesh in the Sunderbans, extending over 600,000ha (Bandaranayake 1998).

Figure 10: Extent of mangroves remaining, compared to coral reefs and tropical rainforests (Source: Valiela et al., 2001)



Seagrass meadows

Seagrasses are seed-bearing, flowering, rooted plants which grow submerged exclusively in marine coastal waters and coastal wetlands. Like grasses in terrestrial habitats, they form meadows on the bed of coastal seas. They are dependent on light penetrating for photosynthesis, therefore they generally grow only in shallow waters, in estuaries and coastal seas. They cannot survive outside water, therefore, they often grow where there is shelter from a sand bar or coral reefs.

Sea-grass beds are important because of their provisioning, supporting and regulating services. Seagrasses have been called ‘coastal canaries’ (Orth et al., 2006). Like canaries that were taken into coal mines to test the quality of the air, seagrasses respond to changes in the quality of water, indicating deterioration of the environment by degrading and declining before dying. These changes are visible very quickly, so that it is possible to take management action (Orth et al., 2006). They are threatened by pollution, over-exploitation, invasive alien species and climate change. (See Annexe 14 for details.)

Sea-grasses are found in coastal waters of every continent except Antarctica. In tropical oceans, they are nearly always found near mangroves and coral reefs.

Sand dunes

In intertidal zones of coastal beaches, sand dunes form where there is enough of sand (sediment between 0.2 and 2.0mm) and adequate wind. If the beach is large enough, then the surface dries between high tides. This dry sand is blown landwards and deposited above the high water mark. Some of this sand collects behind rocks or clumps of seaweed. Here, the roots and underground parts of grasses and other specialised vegetation trap the sand from being blown away. The wind then starts eroding sand particles from the windward side and depositing them on the side protected from the wind. Gradually, this action causes the dune to move inland, accumulating more and more sand as it does so. More and more vegetation grows on these dunes, resulting in an often unique assemblage of flora and fauna (Hesp, 2000).

These ecosystems provide humans with regulating, supporting and cultural services but are threatened by over-exploitation and habitat destruction. (See Annexe 15 for details.)

Sand dunes are found worldwide but are less developed in tropical and subtropical zones (where there are lower wind velocities and damper sand) (Packham & Willis, 1997).

Estuaries and Lagoons

Estuaries

An estuary is the last, wide part of a river before it reaches the sea, i.e., it is the tidal mouth of a river. Estuaries are, therefore, important in the movement of sediment from rivers to the sea. Fresh water from the river mixes with the salt water of the sea and creates a transition zone between land and sea. There is always a free connection to the sea in an estuary (NOAA, 2008a).

Lagoons

A lagoon is a body of water cut off from the sea by a sand bank/ spit or coral reef (http://www.wordnet.princeton.edu/perl/webwn). Both estuaries and lagoons can have rivers flowing into them. The main difference between the two is the flow dynamics of the water bodies: in estuaries, the water flows fast and strong, while in lagoons the water is more shallow and sluggish (Ranjit Galappatti, personal communication).

In both estuaries and lagoons, water is brackish[9].

Lagoons and estuaries are productive. The provisioning service of lagoons and estuaries allow for many fisheries-related livelihoods in these ecosystems. They also provide long-term supporting livelihoods in the these ecosystems.

Lagoons and estuaries are under threat from both coastal erosion – which can change the physical structure of mouths and spits – changing lagoon morphology, as well as upstream pollution and hydrology changes. (See Annexe 16 details.)

Coastal lagoons occur all over the world and on every continent except Antarctica. Together with barriers, flats and marshes they occupy about 11% of the world coastline, the longest single stretch being the 2,800km stretch of lagoons landward of barrier islands on the east coast of the USA (http://www.sms.si.edu/irlspec/Whatsa_lagoon.htm).

[9] Brackish water is water that is saltier than fresh water, but not as salty as seawater.

Water salinity based on dissolved salts in percent (%)			
Fresh water	Brackish water	Saline water	Brine
<0.05%	0.05-3.0%	3.0-5.0%	>5%

Ecosystems are complex and yield a wide range of ecosystem goods, which are used by people for food, construction, fuel, income and other uses. More importantly, they deliver ecosystem services that form the basis for human well-being. (See Figure 1.) In short, ecosystems are valuable because people – living both near them and those far away - depend on them for a variety of reasons to support their well-being (Emerton, 2006). In addition, ecosystem services underpin economic growth at the national level, commerce, trade, global markets and economic processes. These are all critical in terms of value, and also in terms of broader multipliers and linkages as regards pro-poor economic growth. Ecosystem service values, therefore, extend well beyond the small-scale/household level.

Therefore, conserving ecosystems, i.e., investing in them because of their economic value to humans, becomes imperative. But, although ecosystems are tremendously valuable to people and national economies, investment in ecosystems is not a mainstream process and is something about which there is still much argument.

The reality is that many of the products and services generated by ecosystems miss detection because they are not traded in markets and therefore, do not come with a price tag. In addition, many of the costs and benefits remain uncaptured, thus missing opportunities for value-addition, for use in poverty alleviation, and for redistributing costs and benefits more equitably. Thus, they remain under-appreciated and undervalued. Because of this, it is difficult to determine what people lose when ecosystems become degraded or are damaged or in contrast, how people benefit from improvements to ecosystems. In this setting of undervaluation and lack of information, investments in ecosystems are traded-off for seemingly more profitable and important uses such as developments including agriculture, aquaculture, infrastructure, that both damage and degrade these ecosystems (Emerton, 2006).

‘If ecosystems are to compete against these alternative uses, there is a need to properly value the various products and services provided so they become an investment opportunity with a good chance of return. Therefore, it is important to value ecosystems so that economic comparisons can be made between maintaining ecosystems or using them for other purposes. In order to assess and value the real environmental and livelihoods impacts of ecosystems on communities, it is necessary to be able to quantify and measure ecosystem loss and environmental damage. It is especially important to do this for proposed land conversions to value the environmental costs of such conversions, and to balance these costs against the benefits of keeping the land untouched by development; and also to assess the socio-economic impacts of ‘developments’ as they impact on ecosystem services and therefore on human and economic well-being. Ultimately, ecosystems must be viewed as developmental infrastructure and valuation of ecosystems used as a decision-making tool in assessing trade-offs with other economic sectors’ (Emerton, 2006).

What is the framework for valuation?

In order to assess and value the real environmental and livelihoods impacts of ecosystems on communities, it is necessary to be able to quantify and measure ecosystem loss and environmental damage. It is especially important to do this for proposed land conversions to value the environmental costs of such conversions, and to balance these costs against the benefits of keeping the land untouched by development. Until now, most development projects such as infrastructure development or agricultural expansion have failed to include the environmental costs of the proposed land conversion. Although Environmental Impact Assessments (EIAs) of large infrastructure and agricultural projects are, in many countries, compulsory by law, the negative environmental impacts are often only described qualitatively and not transformed into economic costs that can be compared directly to, for example, the economic benefits of, for example, increased agricultural production (Emerton, 2006).

To deal with this issue of measuring ecosystem benefits, the theory of Total Economic Value (TEV) was presented almost twenty years ago as a framework to identify these environmental costs and benefits, which, then, could be mainstreamed into project evaluation.

TEV is now one of the most widely used conceptual frameworks and deals with the following:

- *Direct values* (benefits derived from the use of environmental goods either for direct consumption or production of other commodities);
- *Indirect values* (benefits provided by ecosystem functions and services);
- *Option values* (premium placed on maintaining an environmental good or service for possible future use);
- *Non-use values* (includes existence value - satisfaction from just knowing that a species or ecosystem is present); and
- *Bequest value* - willingness to pay to ensure that future generations inherit a particular environmental asset and intrinsic value (i.e., the value of a species or ecosystem in its own right independent of any value placed on it by humans).

Figure 11: Total Economic Value (Source: Emerton, 2006)

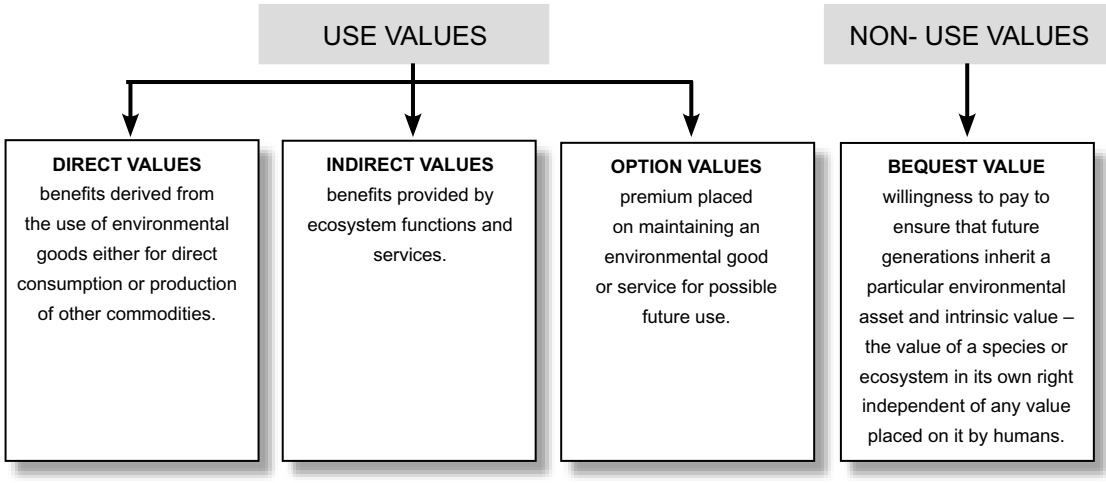
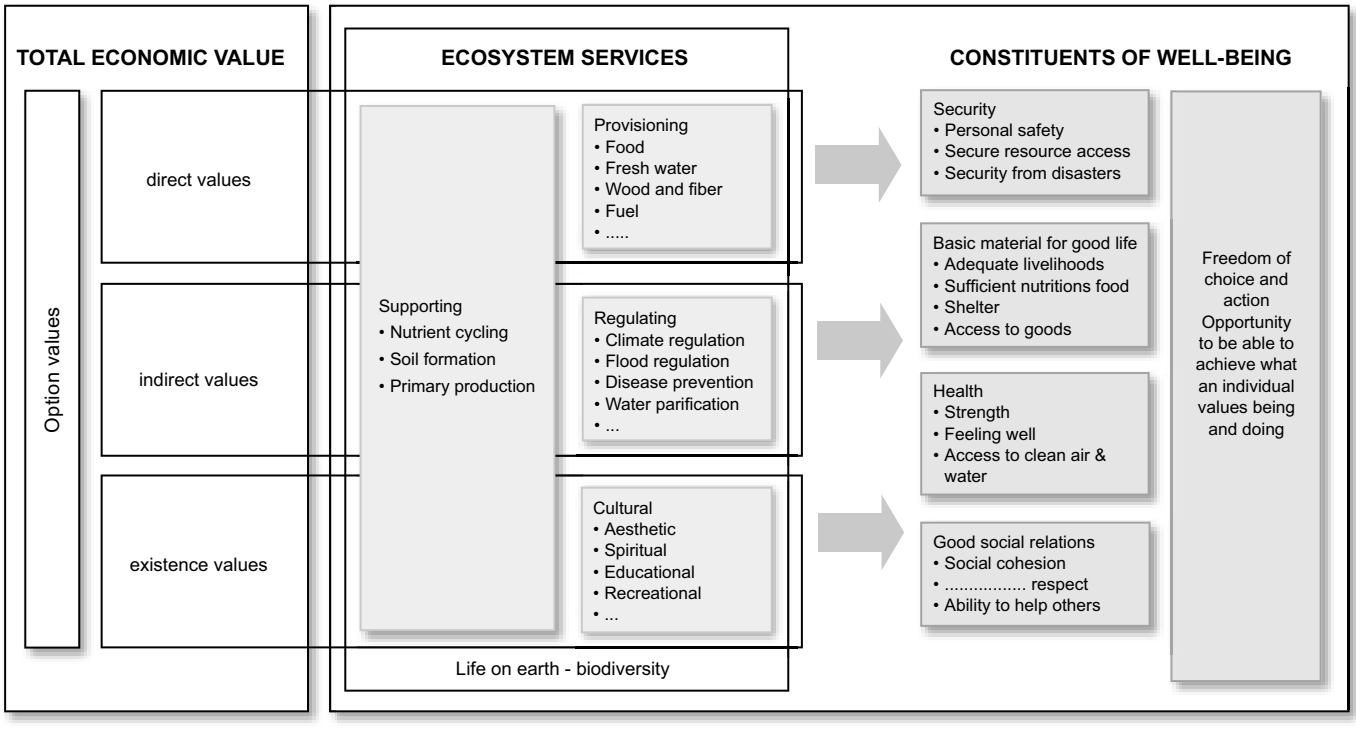


Figure 12: Total Economic Value related to the MA framework (Source: Emerton, 2006)



Now, a wide range of valuation techniques and methods exist and their application is becoming more widespread - although yet to be institutionalised in most conservation and development planning and appraisal processes. These valuation techniques and methods rely on a human-centred approach, so that values are determined by people's preferences. (See Volume 3 for more details.)

Not surprisingly, natural resources make important contributions to the national economies of many Asian countries.

Provisioning Services:

- Annual exports from fishery products from south, southeastern countries and China total 13,411 million USD, with as many as 27 million fishermen engaged in fisheries (WRI, 2002).
- The annual export of marine aquarium fish from Southeast Asia alone is estimated to be between 10-30 million fish with a retail value of up to 750 million USD (Bruckner, 2006).
- The total net value of local fisheries in Ream National Park, Viet Nam is 515,525 USD per annum (Emerton et al., 2002).
- Timber revenues from the forests of Sekong Province earn Lao PDR a total of 605,000 USD per annum (Emerton, 2005).
- The average value of non timber forest extraction is estimated at PPP[10] 2,455 USD per housefold/ year and PPP 40.7 USD/ household/ year in Malaysia (Svarrer & Smith Olsen, 2005).
- The value of medicinal plants extracted from the Sinharaja World Heritage Site, Sri Lanka is estimated to be 22 USD per household (net) and 1.4 USD per hectare for nine months (Batagoda et al., 2000).
- The value of drinking water provided by Bhoj Wetland, India is nearly 2,400,000 USD (Verma, 2001).
- In Maldives marine and coastal tourism contributes almost a fifth of GDP[11] and a third of government revenues (Emerton, 2006).

Regulating Services:

- In India, forests provide water regulation and flood control valued at 72 USD billion per year (http://www.fao.org/docrep/t4450e/T4450E0m.htm).
- Muthurajawala Marsh, Sri Lanka provides flood protection and water treatment services valued at 2,500 USD per hectare to surrounding urban communities (Emerton, 2005).
- The value of fisheries protection by undisturbed forests in Bacuit Bay in the Philippines (calculated through loss and extent of soil erosion) was estimated to be 264 USD per hectare per year (Hodgson & Dixon, 1988).
- The economic value of Asia's wetlands is estimated to be 1.8 billion USD per annum (WWF, 2004).

Supporting Services:

- The value of carbon sequestration in tropical forests ranges from 650 - 3,500 USD per hectare in terms of NPV[12] (IIED, 2003).
- The value of biodiversity and endangered species in terms of value per hectare in Himachal Pradesh, India is 500.6 USD (Verma, 2000).
- The total value of standing stock (an indirect measure of primary production) of the forests in Himachal Pradesh, India is estimated at about 10,200.5 million USD (Verma, 2000).

Cultural Services:

- The total recreational value of Ho Mung Islands, a marine protected area in Viet Nam is estimated to be 7.7 million USD per annum (Khanh Nam & Tran Vo Hung Son, 2001).

Table 2: Economic value of Muthurajawela marsh, Sri Lanka (Source: Emerton and Kekulananda, 2002)

Economic benefit	*Value (USD/year)*	*Value (USD/ha/year)*
Flood attenuation	5,394,556	1,758
Industrial wastewater treatment	1,803,444	588
Agricultural production	336,556	110
Support to downstream fisheries	222,222	72
Firewood	88,444	29
Fishing	69,556	23
Leisure and recreation	48,000	16
Freshwater supplies for local populations	42,000	14
Total	8,072,111	2,631

[10] PPP is Purchasing Power Parity: the estimate of the amount of adjustment needed on the exchange rate between countries in order for the exchange to be equivalent to each currency's purchasing power.

[11] GDP is Gross Domestic Product; the total market value of all goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports.

[12] NPV is Net Present Value: the sum of discounted net benefits (i.e. benefits minus costs), which shows whether a project generates more benefits than it incurs costs.

The difference between natural hazards and natural disasters

The difference between natural hazards and natural disasters must be made clear in this section. A natural hazard is a naturally occurring phenomenon that is harmful to humans and has the potential to cause damage. Natural hazards are, therefore, events such as drought, wildfires, cyclones, typhoons, earthquakes and tsunamis. Natural hazards cannot be prevented, but they can be expected (http://www.unesco.org/science/disaster/about_disaster.shtml.).

A natural disaster occurs when a natural hazard causes a large number of deaths, displacements and damage to human well-being, as well as to ecosystem well-being. Applying various safeguards can prevent or reduce the effect of natural disasters – i.e., natural disasters can be reduced or prevented. *This is a basic difference between a natural hazard and natural disaster.*

It should also be noted that natural hazards do not automatically give rise to natural disasters. Many human actions - such as bad land use planning, deforestation, human development in hazardous areas - worsen the impacts of natural hazards and cause natural disasters.

Risk and vulnerability

Risk is the potential of a natural hazard to cause damage. But risk is not equal among communities and people. Some people are more at risk from a natural hazard than others. The impacts are different for different people because some people are better able to cope with a natural hazard than others. *The difference in the capability to cope is vulnerability.*

Various elements such as social, environmental, economical and infrastructural factors affect the capability of communities to cope with disasters (Kasperson & Kasperson, 2001). For example, consider a house that has been built on a slope. The risk for the damage is from a landslide. The people whose house is built on this slope are, therefore, physically vulnerable to landslides. The poor and the marginalised are more vulnerable to natural hazards as they lack basic necessities of life – they are socially vulnerable. Communities who are resistant to change and are negative in their approach to life are attitudinally vulnerable. People living near degraded ecosystems and lack basic ecosystem services are environmentally vulnerable.

Figure 13a: The different elements of vulnerability

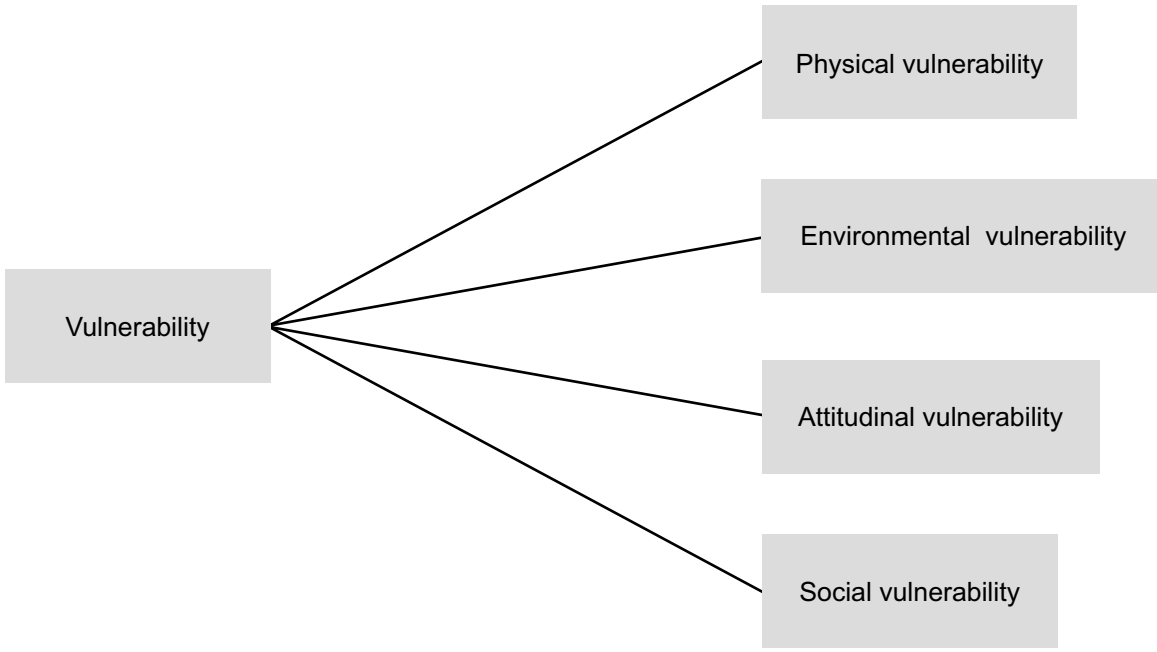
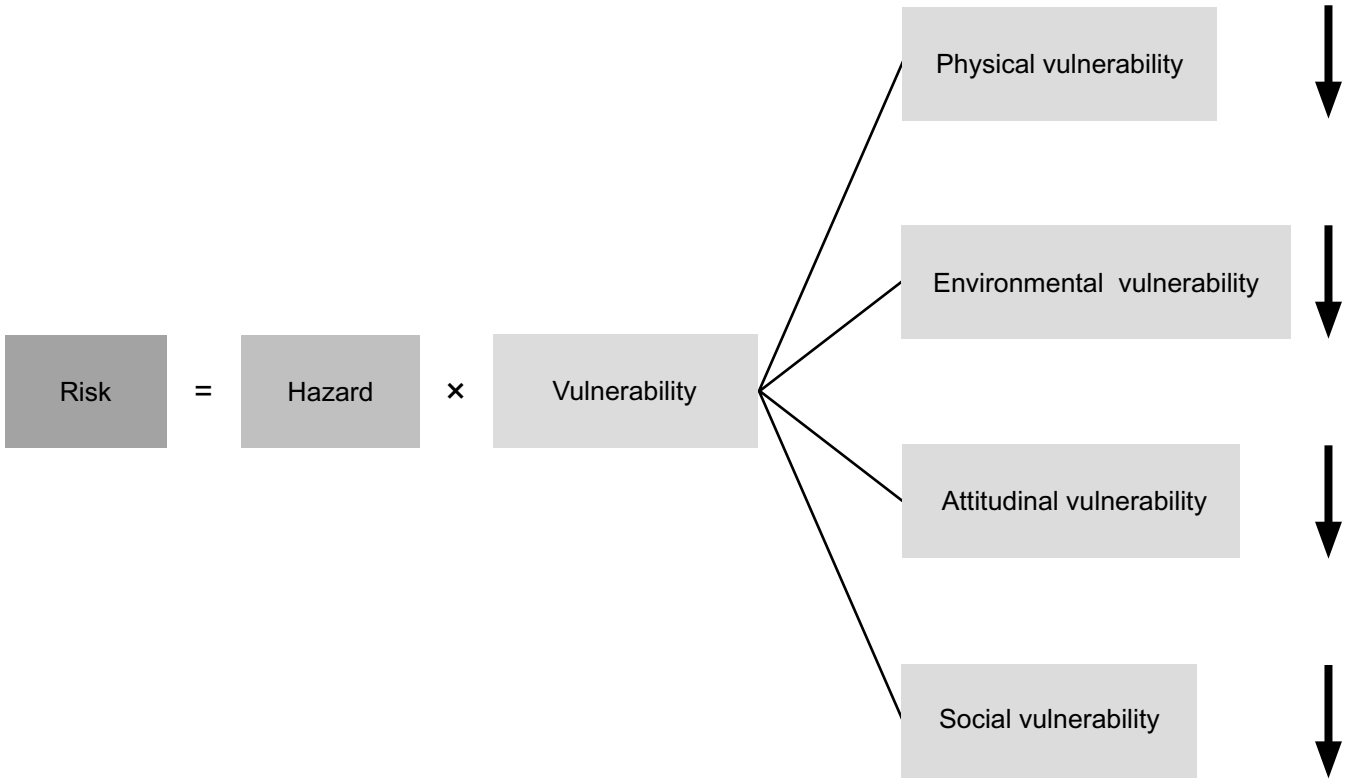


Figure 13b: The relationship between risk, hazard and vulnerability

The force of a hazard at a given time is constant - i.e., you can not change the hazard. Given that constant, in order to reduce risk, all components of vulnerability must be reduced.

Figure 13c: Risk, hazard and the different elements of vulnerability



Preparing for natural disasters is all about reducing vulnerability.

Natural hazards

Natural hazards can be a) geological, b) hydrological and c) climatic. Because of various factors, some areas of the earth are more prone to certain kinds of hazards than others.

Geological hazards

Earthquakes:

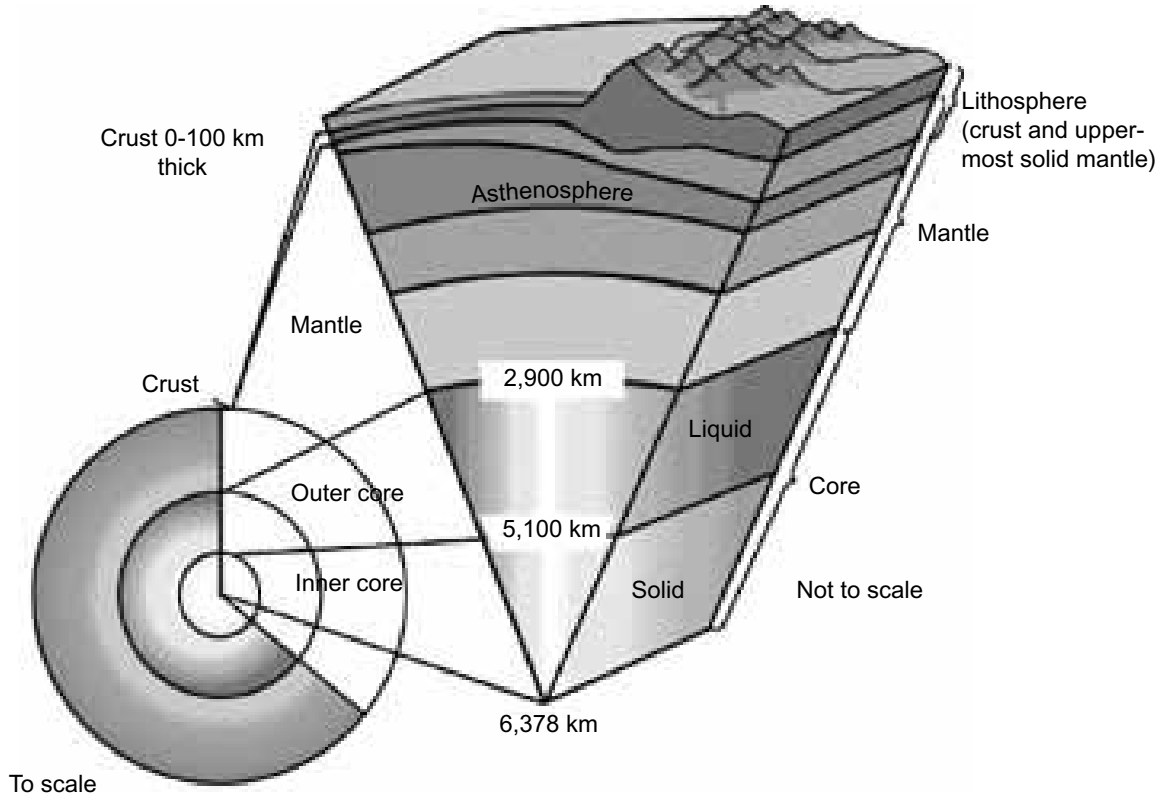
These hazards originate from geological[13] conditions. In order to understand some geological hazards, it is necessary to detail the theory of plate tectonics.

The structure of the earth is rather like that of a par-boiled egg. Outermost is the earth's *crust*, which is hard and brittle. Under that is a hotter and denser, semi-solid rock called the *mantle*. Right at the centre of the earth is the *solid core* (made up of inner and outer parts). Each layer has different chemical and mechanical properties.

The uppermost part of the mantle is harder than the rest, and with the crust, forms the *lithosphere*[14], which functions like a shell. Like a shell, this lithosphere is brittle and can fracture.

Underneath the lithosphere is the part of the mantle that is dense and semi-solid, and the inner *asthenosphere*[15]. Although the asthenosphere is a semi-solid, it can compress, stretch and flow without fracturing, in the same way that cream flows (http://csmres.jmu.edu/geollab/fichter/PlateTect/erthstru.html).

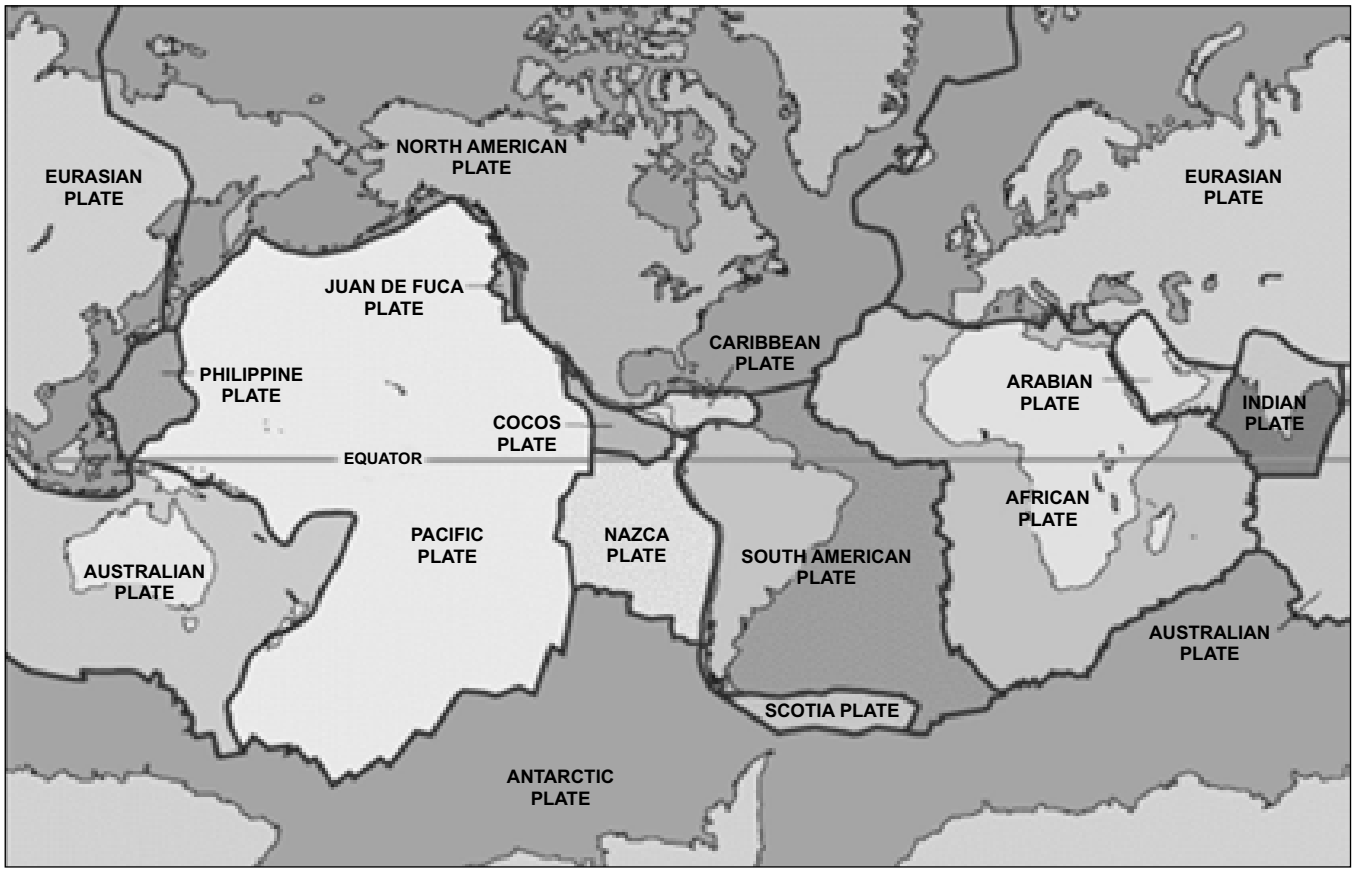
Figure 14: Cutaway views showing the internal structure of the earth
(Source: http://pubs.usgs.gov/gip/dynamic/inside.html)



[13] Geology is the science of the solid matter that makes up the earth.
[14] '*Lithos'* is stone in Greek.
[15] '*Sthenos'* means without strength in Greek.

Tectonic theory explains that the lithosphere is made of separate tectonic plates, which float on the more fluid asthenosphere. The surface of the Earth consists of 14 major plates and 38 minor ones, totalling 52 plates.

Figure 15: Tectonic plates of the world (Source: http://geology.about.com/library/bl/maps/blcrustalplates.htm)



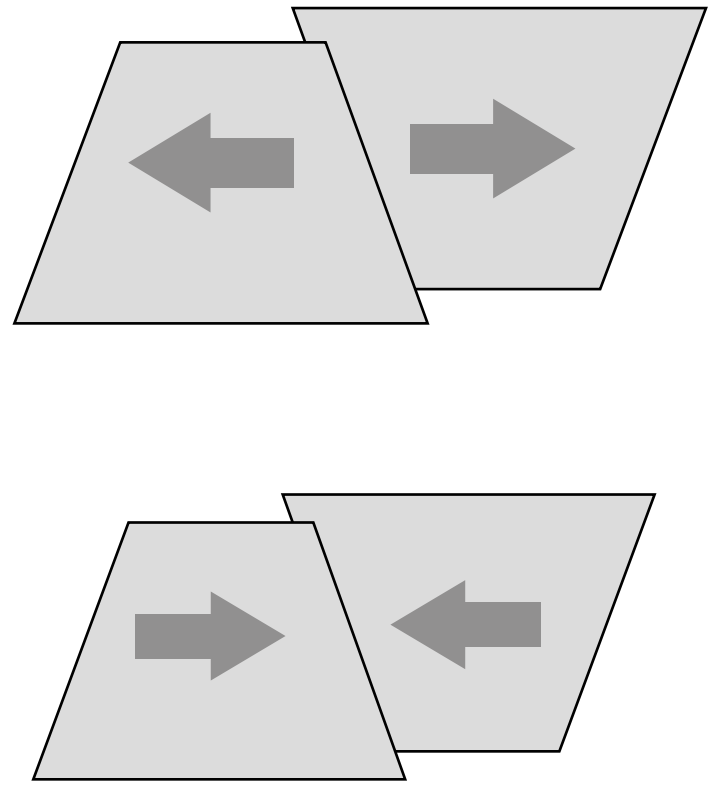
Lithospheric plates are about 100km thick and are made up of both oceanic and continental areas.

The heat from the core of the earth moves outward constantly towards the outer mantle (the asthenosphere), which, already being hot and liquid, moves, because of this heat, towards the surface. The points at which this heat surfaces are at ocean ridges. The hotter liquid rises to the surface and spreads sideways, taking the lithospheric plates (both oceans and continents) with it as if on a slow conveyor belt. These movements – called tectonic movements – happen because the lithosphere is solid and the asthenosphere is not. Plates move, on average, about 10-40mm per year.

The lithospheric plates form three types of boundaries.

1) *Divergent or extensional* boundaries – where plates move away from each other (as seen in the East African Great Rift Valley);
2) *Convergent of compressiona*l boundaries – where plates move towards each other (as seen in the Sumatra-Andaman earthquake); or
3) *Strike slip or transform boundaries* – where plates slide past each other (as seen in the San Andreas fault in California). (See Figure on opposite page.)

Figure 16: Types of boundaries: top: *Extensional*; middle: *Compressional*; and bottom: *Transform* (Source: http://geology.about.com/library/bl/blnutshell_fault-type.htm)



When a lithospheric plate under the sea converges against another plate under the sea or on land, it sinks (is *subducted*) into the asthenosphere. These subduction zones are sea trenches. In contrast, when two lithospheric plates on land converge, they bang together to form huge mountain ranges. For example, when the Deccan (Indian) plate – consisting of the Indian subcontinent – crashed into the Eurasian plate, the great Himalayan range of mountains were formed.

When plates move at boundaries, there is friction and the earth shakes or becomes displaced – causing earthquakes.

The deepest earthquakes and the ones with the greatest magnitude take place at compressional boundaries, where they can go as deep as 700km and their magnitudes can be as high as 9 on the Richter[16] scale. Earthquakes at transform boundaries are usually less than 8.5 on the Richter scale and are shallow – about 25km deep. Earthquakes at extensional boundaries are the least powerful and are usually less than an eight on the Richter scale[17].

The epicentre of an earthquake is the point on the Earth's surface that is directly above the point where an earthquake starts.

The 2004 Indian Ocean earthquake (also known as the Sumatra-Andaman earthquake) occurred in the ocean when the India plate slipped about 15m under the Burma plate, causing an earthquake whose epicentre was north of Simeulue Island, off the western coast of northern Sumatra. The magnitude of the earthquake was measured to be 9.3 on the Richter scale and is the second largest earth quake ever recorded. (Since 1900, the only other earthquake recorded with a greater magnitude was the 1960 Great Chilean Earthquake with a magnitude 9.5.) The length of the entire earthquake site (fault zone) was about 1,200km, and the sea floor displaced by an average slip of 11m with a maximum of 20m.

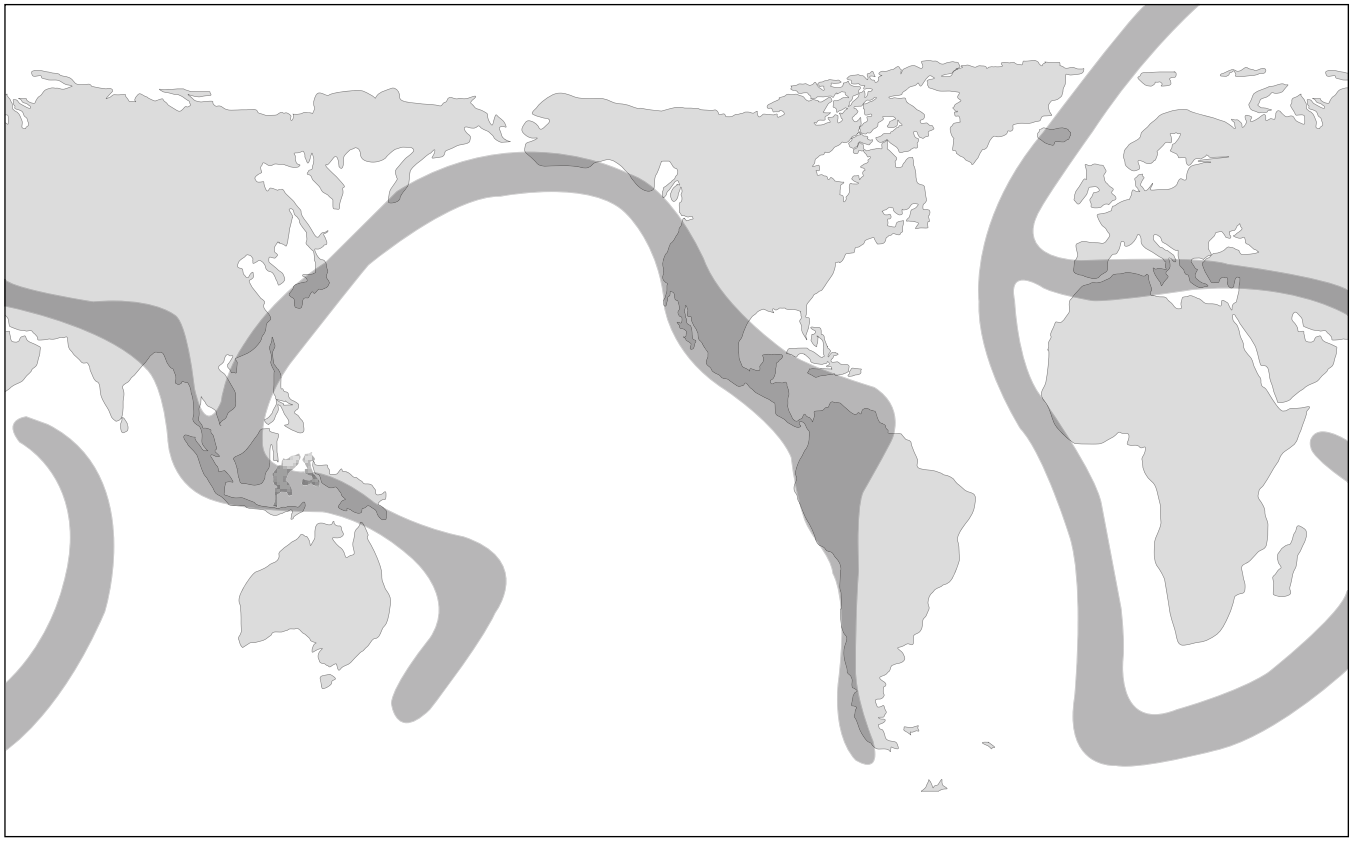
The 2004 Indian Ocean earthquake has also the longest duration of faulting ever observed, lasting between 8.3 to 10 minutes, and it was large enough that it caused the entire planet to vibrate over a centimetre. It also triggered earthquakes in other locations as far away as Alaska (http://www.en.wikipedia.com).

[16] The Richter scale is a scale for measuring the magnitude of earthquakes. The scale is logarithmic so that a recording of 7, for example, indicates a 'shaking' of the ground 10 times as large as a recording of 6.

[17] Tsunamis are created by relatively shallow earthquakes of high magnitude.

It should be noted clearly that earthquakes do not happen randomly in the world, but are usually concentrated near tectonic plate boundaries. Therefore, some areas are more earthquake prone than others. For example, California in the US is an earthquake prone area, while Florida is not.

Figure 17: Earthquake prone areas in the world
(The dark grey swathes depict areas where earthquakes are most likely to occur.)
(Source: www.pvsd.ca/.../planning/thecrust/thecrust.htm)



- An earthquake measuring 3-5 on the Richter scale is considered minor to light; 5-7 is moderate to strong; 7-8 is major and 8 or more is great.
- It is estimated that there are 500,000 detectable earthquakes every year. Of these, 100,000 can be felt and 100 cause damage.
- The U.S. Geological Survey locates 12,000 to 14,000 earthquakes each year; that is, about 35 per day.
- Southern California has an average of about 10,000 earthquakes per year. The majority of these quakes are minor.
- About 20 major earthquakes occur every year (http://science.nationalgeographic.com/science/earth/natural-disasters/earthquake-profile.html).

Volcanoes:

Volcanoes are openings in the earth's surface through which liquid material from the earth's core (*magma*), gases, and other substances burst open (*erupt*).

Volcanoes are found commonly at tectonic plate boundaries, but there are also volcanic hot spots (such as the Hawaiian Islands), which are other places in the earth's crust where magma erupts.

Some volcanoes erupt explosively, while others erupt slowly. Some volcanoes release toxic gases, hot rock and hot ash. Volcanoes can trigger other natural hazards such as earthquakes, landslides, tsunamis (in the case of undersea eruptions) and fires.

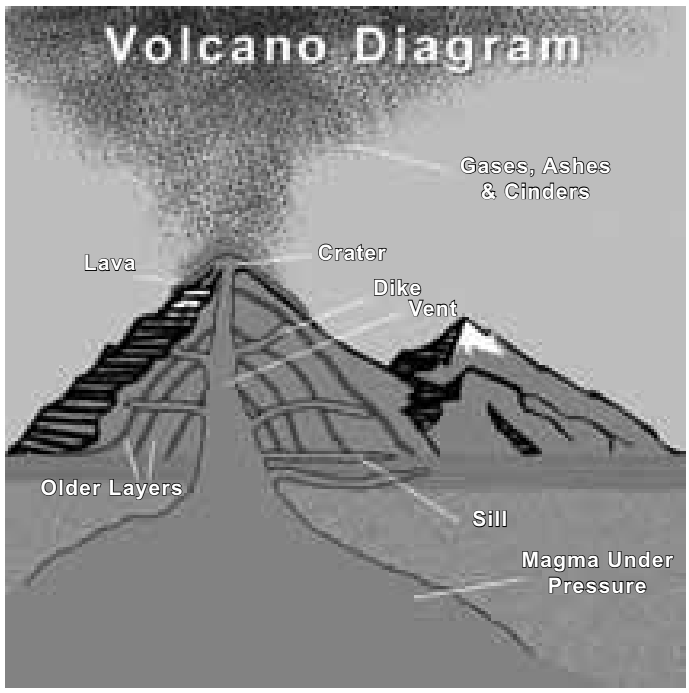
Because volcanoes are found at tectonic plate boundaries, earthquake prone areas and volcanic areas overlap. Elsewhere in the world volcanoes are found in the Pacific Rim (which outlines the Pacific Ocean), also called 'the Ring of Fire' because of its long history of volcanic eruptions. Many countries around this 'Ring of Fire' are at risk from volcanic eruptions. These include Japan, the Philippines, Indonesia, New Guinea, New Zealand, and many of the South Pacific Islands as well as Chile, Peru, Ecuador, Columbia (http://pubs.usgs.gov/gip/volc/text.html.).

There also are volcanoes in the Mediterranean and Middle East including Italy, Greece, Turkey, Iran, Saudi Arabia, Yemen and Pakistan. The Great Rift Valley in eastern Africa also has many volcanoes found in the countries of Ethiopia and Kenya.

It is estimated that there are at least 1,500 and as much as 3,000 active volcanoes in the world.

Volcanoes can occur at any time of year or day. Because volcanoes erupt over and over again, layers of lava erupt and harden resulting in the formation of a mountain – called a volcanic island if it is formed in the sea (http://pubs.usgs.gov/gip/volc/text.html).

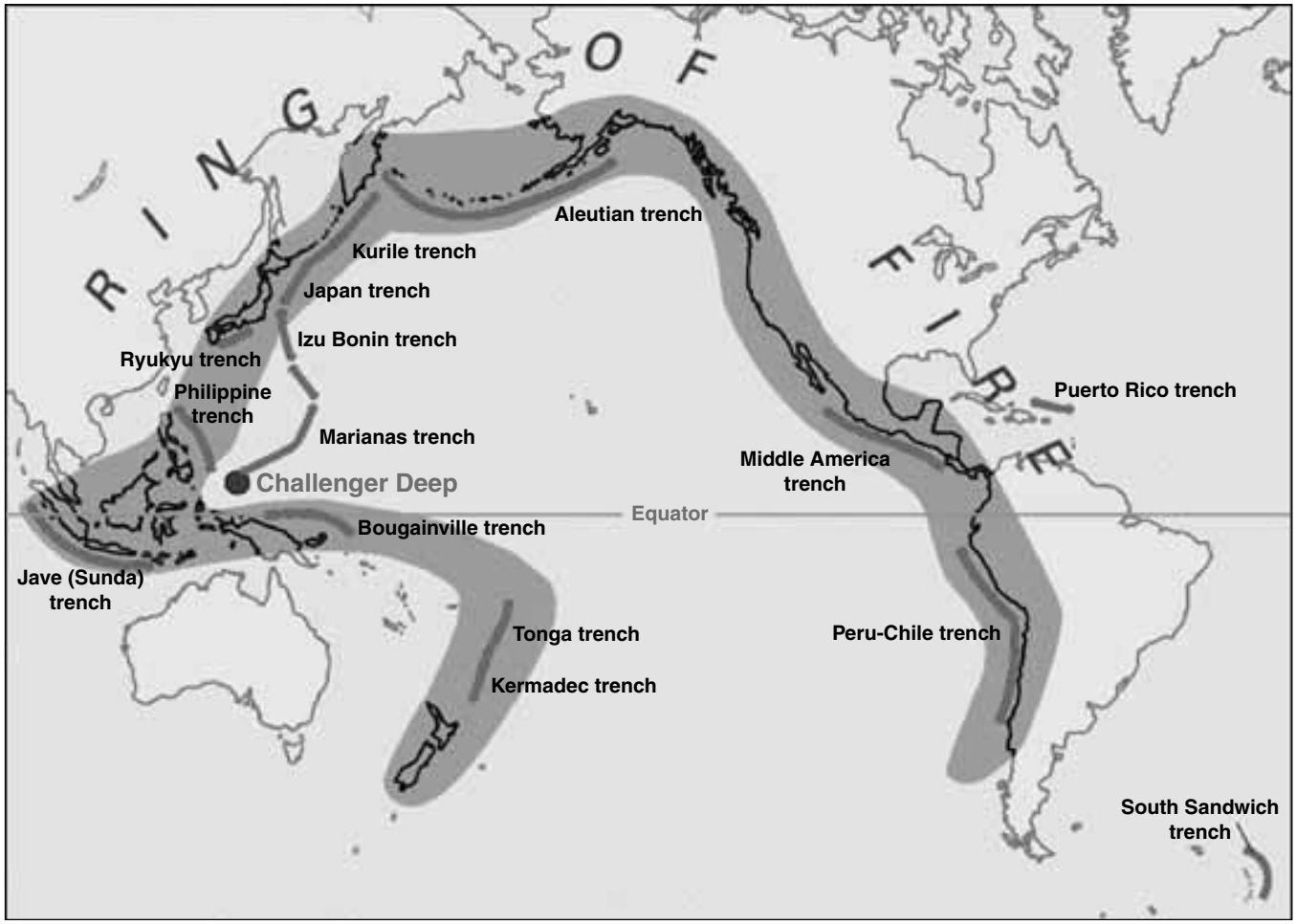
Figure 18: Cross section of a volcano
(Source: http://pubs.usgs.gov/gip/volc/text.html)



Mount Vesuvius is a volcano found near the city of Naples in Italy. Its eruption in AD 79 led to the destruction of the Roman cities of Pompeii and Herculaneum. It has erupted many times since then and is considered as one of the most dangerous volcanoes in the world because 3,000,000 people now live close to it (http://en.wikipedia.org/wiki/Mount_Vesuvius).

Krakatoa is a volcanic island in the Sunda Strait between Java and Sumatra in Indonesia. Throughout history, it has erupted repeatedly with disastrous consequences. The best known eruption was in 1883, which expelled more than 25km^3 rocks and ash and generated the loudest sound recorded in history. The sound was heard as far away as Australia and islands near Africa (http://en.wikipedia.org/wiki/Krakatoa).

Figure 19: Volcano prone areas in the world - The Pacific 'Ring of Fire'
(The darker grey swathes depict areas where volcanoes are common.)
(Source: http://upload.wikimedia.org/wikipedia/commons/thumb/0/09/
Pacific_Ring_of_Fire.png/800px-Pacific_Ring_of_Fire.png)



Landslides:

Landslides are mass movements of rock, debris and soil down a slope of land. In nature, landslides can be caused by many events. Any time tectonic plates move, the soil that covers them moves with it. When earthquakes occur in areas with steep slopes, this soil can slip causing landslides. Volcanic eruptions, melting glaciers, excessive snow and rainfall and erosion from rivers can also cause landslides.

The structure of soil, the amount of rain, the water table and the steepness of the slope are all factors that influence landslides. The large amount of soil loosened and released by a land slide can, on occasion, be carried down as debris flows that have buried whole villages.

An unusually strong storm in December 1999 poured down 911mm of rain over just a few days in the Vargas state of Venezuela, triggering soil instability and flow of debris (http://en.wikipedia.org/wiki/1999_Vargas_mudslide).

Hydrological Hazards

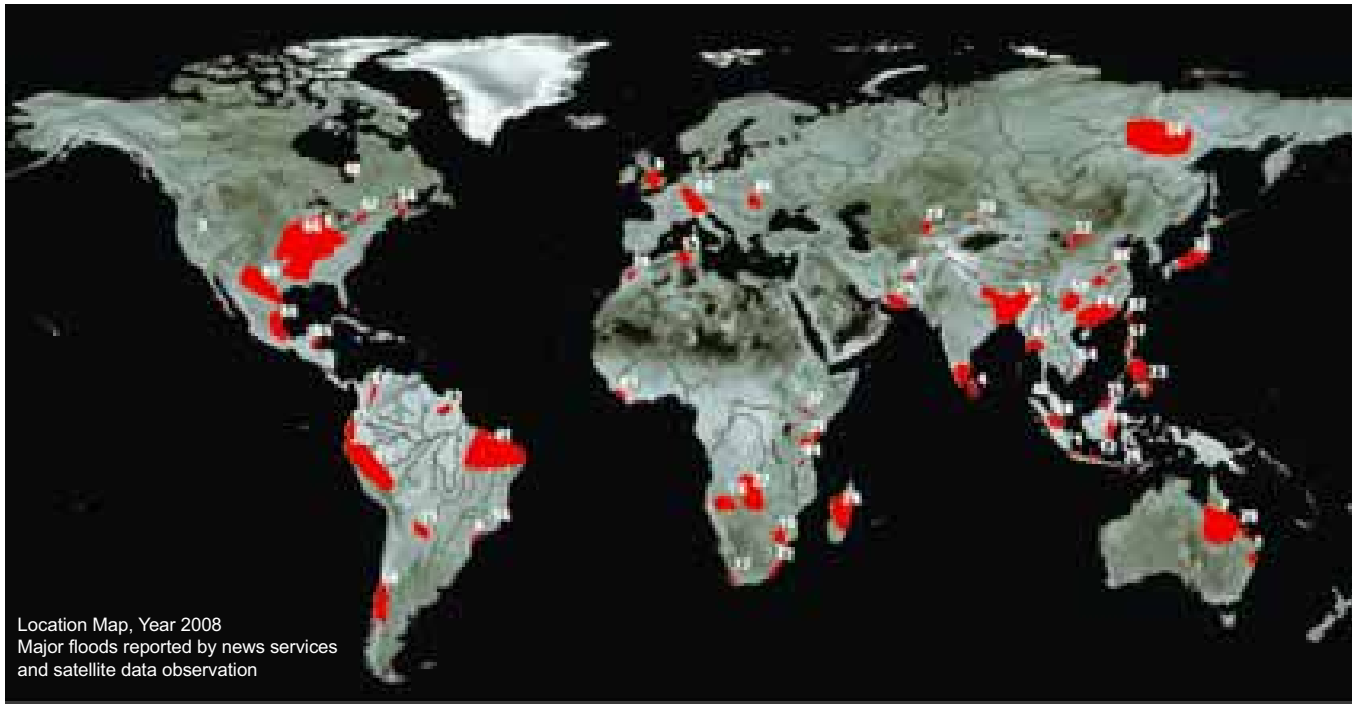
Hydrological hazards originate from and relate to the activities of water. There are many types of hydrological hazards.

Floods:

Floods occur when usually dry areas on banks of rivers, streams, lakes, or coastal areas become submerged with water. Floods can be set off by severe thunderstorms, tornadoes, tropical cyclones, monsoons or melting snow. In coastal areas, storm surges caused by tropical cyclones, tsunamis, or rivers swollen by extremely high tides can cause flooding. Floods occur in both dry and wet environments and in mountains and lowlands. In dry areas, especially those situated at the base of mountain ranges, flash flooding[18] can occur. This is an extremely dangerous type of hazard resulting from intense rainfall in a short period of time that moves, at high speed, downhill.

In temperate regions around the world, spring floods are common and occur because of melting snow. In tropical regions – particularly in Asia - monsoons bring heavy rains that cause recurrent floods.

Figure 20: Major floods reported in 2008 (Source: Dartmouth Flood Observatory)



[18] Flash floods can occur after a period of drought when heavy rain falls onto very dry, hard ground that the water cannot penetrate.

The land area of Bangladesh consists of a vast floodplain formed by a network of rivers connected to three major rivers that supply the Delta. There is an entirely separate area, supplied by the Karnaphuli river, which is not prone to severe flooding, in the south east corner of the country. The combined flood plains of the Ganges, Brahmaputra and Meghna rivers provide much of the very fertile and productive agricultural land. These rivers serve as the main source of water for cultivation, for commercial transportation and for the provision of fish. More than 60% the net arable land is cultivated in the rainy season and nearly 40% of the land is cultivated during the dry winter months. The flat terrain makes it impractical to construct gravity-fed irrigation canal systems. The plentiful groundwater, annually re-charged by the monsoons, is extracted everywhere for irrigating fields.

These rivers of Bangladesh shape both its terrain and the livelihoods of its people. Bangladesh has a land area of only 144,000km^2 (http://www.en.wikipedia.com) but the Brahmaputra (Jamuna) and Ganges which originate far away from the borders of Bangladesh on either side of the Himalayan range reach bring an enormous combined runoff which has to pass through Bangladesh to reach the sea. The Meghna, although it has a relatively much smaller basin, drains areas such as the Megalaya hills that experience some of the highest rainfall in the world.

Before 1776, the Brahmaputra and Ganges flowed separately into the Bay of Bengal. A major earthquake in 1776 shifted the course of the Brahmaputra towards a minor river called Jamuna, which connected it to the Ganges. Jamuna has now taken over as the major channel of the Brahmaputra, meeting the Ganges at Aricha to the west of the capital city Dhaka. The combined flows of the Jamuna and Ganges are conveyed by the Padma river. The Padma then meets the Meghna and together they flow into the Bay of Bengal as the Lower Meghna.

The Jamuna (as the Brahmaputra is known in Bangladesh) has many tributaries (such as the Teesta and Atrai) that flow in from the west and several distributaries (or spill channels) that carry water eastwards and south. The downstream reaches of the Ganges which also has many tributaries feed it from the north on its left bank, has many right bank distributaries carrying water and flood overflows southwards, into the southwest region of Bangladesh - which is a network of river channels and tidal creeks of all dimension intimately connected to the tides (with a range of approximately 3m) of the Bay of Bengal. Many of these distributaries reach the Bay of Bengal though very large estuaries that were, many years ago, the successive outlets of the Ganges.

The flood plain levels are determined by the settling of sediments carried by the overbank flow of flood water. It is usual for at least a part of the flood plains to be flooded every year. In the coastal regions such as the Sundarban mangrove forest, the land levels are such that they are flooded by the highest tides (about 2m above sea level). The deposition of silt makes the delta grow outwards, as well as raising the flooded areas by very small amounts every year. However, consolidation of land under its own weight over the centuries partly counteracts the effect of siltation.

The overall land profile of Bangladesh rises gradually from about 2m above sea level in the south to only about 12m in the north of the country. In the north east however, the land levels are very low – even below 2m in some areas. This results in these lands being flooded for several months after the flood has passed. The water levels in the major rivers

of Bangladesh might fluctuate by 9m from the driest season to the highest flood. The fact that the three major rivers meet means that they can affect each others flood levels. The worst possible floods occur when the flood peaks of the Ganges and Brahmaputra coincide.

The combination of the three major, easily flooded rivers, the low lying nature of the terrain, makes Bangladesh one of the most flood prone countries in the world (www.country-studies.com/bangladesh/riversystems.html). In 1998, Bangladesh was hit by the 'worst flood of the century' which covered approximately 100,000km^2 (one third the size of Great Britain and 66% of the land area) for two and a half months from July to September. At the height of the floods, 52 out of 64 administrative districts were flooded. Heavy rainfall in the catchment area of three major rivers (Ganges, Brahmaputra, Meghna) combined with above normal melting of ice in the Himalayas created this enormous flood (Dartmouth Flood Observatory, 2008).

(Source: Ranjit Galappatti, personal communication.
Map: http://upload.wikimedia.org/wikipedia/commons/e/ef/Bangladesh_LOC_1996_map.jpg)

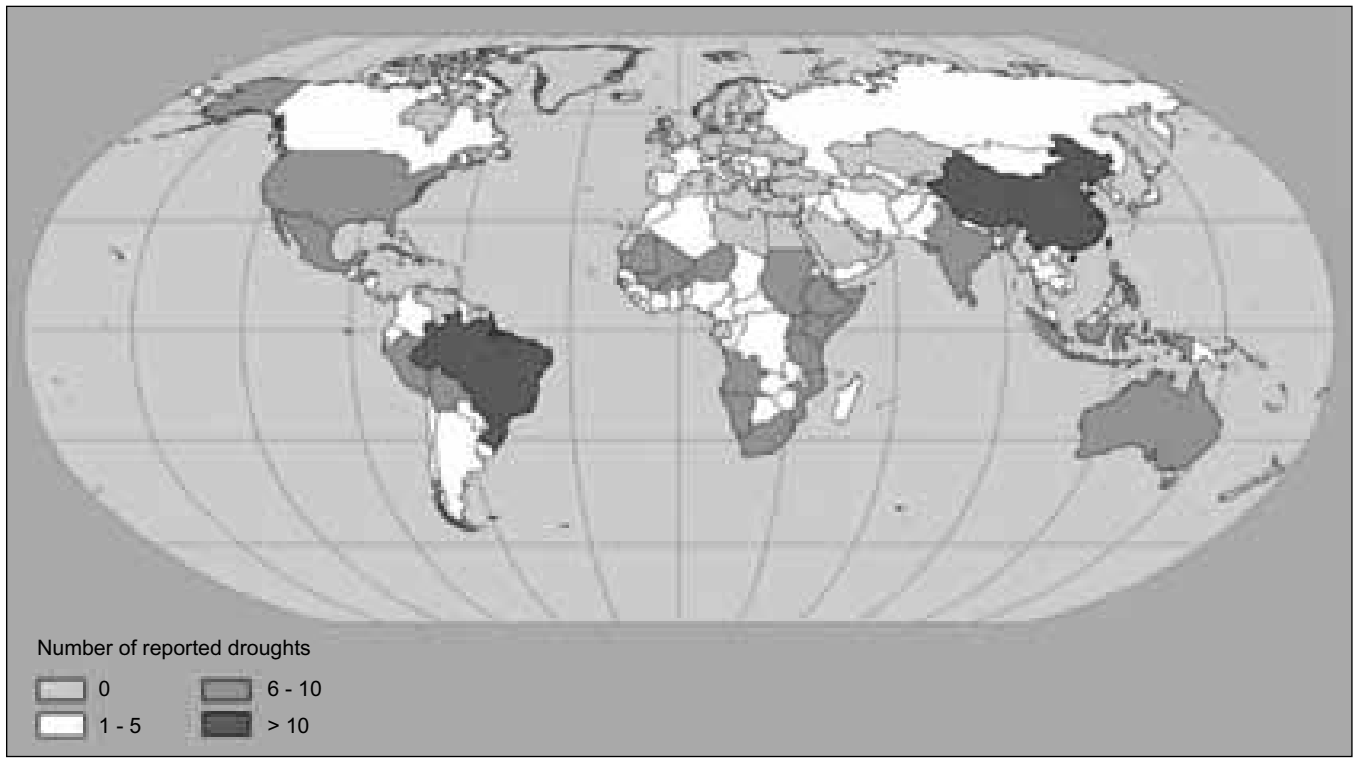
Drought:

If floods are caused by the excess of water, then drought is caused by the opposite: the lack of water. A drought is an extended period during which there is no soil water. When a drought occurs, there is not enough water for human needs, agriculture and ecosystems.

Droughts must not be confused with dry seasons. For example, in Sri Lanka, the northeastern, northwestern and southeastern parts of the island are fed only by a single monsoon – the north east monsoon which extends from November to February each year. For the rest of the year, there is an annual dry season from March to August. When the north east monsoons are delayed, then the dry season can become extended, causing a drought.

In Australia, in late 2006, rain that falls between late winter and mid spring failed. The average rainfall in South Australia that resulted was the lowest since 1900, causing a drought (http://en.wikipedia.org/wiki/Drought_in_Australia).

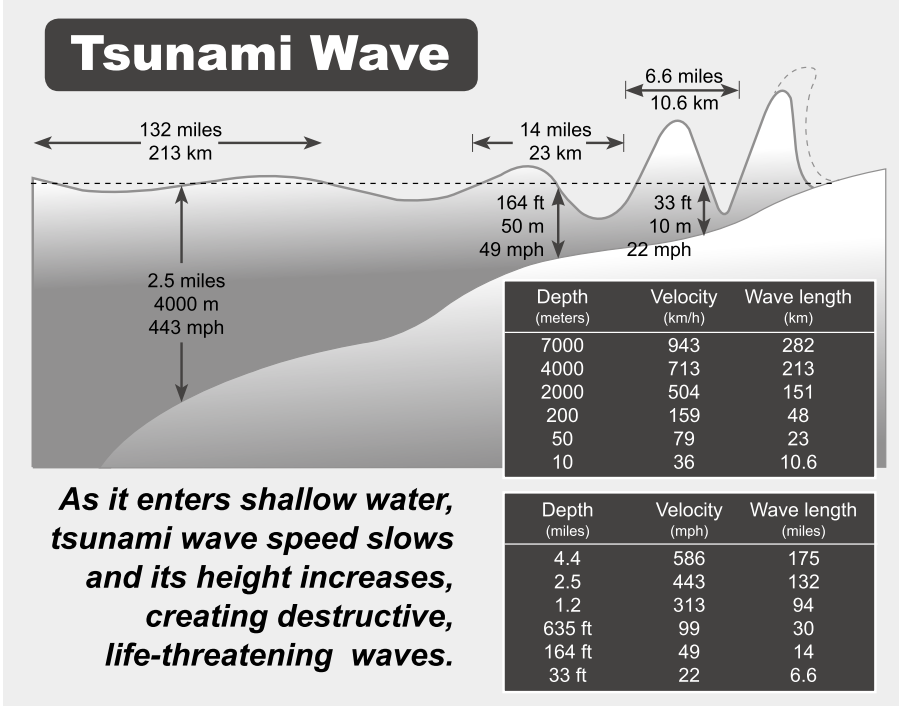
Figure 21: Number of drought disasters reported by country: 1970-2006
(Source: Centre for epidemiology of disasters, 2007)



Tsunamis[19] :

A tsunami is a series of waves that is generated when a large body of water is displaced. The most common natural cause of a tsunami is an earthquake, followed by volcanic eruptions. When the sea floor changes as a result of an earthquake (mostly commonly through subduction at plate boundaries), water is displaced vertically. This water then radiates like ripples in a pond.

Figure 22: Diagram of a tsunami waves
(Source: http://ioc3.unesco.org/itic/files/tsu_wave_characteristics.pdf)



Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

Depth (miles)	Velocity (mph)	Wave length (miles)
4.4	586	175
2.5	443	132
1.2	313	94
635 ft	99	30
164 ft	49	14
33 ft	22	6.6

There is difference of an order of magnitude between the properties of tsunami waves and wind waves normally observed in the sea. Waves are characterised by their *height,* their *period* (the average time taken between two wave crests passing a given point) and the *wave length* (the distance between two crests). Normal ocean waves have heights in the range of a few a centimetres in a very sheltered area, to even ten metres at the worst of a severe storm. The wave periods observed are a few seconds in choppy seas to swell waves of periods up to 20 seconds or more. Tsunami waves, on the other hand, have periods of the order of 20 minutes (more than 1,000 seconds) and wave lengths exceeding 200km in deep water.

Deep water waves (where the wave length is much larger that the water depth) propagate at speeds proportional to the square root of the wavelength. In shallow water where the water depths are much smaller than the wavelength, the speed of propagation of waves is proportional to the square root of the water depth. Paradoxically, tsunami wavelengths are so large that they behave like shallow water waves even in the deepest ocean. A tsunami wave - which travels as fast as a jet aircraft over the deep ocean - will slow down as soon as it crosses the continental shelf and really come down to ordinary wave speeds as it approaches the shore. As the wave slows down it shortens and steepens. The wave height that was less than a metre in deepwater could be more than ten metres high as it comes ashore. This not an unfamiliar phenomenon – the waves we witness on the beach (which do not appear to be very high when they are out at sea) – also slow down and grow in height before they come ashore.

- Japan has the most recorded tsunamis of all the countries of the world. The number of tsunamis totals 195 over a 1,313 year period, averaging one tsunami every 6.7 years, the highest rate in the world. (http://en.wikipedia.org/wiki/Historic_tsunami)
- The Indian Ocean tsunami of December 2004 displaced a trillion tons of water (Kerr, 2005).

[19] The word tsunami comes from the Japanese meaning harbour (‘*tsu*’) and wave (‘*nami*’). Fishermen coming into the harbour after tsunami found the harbour wrecked but had not observed any disturbance in the open sea.

Climatic hazards

Climatic hazards are those hazards that are associated with the climate and weather.

Hurricanes/Tropical Cyclones/Typhoons:

The name of this natural hazard depends on where it occurs: it is called a *typhoon* in the western North Pacific and South China Sea; a *hurricane* in the Atlantic, Caribbean, Gulf of Mexico, and in the eastern North and central Pacific Ocean; and a *tropical cyclone* in the Indian Ocean and South Pacific region. In this manual, the term tropical cyclone will be used.

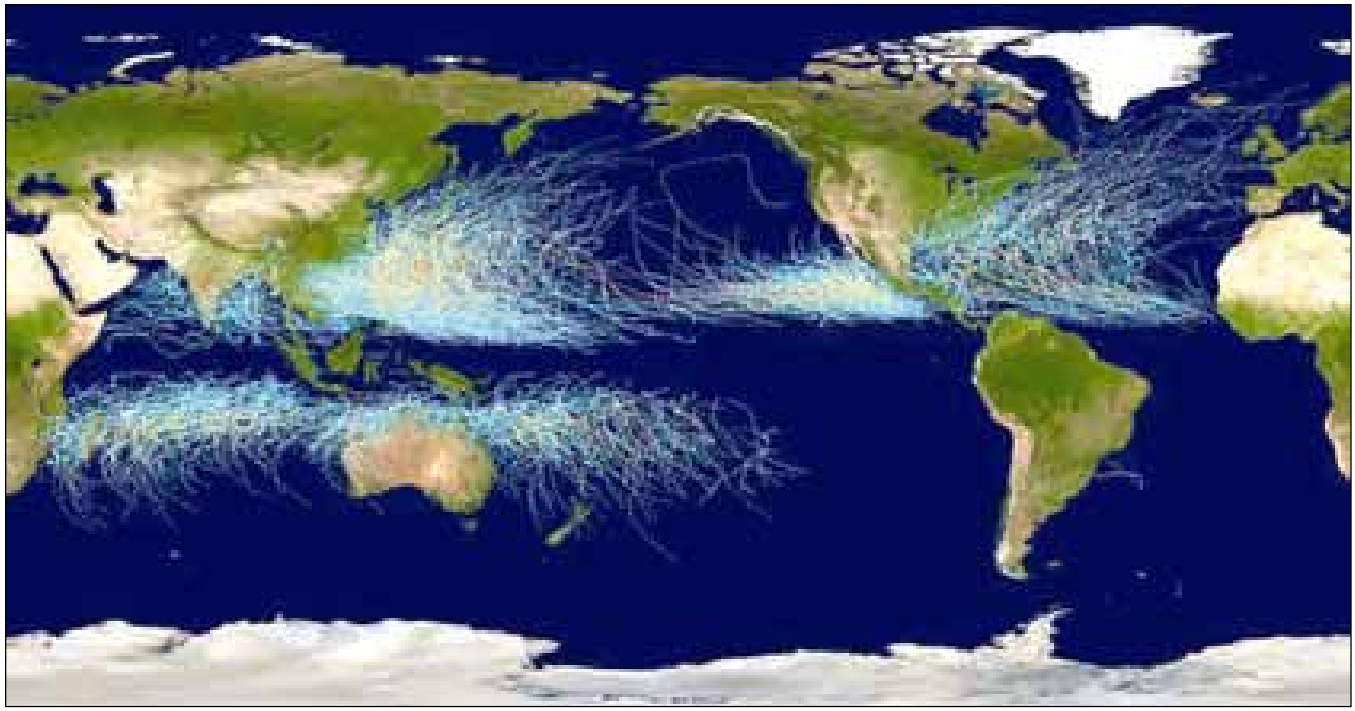
Tropical cyclones are huge, rotating masses of wind and thunderstorms up to hundreds of kilometres across, which form around areas of very low atmospheric pressure over warm tropical waters. Winds can reach speeds of 200km per hour or more. Tropical cyclones, therefore, produce not only heavy, lashing rain but also gale-force winds. The combination of wind-driven waves and the low-pressure of a tropical cyclone can produce a coastal storm surge (a raising of the sea level) which, when approaching the shore, can flood coastal areas and wash away everything in its path.

As the cyclone moves over land, it loses energy, so coastal areas are most affected by tropical cyclones.

About 80 tropical cyclones form every year (http://www.aoml.noaa.gov/hrd/tcfaq/C5c.html.).

Like earthquakes and volcanoes, tropical cyclones are more common in some areas of the world than others. They are found in a belt between 10-30° latitude from the equator.

Figure 23: Distribution of tropical cyclones
(Source: http://upload.wikimedia.org/wikipedia/commons/2/23/Global_tropical_cyclone_tracks-edit2.jpg)



Typhoon Tip is the largest and most intense tropical cyclone on record. It developed near the Pacific island of Pohnpei in 1979. After passing Guam, it reached peak winds of 305km/hr and a worldwide record low pressure of 870mbar and it was the largest tropical cyclone on record with a diameter of 2,220km (http://en.wikipedia.org/wiki/Typhoon_Tip).

Other natural hazards

*Wildfire*s:

Wildfires (also known as bushfires) are uncontrolled fires in forests, grasslands and scrublands. In areas where wildfires are common, the climate is moist enough to let vegetation grow effectively, but there is a long, dry, hot spell during which vegetation becomes dry enough to burn. Volcanic eruptions, lightning and changes in climatic conditions can set off wildfires.

Forest fires are natural parts of ecosystems in many forest types. For example, in coniferous forests they are a frequent and expected event and both flora and fauna are adapted to cope with fire.

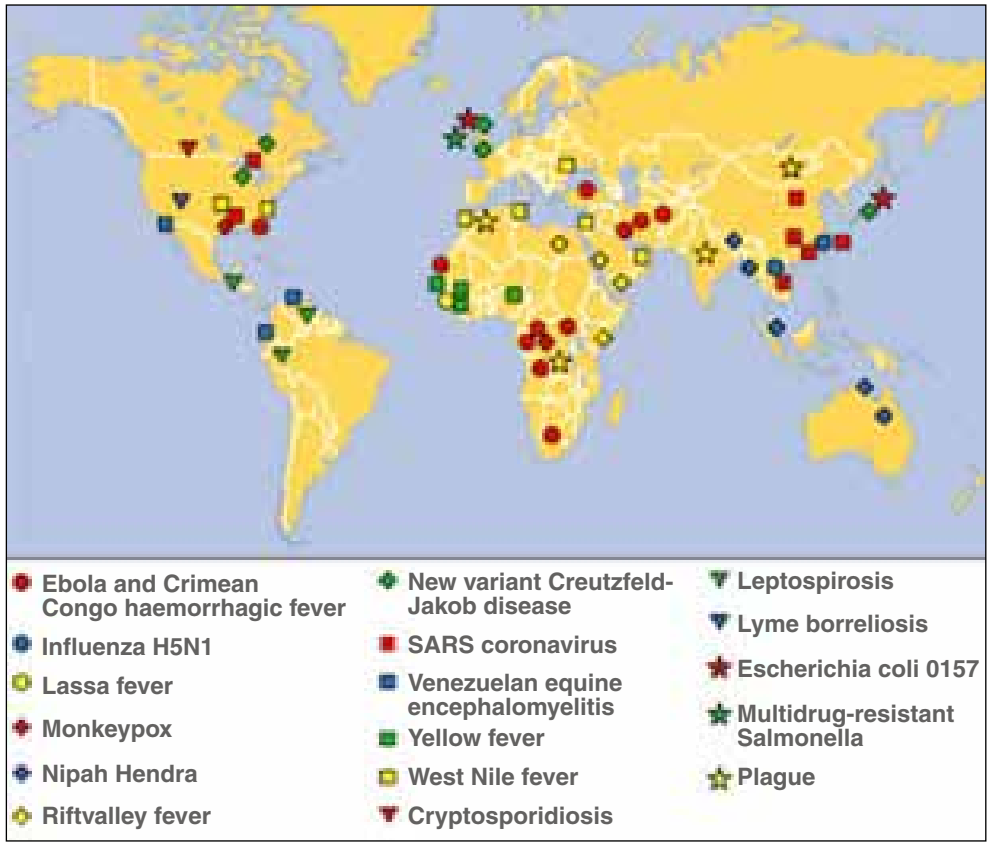
Wildfires occur in much of Australia and forested areas of the USA and Canada, as well as in the grasslands of South Africa.

> In 1998, a severe drought and some strong but dry storm fronts sparked off fires in Yellowstone National Park in the USA burning a total of 3,213km² or 36% of the park (http://en.wikipedia.org/wiki/Yellowstone_fires_of_1988).

Disease:

Infectious disease that can spread rapidly through a population is also a natural hazard. A disease that spreads in a particular locality is called an *outbreak* and one that spreads through a country or a region is called an *epidemic*. A disease that spreads throughout the world is a *pandemic*.

Figure 24: Emerging and re-emerging diseases (Source: WHO, 1996)



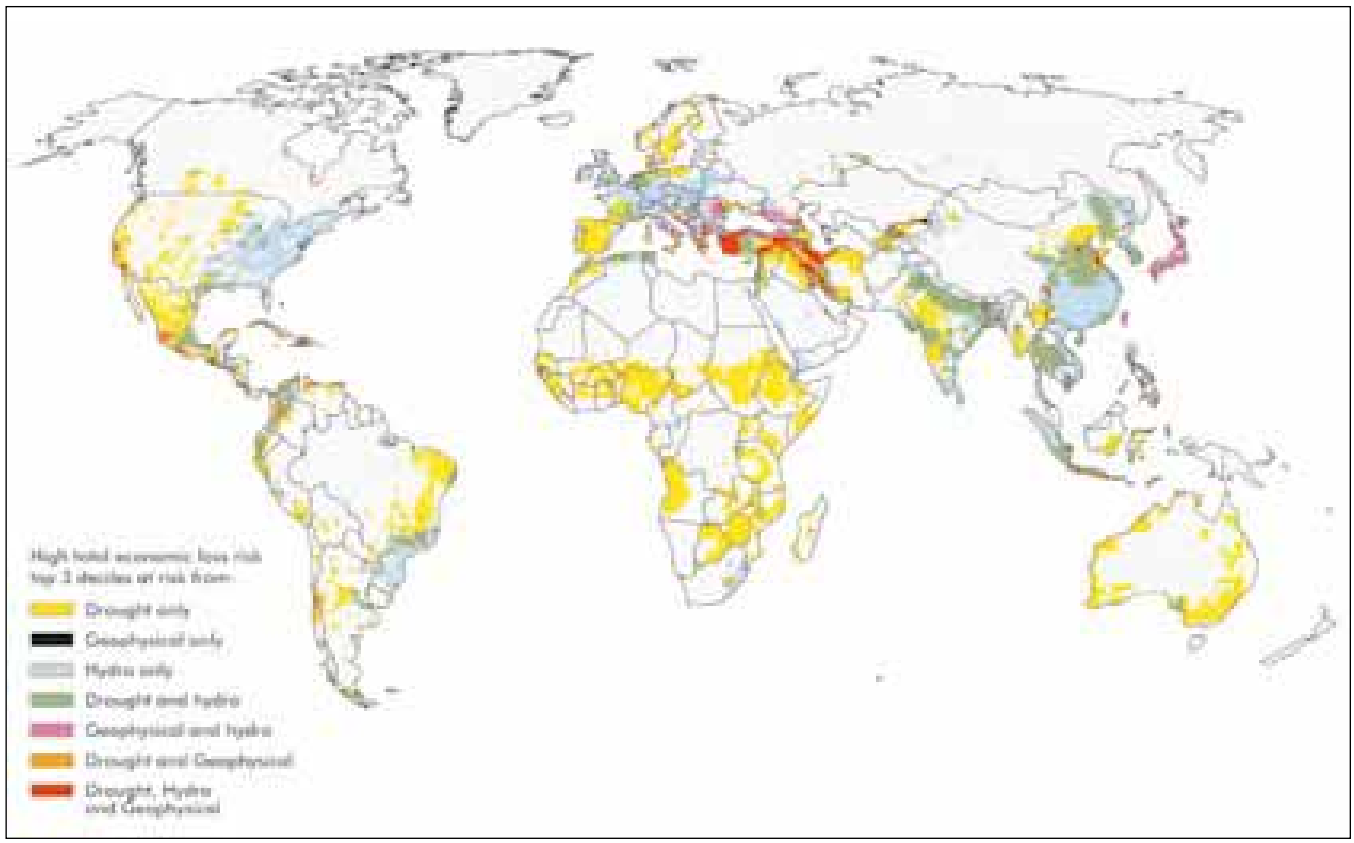
Dengue, chikungunya, Ebola and influenza are such infectious diseases.

Some diseases – such as malaria, yellow fever, cholera and diphtheria - are re-emerging diseases. That is, they are diseases that have been around for decades or centuries, but have come back in a different form or at a different location. In addition, now there are emerging diseases – those that have not been recorded before – such as HIV/AIDS, Severe Acute Respiratory Syndrome (SARS) and Avian Flu.

It is estimated that, globally,

- There are about 1,400 earthquakes every day and a volcano erupting every week (McGuire, 2002).
- There are about 40 fully formed tropical cyclones every year (Lal, 2001).
- Floods and landslides are too many to count.
- A new satellite-based method for early detection, monitoring and analysis of drought shows that nearly 20% of the earth has been affected by drought over the past two years (http://www.publicaffairs.noaa.gov/releases2001/oct01/noaa01102.html).
- An average of 15,000 fires burn 23,000m^2 of forest, grass, crop and townships each year in Australia (http://www.acfonline.org.au/news.asp?news_id=66&c=294135).
- In the last five years alone, the World Health Organization has identified more than 1,100 epidemics in the world, including cholera, polio and bird flu (WHO, 2007).

Figure 25: Natural hazard hotspots, by risk type (Source: UNEP/GRID-Arendal, 2008)



Natural disasters

Natural disasters occur when natural hazards cause death and destruction. When vulnerability is high, then the risk from a hazard increases. Vulnerability increases through many human activities such as:

- Inappropriate land use: such as building in areas prone to floods, on slopes prone to landslides, coastlines prone to hurricanes and storm surges, or volcanic slopes prone to volcanic eruptions.
- Increasing the severity of a natural hazard: for example, deforesting hill slopes worsens floods, and over-grazing by livestock worsens drought.
- Increase in human population: population growth, urbanisation, improperly built housing and public buildings, poor infrastructure maintenance, increasing poverty. For example, increased poverty and population worsen the effects of drought and cause famine, which is a natural disaster.
- Alteration of the natural environment: for example, deforestation, land reclamation of wetlands, over-grazing of grasslands.
- Globalisation: increased air travel is increasing disease epidemics and pandemics.

Natural disasters can be grouped according to how fast or slow they occur.

Table 3: Rapid and slow onset and cyclic disasters.

Type of disaster	*Rapid onset*	*Slow onset*	*Cyclic/recurring*
Natural disasters	Tsunamis, volcanic eruptions, earthquakes, floods, landslides, cyclones.	Drought, famine.	Floods in some areas, drought, wildfires.
Human made disasters	Violent conflict, accidents with hazardous chemicals, oil spills, biological warfare.	Conflict, pollution from acid rain.	Violent conflict.

Asia is the continent most impacted by disasters triggered by natural hazards.

Figure 26: Natural hazards in the Asian region, current situation.
(Source: http://www.pdc.org/atlas/html/atlas-init.jsp#. The triangles are active volcanoes and circles are active earthquakes; the different colours represent different magnitudes. Accessed August 30, 2008)

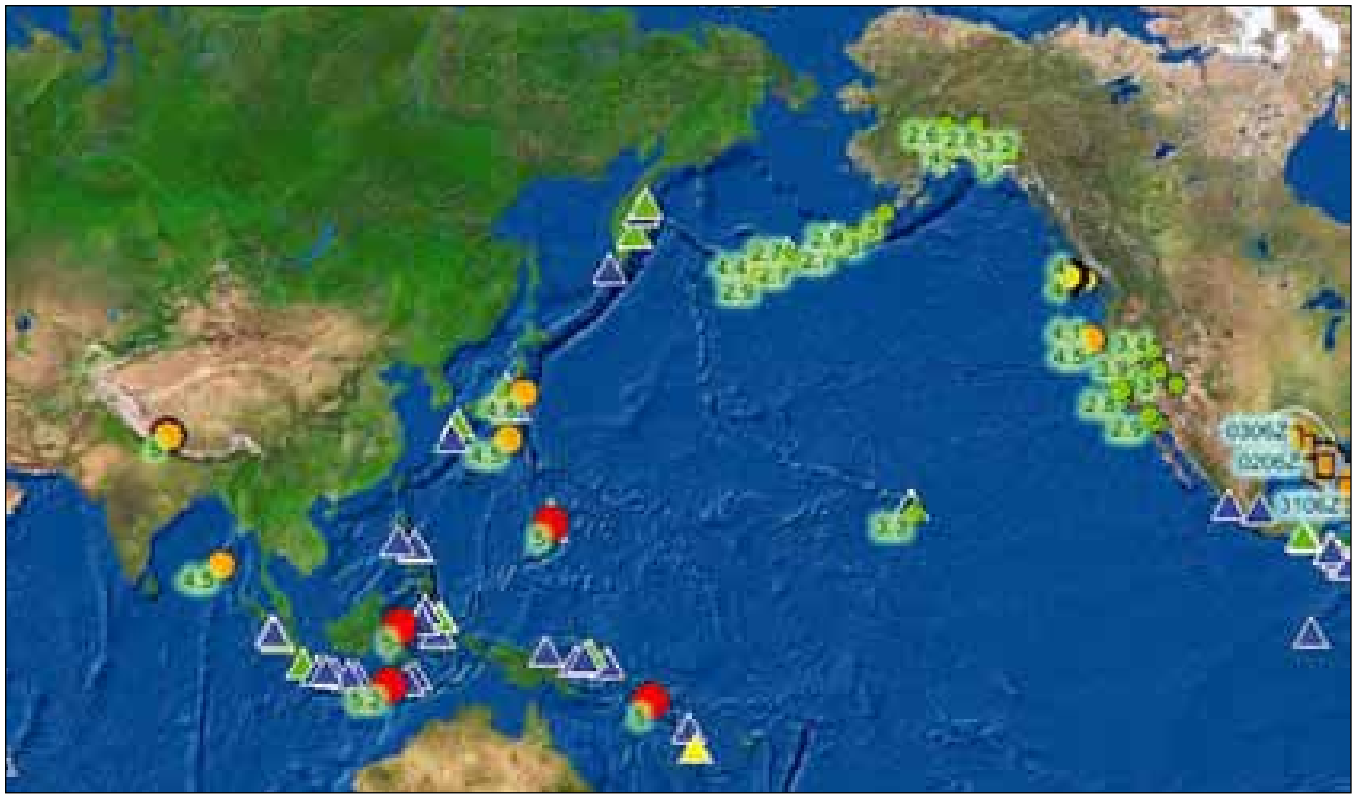


Table 4: Some of the worst natural disasters recorded (evaluated by the number of human deaths)
(Source: http://en.wikipedia.org/wiki/List_of_natural_disasters_by_death_toll)

Type of natural disaster	*Year*	*Location*	*No of human deaths*
Earthquake	1556	Shaanxi, China	830,000
Volcano	1815	Mount Tambora, Indonesia	92,000
Landslide	1999	Vargas, Venezuela	30,000-50,000
Flood	1931	Yellow River, China	1,000,000-4,000,000
Famine	1958-1961	China	20,000,000-43,000,000
Tsunami	2004	Indian Ocean	283,000
Tropical cyclone	1970	Bangladesh	500,000-1,000,000
Wildfire	1871	Wisconsin, USA	1,200-2,500
Disease (Small pox)	20th century	Worldwide	> 300,000,000
Disease (AIDS)	20th century	Worldwide	5 deaths/minute

Table 5: Some of the worst natural disasters recorded (evaluated by cost)
(Source: http://en.wikipedia.org)

Type of natural disaster	*Year*	*Location*	*Damage in USD*
Earthquake	1995	Japan	131,500,000,000
Volcano	1980	USA	1,500,000,000
Landslide	1998	China	890,000,000
Flood	1988	Soviet Union	60,000,000,000
Famine	1982	Australia	6,000,000,000
Tsunami	2004	Indian Ocean	Immediate 8.4 billion
Tropical cyclone	2005	USA, Hurricane Katrina	81.2 billion
Wildfire	1997	Indonesia	17,000,000,000
Disease (AIDS)	2007	Worldwide	10 billion for the year.

Table 6: Natural disasters in Asia in 2008
(Source: http://en.wikipedia.org/)

Type of natural disaster	*Location*	*No of human deaths and displacements*	*Damage in USD*
Tropical storm	Southern Myanmar	22,980 deaths and more than 40,000 other people are reported missing.	10 billion
Earthquake	Sichuan province, China.	69,197 deaths; 374,176 injured; 18,222 missing. 4.8 million people homeless, though the number could be as high as 11 million.	Exceeding 15 billion.
Floods	South Asia – monsoon season	More than 2,000 deaths in South Asia since the monsoon season began in June, mainly in India's northern state of Uttar Pradesh. Two million displaced.	Not yet estimated.

Although this manual focuses on natural disasters and their effects on ecosystem well-being and therefore, human well-being, it is worthwhile to note that two human-made disasters - oil spills and wars - also impact heavily on ecosystems.

Oil Spills

Oil spreads primarily on the surface, but wave and wind currents move these oil slicks over large areas of pelagic (in the open sea) and coastal habitats. The immediate consequence is mass mortality and contamination. The worse, long term effect is the damage to various levels of foods webs, sometimes permanently.

Oil spills have enormous impacts on fisheries. When oil slicks reach coastlines, they affect tourism and coastal communities. Oil spills, therefore, have long term effects on both society and the economy (http://www.waterencyclopedia.com/Oc-Po/Oil-Spills-Impact-on-the-Ocean.html).

- Between 1995 and 2004, there were 232 oil spills from tankers that spilled seven or more tonnes into oceans near 60 countries.
- During this period, USA had the highest frequency of oil spills (24% of the above) and South Korea, the second highest (6.4%).
- Oil spills have decreased in frequency in the last 30 years due to better preventative management (Huijer, 2008).

In July 2003, the oil tanker Tasman Spirit - carrying a cargo of 67,535 tonnes of crude oil – became grounded in the channel of the port of Karachi, Pakistan. It broke in August and 27,000 tonnes of cargo were lost initially, with further losses later.

It occurred in an area of extensive mangrove forests and coastal habitats, important for green and Olive Ridley turtles, cetaceans (dolphins, porpoises and beaked whales), several marine reptiles, over 50 species of birds and 200 species of fish and crustaceans, many of which are important commercially.

Immediately as a result of the spill, 11,000 tonnes of volatile organic compounds caused air pollution. Beaches were contaminated severely. Over five hundred kilograms of dead fish were found. Mangroves vegetation died (IUCN/UNEP/UNDP, 2003).

Wars

Wars have had catastrophic effects on human well-being. In this century and the last, the two World Wars, the Viet Nam War and the Gulf Wars of 1991 and 2003 took prominence, but there have been many small scale, domestic, civil wars (in Africa, Asia, Europe and the Middle East) that have been equally disastrous.

The impact of wars of the environment is manifold. The following description does not include preparing for war – such as the testing of weapons and hazardous waste disposal – and limits itself to post war damage. Using the MA framework, and some of the main drivers of ecosystem change, the following box provides a snapshot of environmental damage from war.

The less obvious but equally important consequence of war is the mass displacement of humans and a concentration and steep increase in the needs of ecosystem services, as well as an increase in the drivers of ecosystem change.

Over-exploitation:

- During the Gulf War of 1991, 8,000 camels were killed (Brauer, 2000).
- From 1998-2003, a civil war was fought in the Democratic Republic of the Congo. Over three million people died in the war, mostly from disease and starvation. More than two million people became refugees. Only 45% of the people had access to safe drinking water. Many refugees hunt wildlife for bush meat and protected areas are raided for minerals and other resources. Ivory poaching is rampant and it is reported that the hippopotamus population in one national park decreased from 29,000 three decades before, to only 900 in 2005.
- During the Viet Nam war, south Viet Nam's lobster fishery industry was reportedly over-fished to supply American soldiers.

Habitat destruction:

- The Viet Nam War of the 1960s and 1970s caused an 'environmental holocaust.' Over 40% of Viet Nam's forests were destroyed by this war. Chemical warfare – involving the application of 72 million litres of Agent Orange – destroyed 14% of Viet Nam's forests and remained in the soil, water and vegetation long after the war. Dioxin, a main ingredient of Agent Orange is carcinogenic[20] and teratogenic[21], and has resulted in spontaneous abortions, skin and lung cancers, lower intelligence and emotional problems among children. Children fathered by men exposed to Agent Orange during the Viet Nam War often have congenital abnormalities. An estimated half a million children have been born with dioxin-related abnormalities.
- The civil war and the Khmer Rouge regime in Cambodia in the 1960s resulted in extensive timber logging to finance war efforts, construction and collection of fuelwood. A total of 35% of Cambodia's forests were destroyed during this period causing severe floods, which in turn, damaged rice crops and caused food shortages. Many landmines were placed during the 1980's, and are still present in the countryside, preventing agricultural use of such land (http://www.lenntech.com/environmental-effects-war.htm).

Pollution:

- On September 11, 2001, terrorists flew airplanes into the buildings of the World Trade Centre in New York. As a consequence of burning jet fuels and their effect on buildings, an atmospheric plume formed, consisting of extremely toxic materials such as asbestos and Polychlorinated Biphenyl (PCB). At the site now called Ground Zero, a large pile of smoking rubble burned intermittently for more than three months.
- The Gulf War of 1991 was one of the most environmentally damaging wars. Iraq dumped approximately one million tons of crude oil into the Persian Gulf, causing the largest oil spill in history. Approximately 25,000 migratory birds were killed, crude oil spilled into the desert, forming oil lakes covering 50km^2 and, in the long term, contaminating ground water aquifers. Many dams and sewage water treatment plants were targeted and destroyed, causing sewage to flow directly into the Tigris and Euphrates rivers; pollutants seeped from bombed chemical plants into these rivers. Drinking water became polluted, resulting in widespread disease. (For example, cases of typhoid fever have increased tenfold since 1991.)
- In addition, non-recyclable food containers, plastic water bottles, aluminium soft-drink cans, and cellophane food packaging, as well effluents from fuel-leaks and spills, solvents, paints, lubricants, acids, and other toxic materials might have been buried in the desert.
- In the Gulf War that began in 2003, 200 blue plastic containers containing uranium were stolen from a nuclear power plant, the radioactive content of the barrels dumped in rivers and the barrels reused as containers as storage facility for water, oil and milk (http://www.lenntech.com/environmental-effects-war.htm).
- In the Kosovo war of the 1990s, NATO bombed Belgrade, the capital of Serbia, and this caused the leakage of hazardous chemicals (chlorine, hydrochloric acid, vinyl chloride) into air, water and soil. The Danube River was polluted by oil, hydrochloric acid and mercury compounds. A lack of clean drinking water and sanitation problems occurred.

(Source for all of the above: http://www.lenntech.com/environmental-effects-war.htm)

[20] capable of causing cancer
[21] capable of causing birth defects

Global warming

Between 1970 and 2004, the annual emissions of carbon dioxide (CO_2) grew by about 80%, and during the last century, the concentration of CO_2 in the atmosphere has risen by twelvefold. Increased emissions into the atmosphere of CO_2 and methane (CH_4) – so called greenhouse gases (GHG) – cause a distinct warming of the earth.

Table 7: Greenhouse gases (Source: UNEP/GRID-Arendal Maps and Graphics Library, 2008)

The main greenhouse gases

Greenhouse gases	**Chemical formula**	**Pre-industrial concentration**	**Concentration in 1994**	**Greenhouse gases**	**Anthropogenic sources**
Carbon-dioxide	CO_2	280 ppmv	358 ppmv	50-200	Fossil fuel combustion; land use conversion; cement production.
Methane	CH_4	700 ppbv	1720 ppmv	12-17	Fossil fuels; rice paddies; waste dumps; livestock.
Nitrous oxide	N_2O	275 ppbv	312 ppmv	120-150	Fertilisers; industrial processes; combustion.
CFCs	CFC12	0	503 pptv	102	Liquid coolants; foams.
HCFCs	CFC-22	0	105 pptv	13	Liquid coolants.
Perfluorocarbon	CF_4	0	110 pptv	50 000	Production of aluminium.
Sulphure hexa-fluoride	SF_6	0	72 pptv	1 000	Production of magnesium.

Note : pptv = 1 part per trillion by volume; ppbv = 1 part per billion by volume, ppmv = 1 part per billion by volume

These gases function much like glass panes in a greenhouse, allowing light in, but preventing heat from escaping. This greenhouse effect, as it is called commonly, is important: without it, the earth would be too cold for humans to live. The problem is that now there is just too much GHG, making the earth too hot.

During the last century, the concentration of CO_2 in the atmosphere has risen by twelvefold, through excessive use of coal and oil, countless vehicles that use up gallons of petrol, and industries that are emitting enormous quantities of CO_2 into atmosphere. Meanwhile, forests (that serve to soak up CO_2) are being cut down. Every year, about 23 billion metric tonnes of CO_2 are emitted into the atmosphere. Until recently, the USA was the major culprit (emitting 21.2% of the world's total) but preliminary findings show that since 2006, China's emissions have surpassed the USA's (MNP, 2006). The Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios projects an increase of global GHG emissions by 25-90% between 2000 and 2030 (IPCC, 2007).

In the meantime, trash and garbage are heaped as solid waste and the livestock industry - rearing millions of herds of cattle and sheep - generates huge quantities of methane.

The result of these emissions and increased greenhouse effect is a distinct warming of the earth. During the last century, global temperature increased by about 0.8°C - measured as the largest increase in thousand years.

The records are startling: the five hottest years on record are in the last decade and this one. The 90s were the warmest decade in a century, with 2005 the hottest year on record worldwide (IPCC, 2007).

The IPCC predicts that for the next two decades the earth will warm about 0.2°C per decade; and even if GHG are kept constant at levels of year 2000, the earth will still warm about 0.1°C per decade (IPCC, 2007).

As a result of this warming, changes are occurring in global weather patterns and resulting in *Climate Change*. Snow cover is decreasing and glaciers are retreating. In 2002, NASA confirmed that the extent of Arctic ice had lessened; glaciers in the European Alps have decreased by approximately half their extent since the mid 1800s and one fifth of their remaining volume since 1980. By 2005, the snow cap that covered the top of Mount Kilimanjaro in Africa for the past 11,000 years had almost disappeared.

Figure 27: Past and future concentrations of CO_2 (Source: UNEP/GRID-Arendal Maps and Graphics Library 2008)

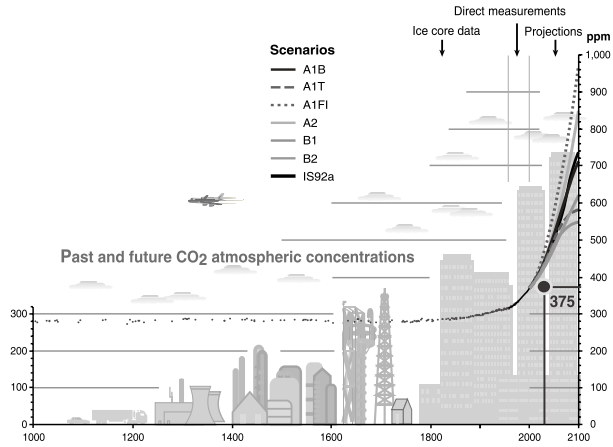
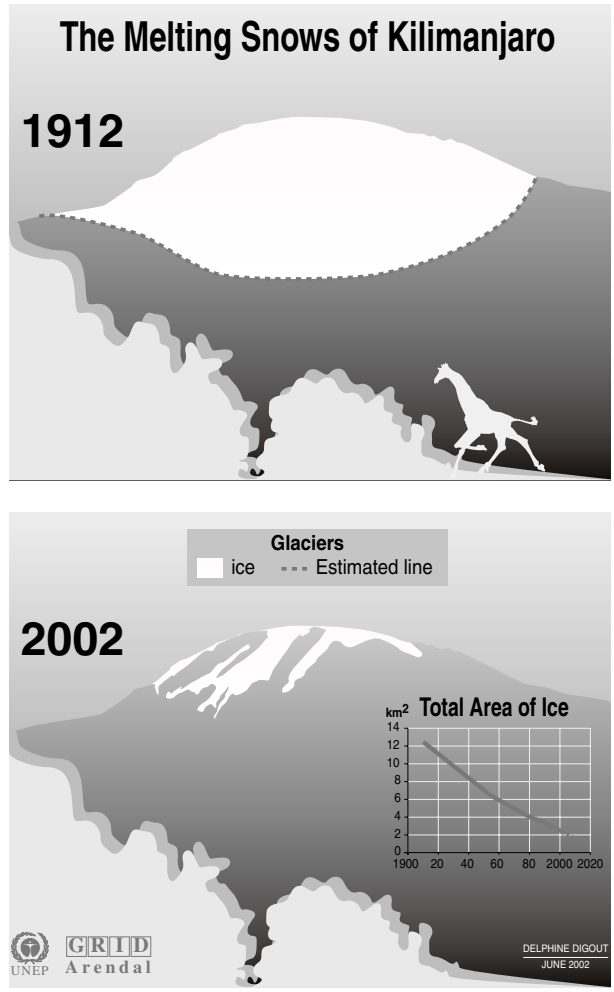


Figure 28: Melting snow on Kilimanjaro (Source: UNEP/GRID-Arendal Maps and Graphics Library, 2008)



Melting snow and retreating glaciers result in an increase in sea levels. The current rate of sea-level rise is three times the historical rate and sea levels have already risen by 10-20cm in the last century (IPCC, 2007). The IPCC predicts that global sea levels will rise between 0.09 to 0.88m by 2100. This could mean that many coastal countries and cities such as Bangladesh and the Maldives, Mumbai and Bangkok could become flooded by seawater. It is estimated that in India alone, millions of people are at high risk from sea level rise. In the short term, the runoff from rapidly melting glaciers can cause landslides and floods downstream. In the short term, rapidly melting glaciers mean intense flooding downstream, but in the long term, the reduced quantity of ice produces less freshwater downstream. The snow melts of the Himalayas feed the Ganges,

Figure 29: The decrease of Arctic sea ice (Source: UNEP/GRID-Arendal Maps and Graphics Library 2008)

Indus and Brahmaputra. The Ganges – which alone provides water to 400 million of people – is predicted to lose two-thirds of its water as a result of climate change (Reid & Simms, 2007).

Coastal flooding will result in sea water entry (intrusion) into fresh water bodies. This will damage fresh water supplies for coastal communities and affect livelihoods and human well-being. In China and Bangladesh, the effects of sea level rise and salt water intrusion are already damaging their economies and environments. Salt water intrusion into lagoons, estuaries and mangroves will damage these ecosystems, affecting the services – such as coastal fisheries, flood regulation and storm protection – that they provide humans (Reid & Simms, 2007).

Another effect of increased CO_2 in the atmosphere is that oceans absorb heat as well. With a density far higher than that of the atmosphere, the oceans absorb far more heat than the atmosphere. The three upper metres of the ocean alone contain as much heat as the entire atmosphere above it. However, the heating of the oceans takes time and there is a time lag between the heating of the atmosphere and the heating of the oceans. More CO_2 becomes dissolved in the oceans, forming the weak carbonic acid – i.e., making the oceans more acidic and directly affecting ecosystems such as coral reefs and marine organisms - ultimately affecting food security.

In addition, ocean currents are becoming affected seriously by global warming. Usually, heat moves from the equator to the poles not only through the atmosphere but also by ocean currents, and the cooler water from the poles is circulated to the equator. Such currents are extremely important in maintaining the climate of continents, especially coastal areas. These currents are driven both by heat and salinity, which, together, determine the density of the water. When both heat and salinity of the oceans change as a result of global warming (salinity increases because of increased evaporation or reduces because of increased runoff from large rivers), these currents change, with serious effects on weather patterns.

Climate change

Because of global warming, there are overpowering changes in the world's climate.

Rainfall patterns are changing and the effects of El Niño and La Niña episodes are worsened, resulting in increased cyclones, flooding and landslides.

What is El Niño?

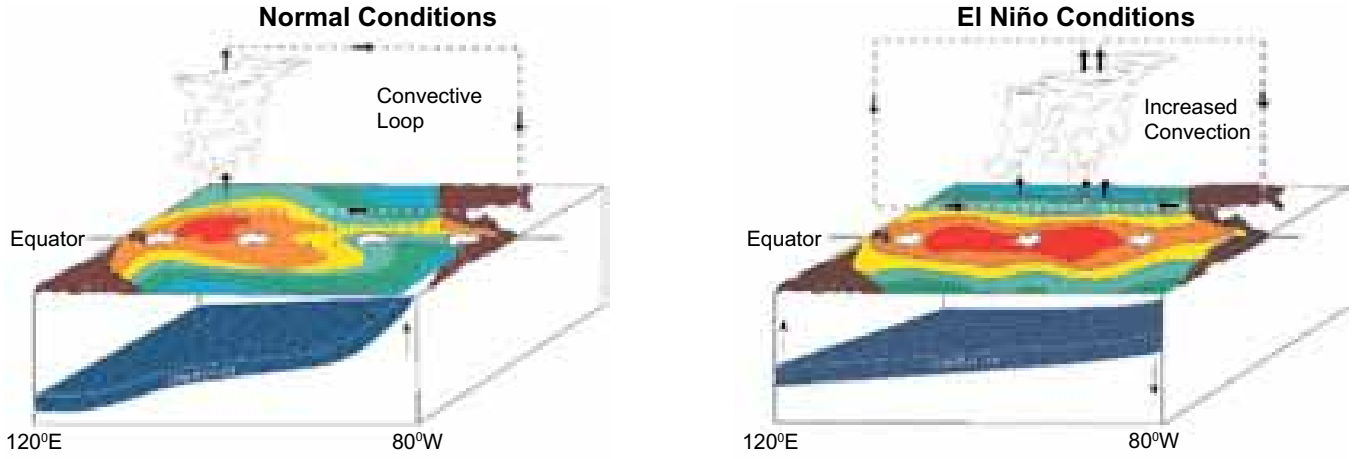
El Niño is Spanish for 'the little boy', referring to the Christ child, because this event is noticed usually around Christmas time. It is a fluctuation of the ocean-atmosphere system in the tropical Pacific Ocean that is important for the world's climate. In normal, non-El Niño conditions, trade winds (prevailing tropical winds) blow towards the west across the tropical Pacific, piling up warm surface water in the west Pacific, so that the sea surface is about 0.5m higher in height and 8°C warmer at Indonesia than at Ecuador. The waters off South America are cool because of an upwelling from the deep and are nutrient-rich, with high marine primary productivity which supports fisheries. During El Niño, the air pressure over the Indian Ocean, Indonesia, and Australia rises, but drops over Tahiti and the rest of the central and eastern Pacific Ocean. The trade winds in the South Pacific weaken. Warm air rises near Peru causing rain in its deserts, while warm water spreads from the West Pacific and Indian Ocean to the East Pacific Ocean. When it spreads, it takes the rain with it, causing rainfall in normally dry areas and drought in normally wet areas. El Niño also results in less upwelling, less nutrients, warmer sea surface temperatures (+0.5°C) and decreased marine primary production near South America.

La Niña, means 'the little girl' in Spanish, meant to reflect that its effects are the opposite to that of El Niño. Here, the result is a lowering of sea surface temperatures by about 0.5°C. It usually follows an El Niño event.

(Source:NOAA, 2008b)

Coral bleaching – mass scale die off of corals – has already occurred worldwide in 1998 as a result of warmer water currents brought by an El Niño event. In 1998, 16% of the world's coral reefs and 50% of the Indian Ocean's coral reefs were bleached. This means that the nearly 500 million people who depend – directly or indirectly – on coral reefs for their livelihoods and to live would have been affected some way or another (Wilkinson, 2004).

Figure 30: Diagram of El Niño conditions (Source: NOAA, 2007)



Lakes and rivers are also warming, and while wet areas are often becoming wetter, dry areas are often becoming dryer. It is predicted that tropical areas will get hotter, that arid areas will become deserts, while temperate regions could become tropical. Dry areas becoming dryer leads to increased droughts and heat waves. These, in turn, lead to famine, increased wildfires, pest attacks, and spread of invasive alien species (IPCC, 2007).

The world's hydrological systems will be rearranged, causing changes in seasonal flows. In water-scarce regions, water availability will be reduced, but increased in some other areas. Generally, the quality of freshwater habitats would be degraded by higher water temperatures. Changes upstream will impact on downstream supplies, affecting water security.

Changing weather patterns are also resulting in changes in the distribution and range of species and are disrupting the natural balance of many ecosystems, with the result that the goods and services that they provide to humans will also be changed or reduced. This will undoubtedly have a serious impact on crops, which, in turn, will lead to food shortages and eventually famine.

Changes in species distribution are also expanding the range of disease vectors such as mosquitoes, so that diseases are spreading, affecting human health.

Figure 31: Climate change and vector-borne diseases
(Source: UNEP/GRID-Arendal Maps and Graphics Library, 2008)

Disease	Vector	Population at risk (million)[1]	Number of people currently infected or new cases per year	Present distribution	Likelihood of altered distribution
Malaria	Mosquito	2,400[2]	300-500 million	Tropics and Subtropics	★★★
Schistosomiasis	Water snail	600	200 million	Tropics and Subtropics	★★
Lymphatic Filariasis	Mosquito	1 094[3]	117 million	Tropics and Subtropics	★
African Trypanosomiasis (Sleeping sickness)	Tsetse fly	55[4]	250 000 to 300 000 cases per year	Tropical Africa	★
Dracunculiasis (Guinea worm)	Crustacean (Copepod)	100[5]	100 000 per year	South Asia, Arabian Peninsula, Central-West Africa	❍
Leishmaniasis	Phlebotomine sand fly	350	12 million infected, 500 000 new cases per year[6]	Asia, Southern Europe Africa, Americas	★
Onchocerciasis (River blindness)	Black fly	123	17.5 million	Africa, Latin America	★★
American Trypanosomiasis (Chagas disease)	Triatomine bug	100[7]	18 million	Central and South America	★
Dengue	Mosquito	1,800	10-30 million per year	All Tropical countries	★★
Yellow Fever	Mosquito	450	more than 5 000 cases per year	Tropical South America Africa	★

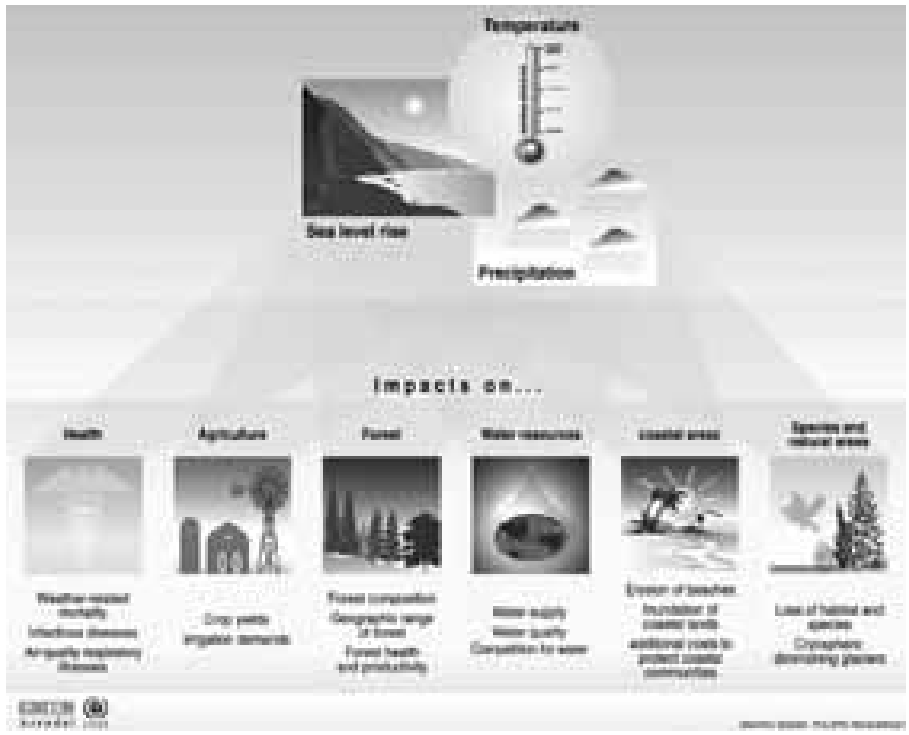
★★★ Highly likely ★★ Very likely ★ Likely ❍ Unknown

1. Top three entries are population-prorated projections, based on 1989 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Ranque, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

GRID Arendal UNEP
GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Figure 32: Potential impacts of climate change
(Source: UNEP/GRID-Arendal Maps and Graphics Library, 2008)



In short, climate change is increasing the frequency of natural disasters.

It is estimated that during the last few decades, an average of 250 million people have been affected each year, with nearly 58,000 deaths as a result of natural disasters. In 2004 alone, natural disasters affected the lives of about 140 million people.

Figure 33: Trends in natural disasters
(Source: UNEP/GRID-Arendal Maps and Graphics Library, 2008)

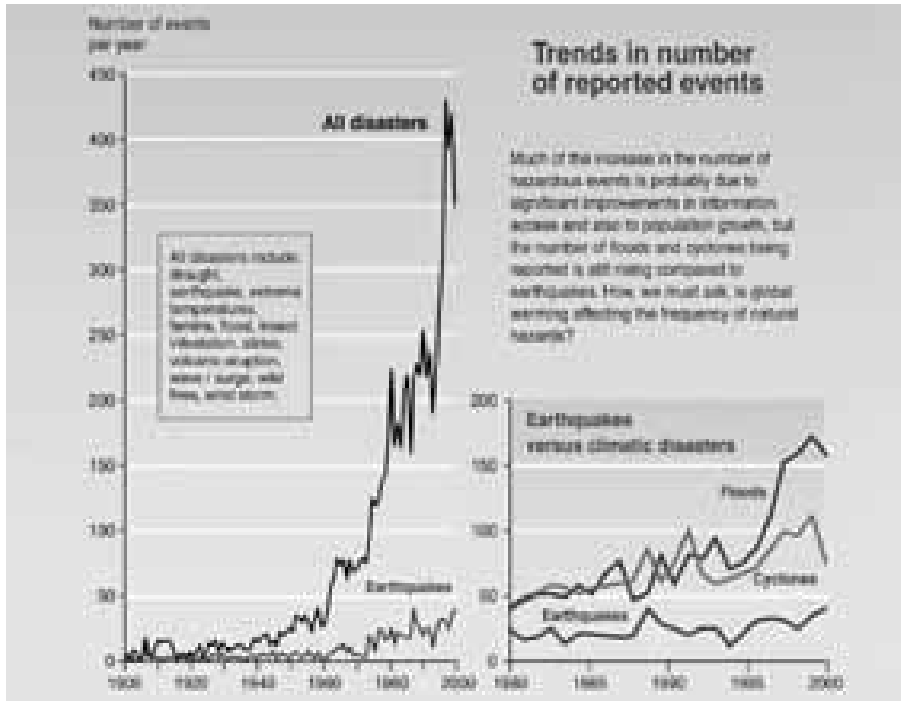


Figure 34: Incidence of floods 1950-2000
(Source: MA, 2005)

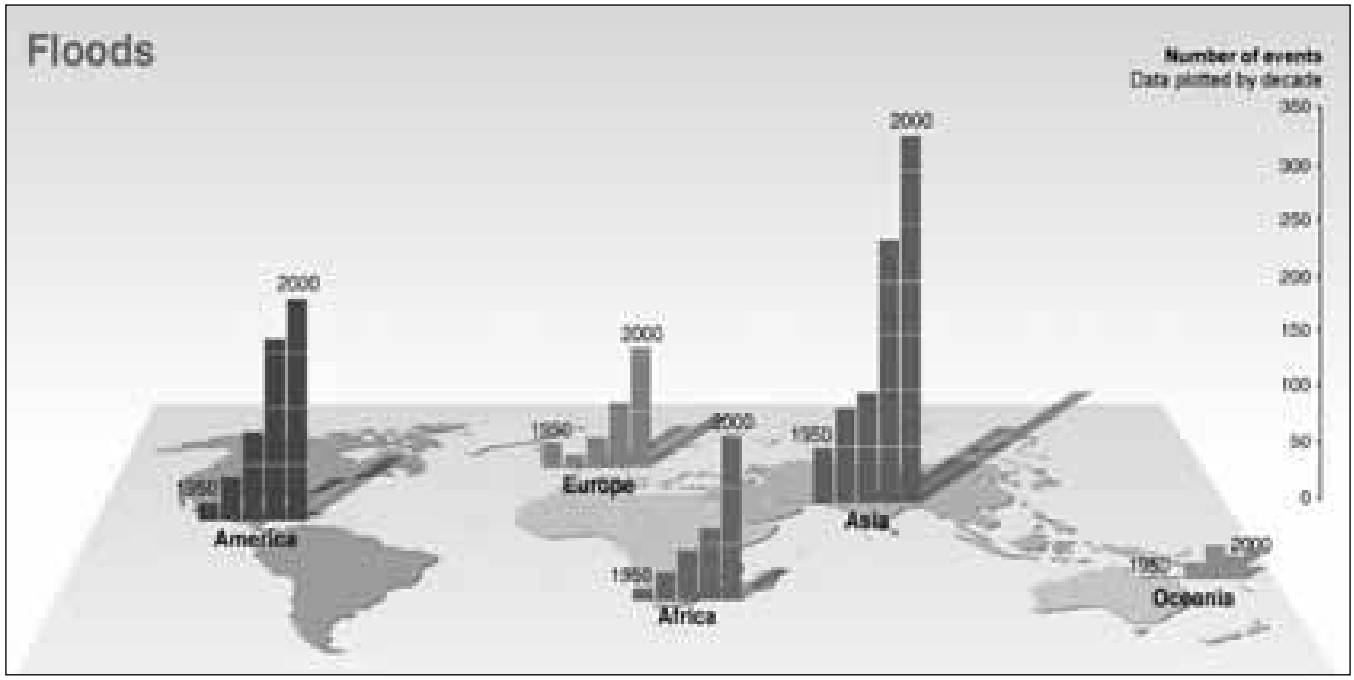


Figure 35: Incidence of wildfires 1950-2000
(Source: MA, 2005)

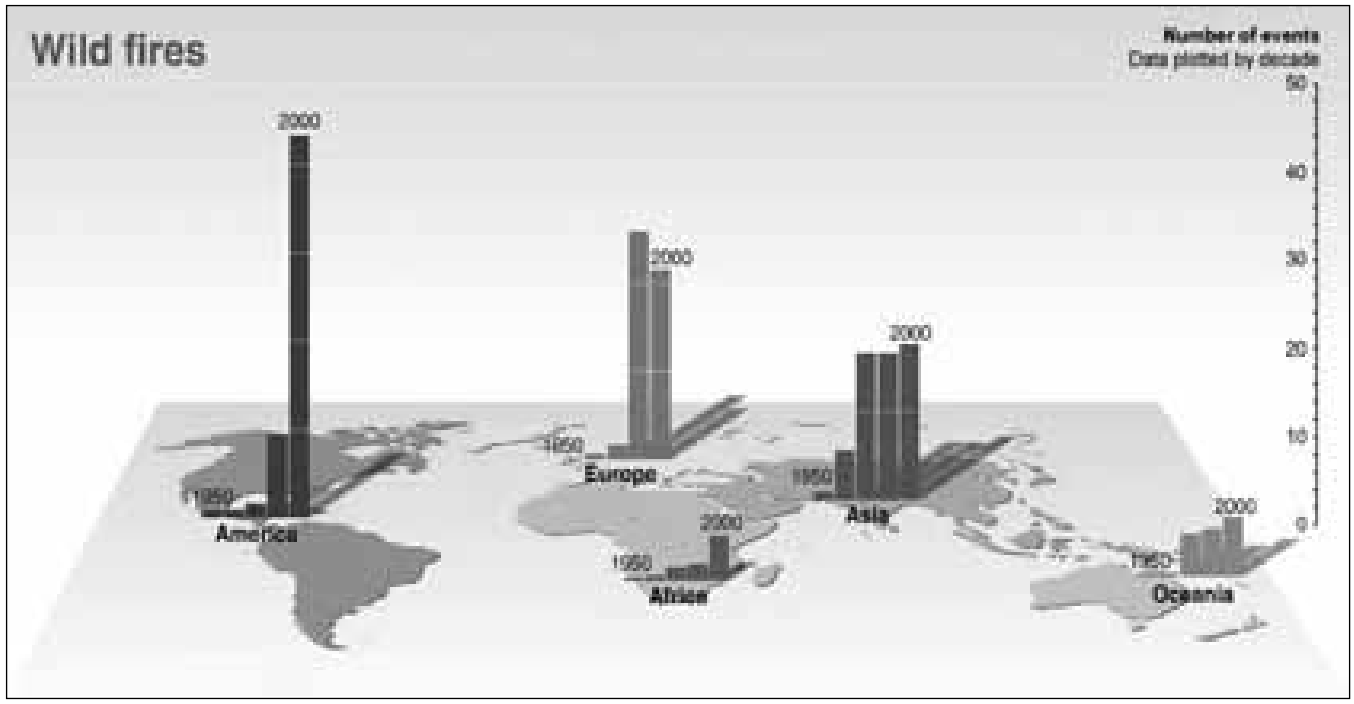
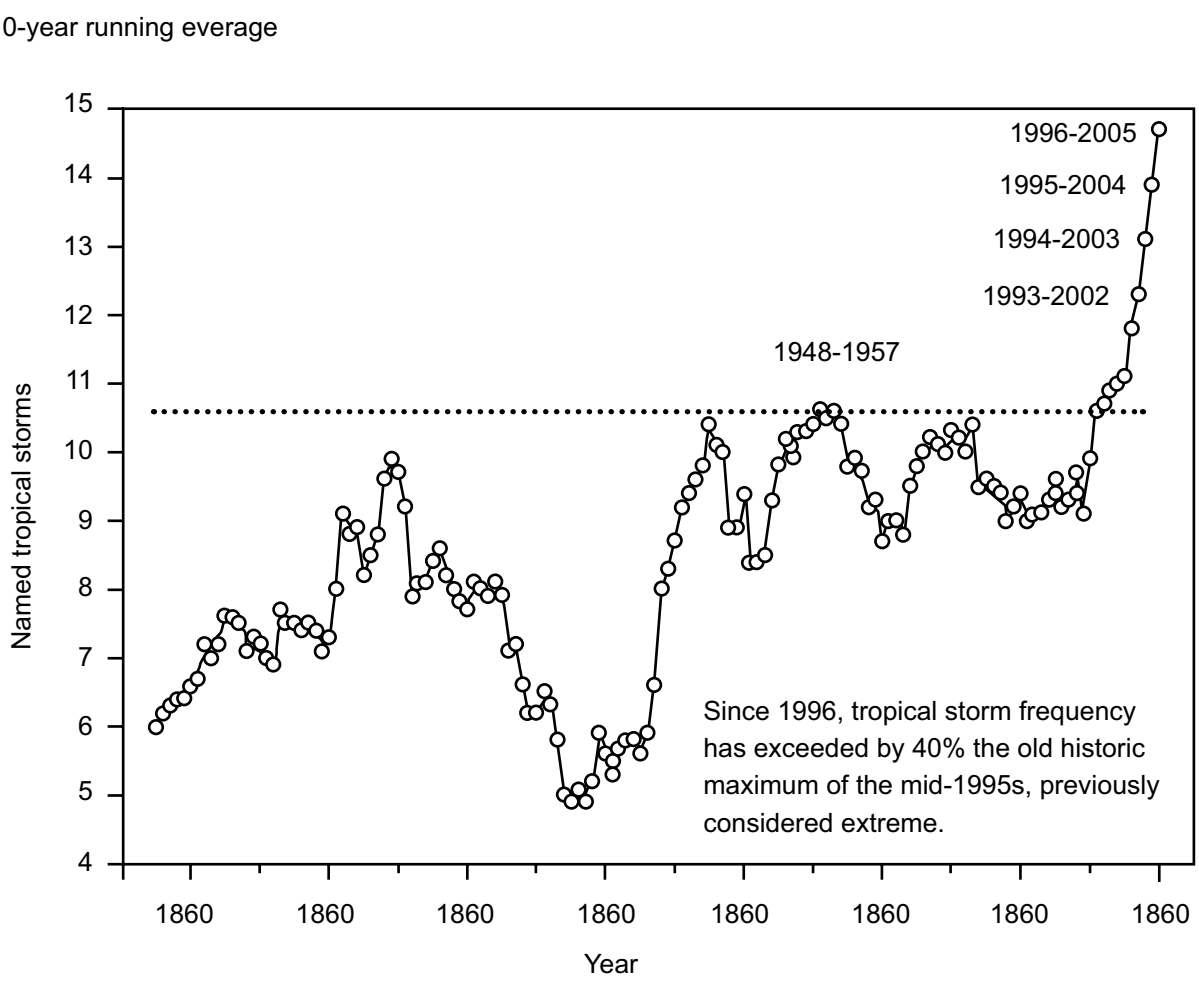


Figure 36: Incidence of tropical storms in the north Atlantic
(Source: National Hurricane Center, 2007)



These impacts of climate change will have significant economic costs. It is predicted that

- Climate change impacts in the extent of arable lands will have economic losses of 56 billion USD. The highest losses are projected for some parts of Latin America, Africa and Asia (IPCC, 2007).
- The impacts of climate change on agriculture could increase the number of hungry people in the world (IPCC, 2007).
- In 1995, 1,400 million people lived in areas with inadequate water supplies. Projections with different climate change scenarios predict an increase of 364 to 1,661 million people living under conditions of water stress by 2020 (IPCC, 2007).
- Estimates of the property damage caused by Hurricane Katrina in 2005 are as high as 135 billion USD (Ackerman & Stanton, 2006).
- The cost of the 2003 heat wave of Europe, when 35,000 people died and there were agricultural losses, was 15 billion USD (Stern, 2006).
- Extreme storms and flooding in the UK are predicted to become more frequent and more severe. It is estimated that the cost of this flooding will be about 40 billion USD by 2080, fifteen times of the present cost (Ackerman & Stanton, 2006).
- In 2005, natural catastrophes caused 220 billion USD worth of damage (Swiss Re 2006 in litt. Ackerman & Stanton, 2006).
- The German Institute for Economic Research (DIW) estimates that if nothing is done to curb GHG emissions, annual economic damages could reach 20 trillion USD by 2100 (expressed in U.S. dollars at 2002 prices), or 6-8% of global economic output at that time (Ackerman & Stanton, 2006).

The link between climate change and the increase in frequency of natural disasters cannot be over-emphasised. The progression is clear: climate change is worsening El Niño and La Niña events; this is causing more intense and more natural hazards such as floods, cyclones, hurricanes and wildfires. Because the intensity and extents of these natural hazards have worsened, they are causing natural disasters. These natural disasters not only retard sustainable development, but also have far reaching knock-on effects. For example, the December 2004 tsunami severely damaged the southern coast of Sri Lanka. In the rush to rebuild, development was unplanned and sited in elephant migratory pathways. In addition, climate change is now extending annual dry seasons into drought. Elephants seeking water during drought meet human settlements, and conflict results. In this example, the tsunami seems to have worsened human-elephant conflict in southern Sri Lanka.

Climate change impacts on Asia, the poor and women:

Increasing natural disasters will have far reaching global effects, but disproportionate impacts on Asia. In fact, Asia is the world's most disaster prone region, having suffered about half of the world's major disasters over the past fifty years, 67% of the casualties and 28% of the economic losses (Reid & Simms, 2007). Each year, natural disasters impoverish millions of people. However, only 0.2% of economic losses were covered by insurance policies, because many of those affected are the marginalised and the poor.

Asia is also the home to over 70% of the world's poor. Tragically, at the forefront of all these events are the poor. In developing countries, the marginalised and poor are already deprived of adequate food, clean drinking water, sanitation, health care etc. In most cases, it is this section of society who is also forced to live in low lying and other hazard prone areas and so are usually the first to be hit by floods, landslides and cyclones. Mostly neglected by their respective governments, they have the fewest resources to deal with these recurrent shocks and stresses. Therefore, the negative consequences of climate change make them less capable of developing any coping, preventing, and mitigating mechanisms (IUCN, 2007).

Amongst the poor, it is the women and children who are the most vulnerable in any disaster. Out of the 1.4 billion people in the developing world who live below the poverty line, 70% are women. After the tsunami, a shocking statistic revealed that the number of deaths of women and children were disproportionately larger than that for men. Vulnerability to disasters depends on control of financial, physical, natural, human and social assets. Compared to men, women in the poor, developing countries traditionally have limited access and control over these assets (IUCN, 2007).

An increase in natural disasters will have overarching impacts on ecosystem services and the global economy but it will cripple Asia, already stressed with overpopulation, poverty, internal conflict, resource overuse and spread of disease.

References

Ackerman, F. and E. Stanton (2006). *Climate change - the costs of inaction*. USA, Tufts University: Global Development and Environment Institute. http://ase.tufts.edu/gdae/ 48 pp.

Allen, G. R. and R. Steene (1994). *Indo Pacific Coral Reef Field Guide*. Singapore: Tropical Reef Research. 378 pp.

Bandaranayake, W. M (1998) Traditional and medicinal uses of mangroves. *Mangroves and Salt Marshes* **2**(3):133-148.

Batagoda, B. M. S., Kerry Turner, R., Tinch, R. and K. Brown (2000). *Towards policy relevant ecosystem services and natural capital values: rainforest non-timber products.* CSERGE Working Paper GEC 2000-06. 43 pp.

Bundesministerium für Bildung und Forschung (BMBF) (2002). *Asia Concept 2002: Positive results of the Asia Concept 1995 and challenges for the years ahead.* Germany: BMBF. 38 pp.

Bruckner, A (2006). *New Threat to Coral Reefs: Trade in Coral Organisms.* http://www.issues.org/17.1/bruckner.htm

Centre for epidemiology of disasters (2007). *Number of drought disasters reported by country 1970-2006.* http://divisionoflabour.com/archives/003409.php

Condit, R. D. M Winsor, and S. P. Hubbell (1996). *NPP Tropical Forest: Barro Colarado, Panama, 1969-1990*. Data set.

Conservation International (2008). http://www.biodiversityhotspots.org/Pages/default.aspx

Dartmouth Flood Observatory (2008). http://www.country-studies.com/bangladesh/river-systems.html

Dartmouth Flood Observatory (2008). *Major floods reported in 2008.* http://www.dartmouth.edu/~floods/Archives/2008global.jpg

Earth Policy Institute (2006). http://www.eia.doe.gov/emeu/iea

Emerton, L. A (2006). *Counting coastal ecosystems as an economic part of development infrastructure*. Colombo: Ecosystems and Livelihoods Group, Asia, IUCN. 12 pp.

Emerton, L. (ed.) (2005). Values and Rewards: Counting and Capturing Ecosystem Water Services for Sustainable Development. IUCN *Water, Nature and Economics Technical Paper No. 1.* Colombo: Ecosystems and Livelihoods Group Asia, IUCN – The World Conservation Union. 93 pp.

Emerton, L., Seilava, R. and H. Pearith (2002). *Bokor, Kirirom and Ream National Parks, Cambodia: case studies of economic and development linkages.* Field study report, Review of protected areas and their role in the socio-economic development of four countries of the Lower Mekong Basin.

Emerton, L. and B. Kekulandala (2002). A*ssessment of the Economic Value of Muthurajawela Wetland*. Colombo: IUCN – The World Conservation Union, Sri Lanka Country Office and Regional Environmental Economics Programme Asia. 31 pp.

Environmental Justice Foundation (2005). *Mangroves: Nature's defence against Tsunamis - A report on the impact of mangrove loss and shrimp farm development on coastal defences*. London, UK: Environmental Justice Foundation. 32 pp.

Global Runoff Data Centre (2008). *Major river basins of the world*. GRDC in the Bundesanstalt für Gewässerkunde, 56068 Koblenz, Germany. http://nofdp.bafg.de/servlet/is/15693/

Hesp, P. A (2000). Coastal sand dunes form and function. *Coastal Dune Vegetation Network Technical Bulletin*. **4**. Rotorua: New Zealand Forest Research Institute Limited. 28 pp.

Hodgson, G. and J. Dixon (1988). Logging Versus Fisheries and Tourism in Palawan. *Occasional Paper 7.* Honolulu, Hawaii: East-West Environment and Policy Institute. 95 pp.

http://csmres.jmu.edu/geollab/fichter/PlateTect/erthstru.html.

http://en.wikipedia.org/wiki/Drought_in_Australia

http://en.wikipedia.org/wiki/Historic_tsunami

http://en.wikipedia.org/wiki/Krakatoa

http://en.wikipedia.org/wiki/List_of_natural_disasters_by_death_toll http://en.wikipedia.org/wiki/Mount_Vesuvius

http://en.wikipedia.org/wiki/Rainforests

http://en.wikipedia.org/wiki/Typhoon_Tip

http://en.wikipedia.org/wiki/1999_Vargas_mudslide

http://en.wikipedia.org/wiki/Yellowstone_fires_of_1988

http://geology.about.com/library/bl/maps/blcrustalplates.htm

http://geology.about.com/library/bl/blnutshell_fault-type.htm

http://ioc3.unesco.org/itic/files/tsu_wave_characteristics.pdf

http://pubs.usgs.gov/gip/dynamic/inside.html

http://pubs.usgs.gov/gip/volc/text.html

http://science.nationalgeographic.com/science/earth/natural-disasters/earthquake-profile.htm

http://upload.wikimedia.org/wikipedia/commons/b/b1/World_population.PNG

http://www.acfonline.org.au/news.asp?news_id=66&c=294135

http://www.andrew.com.

http://www.aoml.noaa.gov/hrd/tcfaq/C5c.html.

http://www.en.wikipedia.com

http://www.fao.org/docrep/t4450e/T4450E0m.htm.

http://www.pdc.org/atlas/html/atlas-init.jsp#.

http://www.publicaffairs.noaa.gov/releases2001/oct01/noaa01102.html

http://www.pvsd.ca/.../planning/thecrust/thecrust.htm

http://www.country-studies.com/bangladesh/river-systems.html

http://www.runet.edu/~swoodwar/CLASSES/GEOG235/biomes/rainforest/rainfrst.html (Accessed 28 August 2008)

http://www.sms.si.edu/irlspec/Whatsa_lagoon.htm

http://www.unesco.org/science/disaster/about_disaster.shtml.

http://www.upload.wikimedia.org

http://upload.wikimedia.org/wikipedia/commons/2/23/Global_tropical_cyclone_tracks-edit2.jpg

http://upload.wikimedia.org/wikipedia/commons/thumb/0/09/Pacific_Ring_of_Fire.png/800px-Pacific_Ring_of_Fire.png

http://www.wordnet.princeton.edu/perl/webwn

Huijer, K (2008). *Trends in oil spills from tanker ships 1995-2004.* International Tanker Owners' Pollution Federation. http://www.itopf.com/_assets/documents/amop05.pdf. 14 pp.

IIED (2003). *Valuing Forests: A Review of Methods and Applications in Developing Countries.* London: Environmental Economics Programme, International Institute for Environment and Development. 80 pp.

Intergovernmental Panel on Climate Change (IPCC) (2007). *Working group III Summary for policymakers.* http://www.ipcc.ch/SPM040507.pdf

IUCN (2000). *Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species*. Gland: Switzerland: IUCN. 21 pp.

IUCN/UENP/UNDP (2003). *Tasman Spirit oil spill Karachi, Pakistan, Assessment report*. http://www.reliefweb.int/ochaunep/edr/Pakistan.pdf. 22 pp.

Kallesøe, M. F., Bambaradeniya, C. N. B. , Iftikhar, U. A., Ranasinghe, T. and S. Miththapala (2008). *Linking Coastal Ecosystems and Human Well-Being: Learning from conceptual frameworks and empirical results*. Colombo: Ecosystems and Livelihoods Group, Asia, IUCN. viii + 49 pp.

Kasperson, R. E. and J. X. Kasperson (2001). Climate change, vulnerability, and social justice. In *The International workshop on vulnerability and global environmental change workshop summary.* Stockholm, Sweden: *Stockholm Environmental Institute.* http://www.sei.se/dload/2001/sei-risk.pdf.

Kathiresan, K. and B. L. Bingham (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology* **40:** 81-251.

Kerr, R.A (2005). South Asia tsunami: failure to gauge the quake crippled the warning effort. *Science* **307**:201.

Lal, M (2001). Tropical cyclones in a warmer world. *Current Science* **80** (9).

Lewinsohn, T. M., Novotny, V. and Y. Basset (2005). Insects on plants: Diversity of Herbivore Assemblages Revisited. *Annual Review of Ecology, Evolution and Systematics* **36**:597–620.

McGuire. B (2002). *A Guide to The End of the World: Everything You Never Wanted to Know*. Oxford: Oxford University Press. 191 pp.

Millennium Ecosystem Assessment (2005). *Ecosystems and Well-being Synthesis report.* Washington DC: Island Press. v+86 pp.

Mittermeier, R. A., Gil, P. R. and C. G. Mittermeier (1997). *Megadiversity: Earth's Biologically Wealthiest Nation*s. Mexico: CEMEX, Agrupación Sierra Madre.

MNP (2006). *Netherlands Environmental Assessment Agency: China now no. 1 in CO_2 emissions; USA in second position*. http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html

National Hurricane Center (2007). http://usasearch.gov/

NOAA (2008a). http://oceanservice.noaa.gov/education/kits/estuaries/welcome.html

NOAA (2008b). http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

Orth, R. J. and 14 others (2006). A global crisis for seagrass ecosystems. *BioScience* **56**(12): 987-996.

Packham, J. R. and A. J. Willis (1997). *Ecology of dunes, salt marsh and shingle*. New York, NY: Springer. 352 pp.

Phillips, R. C., and E. G. Menéz (1988). Seagrasses. *Smithsonian contributions to the Marine Sciences*. Washington DC: Smithsonian Institution Press. 34 pp.

Poverty Database World Bank (2008). http://wbln0018.worldbank.org/dg/povertys.nsf/Poverty+assessment?openview&count=1999.

Khanh Nam, P. and Tran Vo Hung Son (2001). *Analysis of the Recreational Value of the Coral-surrounded Hon Mun Islands in Vietnam.* EEPSEA Research Report. International Development Research Centre, Ottawa, Canada. 46 pp.

Reid, H. and A. Simms (2007). *Up in smoke? Asia and the Pacific. The threat from climate change to human development and the environment*. UK: International Institute for Environment and Development. 96 pp.

Ross, S. M. Thornes, J. B. and S. Nortcliff (1990). Soil Hydrology, Nutrient and Erosional Response to the Clearance of Terra Firme Forest, Maracá Island, Roraima, Northern Brazil. *The Geographical Journal* **136**:267-282.

Svarrer, K. and C. Smith Olsen, (2005). The Economic Value of Non-Timber Forest Products- A Case Study from Malaysia *Journal of Sustainable Forestry* **20(**1): 17 – 41.

Sodhi, N.S., Koh, L. P.. Brooks, B. W. and P.K.L. Ng (2004). Southeast Asian biodiversity: an impending disaster. *Trends in Ecology and Evolution* **19**(12): 654-659.

Spalding, M. D. (1997). *The Global distribution and Status of Mangrove Ecosystems*. Intercoast Network: Mangrove Edition. Special Edition **1**: 20-21.

Spalding, M., Taylor, M., Ravilious. C., Short, F., and E. Green (2003). The distribution and status of seagrasses. Pp 5- 26 in Green E. P. and F. T. Short (2003) *World Atlas of Seagrasses*. Berkely, CA: UNEP-WCMC, University of California press. xii+298 pp.

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Natural hazard hotspots by risk type.* http://maps.grida.no/go/graphic/natural-hazard-hotspots-by-risk-type (Accessed 28 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Climate change and vector-borne diseases.* http://maps.grida.no/go/graphic/climate_change_and_vector_borne_diseases (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Main greenhouse gases.* http://maps.grida.no/go/graphic/main_greenhouse_gases1 (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Melting snow on Kilimanjaro*, http://maps.grida.no/go/graphic/melting_snow_on_kilimanjaro (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Past and future CO_2 concentrations.* http://maps.grida.no/go/graphic/past_and_future_co2_concentrations (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Potential climate change impacts.* http://maps.grida.no/go/graphic/potential_climate_change_impacts (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). T*he decrease of Arctic sea ice, minimum extent in 1982 and 2007, and climate projections* http://maps.grida.no/go/graphic/the-decrease-of-arctic-sea-ice-minimum-extent-in-1982-and-2007-and-climate-projections (Accessed 30 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Trends in natural disasters* [Internet]. [cited 2008 Aug 28]. Available from: http://maps.grida.no/go/graphic/trends-in-natural-disasters.

UNEP/GRID-Arendal Maps and Graphics Library (2008). *Tropical cyclone frequency*. http://maps.grida.no/go/graphic/tropical-cyclone-frequency (Accessed 28 August 2008)

UNEP/GRID-Arendal Maps and Graphics Library (2008). *World poverty distribution*. UNEP/GRID-Arendal Maps and Graphics Library, http://maps.grida.no/go/graphic/world-poverty-distribution (Accessed 28 August 2008)

U.S. Census Bureau (2008). http://www.census.gov/compendia/statab/tables/08s1295.pdf.

Valiela, I. Bowen, J. L. and J. K. York (2001). Mangrove Forests: One of the World's Threatened Major Tropical Environments *BioScience* **51** (10): 807-815.

Verma, M (2000). *Economic Valuation of Forests of Himachal Pradesh.* International Institute for Environmental Development. 7 pp.

Veron, J. E. N (2000). *Corals of the World*. Townsville, Australia: Australian Institute of Marine Science. 3 volumes.

WHO (1996). *The World Health Report 199*6. Geneva: WHO. vi + 137 pp.

WHO (2007). *The World Health Report 2007*. Geneva: WHO. 95 pp.

Wilkinson, C (2004). *Status of Coral Reefs of the World*, 2004 (Vol 1) Townsville, Australia: Australian Institute of Marine Science. xiv + 301 pp.

World Bank Country tables (2005). http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK: 1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html

World Resources Institute (2002). *Earthtrends database.* http://earthtrends.wri.org/

WWF (2007). http://www.panda.org/about_wwf/where_we_work/ecoregions/about/habitat_types/index.cfm)

WWF (2004). *The Economic Values of the World's Wetlands*. http://assets.panda.org/downloads/wetlandsbrochurefinal.pdf

Annex 1: a) At a glance: services provided by, and threats to lowland tropical rainforests.

Services	Description	Threats
Provisioning services (Goods)		
Food (fruits, vegetables, flavourings, spices and nuts)	Tropical rainforests support diverse plant species, of which an estimated 75,000 species are edible.[1] Fruits (such as bananas, avocados papayas, citrus fruits), vegetables (such as legumes, cassava, peppers, okra) flavourings (such as cocoa, vanilla, sugar), spices (such as nutmeg, ginger, cardamom and cinnamon) and nuts (such as peanuts, Brazil nuts, macadamia and cashew nuts) originated in the rainforest.	Habitat destruction by over-exploitation of land: slash and burn cultivation practices, cattle ranching, construction of dams for hydropower and logging of timber for hardwoods (such as mahogany, teak and rosewood) pose severe threats to tropical rainforests. Recent global estimates suggest that around 150,000km^2 of tropical rainforest - equivalent to the size of England and Wales - is destroyed every year. In addition, a similar area is damaged or degraded.[2] Conversion for cultivation: rainforests are cleared for tea and rubber plantations in Sri Lanka and for oil palm cultivation in Thailand and Malaysia.
Timber and fuelwood	Forestry is important both to the world's economy and local economies of many countries. Of the annual production of timber from tropical rainforests, 85% is used for fuel; 10% for local timber needs and 5% for export.[1] Indonesia is the world's largest exporter of tropical timber, generating more than 5 billion USD annually.[3] Rainforest timbers such as Mahogany, *Sapele*, Teak, *Meranti*, Greenheart and *Ramin* are used for a variety of purposes - ranging from furniture manufacture, paper, window sills, door frames, flooring, furniture, toys and kitchen utensils.[2]	Over-exploitation: industrial logging is one of the primary causes of global deforestation. Habitat destruction: the annual loss of primary forest cover is 60km^2/yr in Sri Lanka, 204km^2/yr in Viet Nam, 668km^2/yr in Cambodia and 14 478km^2/yr in Indonesia.[4] Legal timber harvesting affects 700,000-850,000ha of forest per year in Indonesia, but widespread illegal logging boosts the overall logged area to at least 1.2-1.4 million ha.[3] *Ramin*, found in Indonesia and Malaysia, is threatened by rampant illegal logging and over-exploitation to supply international markets, as well as by forest degradation. Fifteen *Ramin* species are categorised as Vulnerable by IUCN.[5]
Medicines	Chemicals obtained from tropical rainforest plants have revolutionised allopathic medicine. Derivatives from rainforest plants are used to treat cancer, malaria, heart disease, bronchitis, hypertension, dysentery and tuberculosis. These include quinine (used to treat malaria) and curare (a muscle relaxant) as well as vincristine and vinblastine (used to treat some forms of leukaemia).	Same as above.

Services	Description	Threats
Other Non Timber Forest Products (NTFPs)	Indigenous tribes in tropical rainforests depend on NTFPs to sustain their way of life. Several *Kayapó* villages in Brazil harvest and process Brazil nut oil for commercial distribution. Other small enterprises being expanded are based on NTFPs such as *copaiba* oil, *cupuaçu* fruit, honey, cocoa, and mahogany seeds.[7] Rattan and natural fibres such as jute, sisal and ramie are used in the production of furniture, floor coverings, bags, baskets, ropes and clothing. Gums and resins, used to make products including boots, paints, adhesives and varnishes are obtained from tropical rain forests. Plant products such as essential oils are used in products including shampoo, soap, perfume, incense, cough drops, make-up, flavourings and drinks. Dried meat preserve soaked in honey is a delicacy enjoyed by the *Veddhas*, an indigenous tribe of Sri Lanka.[8]	Habitat destruction by over-exploitation of land: slash and burn cultivation practices, cattle ranching, habitat fragmentation, construction of dams for hydropower and logging pose severe threats to tropical rainforests. Over-exploitation of rattan (*Calamus*) in Sri Lanka threatens several species, namely *C. pachystemonus, C. radiatus* and *C. ovoideus.*[9]
Supporting services		
Biodiversity	Tropical rainforests support the greatest diversity of living organisms on earth. They cover less than 10% of the earth's land area but hold 50% of the earth's terrestrial species.[10] The ancient tropical forests of Malaysia are home to 2,650 tree species, 700 species of birds, 350 species of reptiles, 165 species of amphibians, 300 species of freshwater fish, and millions of invertebrate species.[11] In the Sinharaja World Heritage Site of Sri Lanka, over 60% of the trees are endemic and many of these are rare. There are 21 endemic bird species, and a number of rare insects, reptiles and amphibians. Endemism is high, particularly for birds (95%). Endemism among mammals and butterflies is also greater than 50%.[12] Despite covering only 0.013% of the world's land surface, Sri Lanka is home to more than 2% of the world's known frog and toad species, many of which live in lowland rainforests.[3]	Habitat destruction by over-exploitation of land: slash and burn cultivation practices, cattle ranching, construction of dams for hydropower and logging pose serious threats to biodiversity. Habitat loss and degradation affect 89% of all threatened birds, 83% of mammals, and 91% of threatened plants. Sixteen thousand one hundred and nineteen plant and animal species are known to be threatened with extinction. This may be a gross underestimate because less than 3% of the world's 1.9 million described species have been assessed for IUCN's Red List of Threatened Species.[13] Invasive alien species (IAS) cause severe damage to rainforests by bringing new diseases and competing with local species. In Sri Lanka, widespread IAS include Koster's Curse (*Clidemia hirta*), and *Diyapara* (*Dillenia suffruticosa)*, *Mimosa invisa* and Guinea grass (*Panicum maximum*).[14] The illegal trade in timber from *Ramin*, an endangered Indonesian tree species, is fuelling the destruction of Indonesian rainforests and driving species such as Critically Endangered Orang-utans (*Pongo pygmaeus*), Sumatran rhinoceros (*Rhinoceros sumatrensis*) and Malayan sun bears (*Helarctos malayanus*) closer to extinction.[15] Global warming is predicted to put at least 20-30% of plant and animal species at risk of extinction.[16]

Annex 1 contd.

Services	Description	Threats
Primary production	Estimated net primary productivity in the Barro Colarado tropical forest of Panama is at least 1,320g/m^2/yr. In comparison, the net primary productivity of the much larger plantations soybean and corn in central Iowa, Illinois and Ohio, USA is 1,700g/m^2/yr.[17]	Habitat destruction: recent global estimates suggest that around 150,000km^2 of tropical rainforest - equivalent to the size of England and Wales - is destroyed every year. In addition, a similar area is damaged or degraded.
Prevention of soil erosion	Tropical rainforest trees have extensive root systems (buttress roots, prop roots) that extend deep into the soil. The presence of leaf litter, which can be a foot thick, acts to minimise the effect of raindrop impact and increases infiltration capacity by soaking up water and releasing it slowly. Hence, the topsoil is anchored and its removal by rapid sediment run-off is prevented.[18]	Habitat destruction by deforestation: without the buttressing root systems of trees and plants and the sponge effect of leaf litter, rapid run-off of rainwater results in soil erosion, removing topsoil. This leads to a build-up of soil in nearby river beds, causing flooding and affecting fresh water biodiversity.
Nutrient cycling	Tropical rainforests have an efficient nutrient cycle. Dead organic matter is decayed rapidly by many species of decomposers and detritivores, aided by the moist conditions of the forest. Carbon and oxygen are released into the air and nitrogen, calcium and phosphorous and other minerals are absorbed immediately by a thick mat of plant roots and root-like fungi (mycorrhizae). The close association between plants and fungi ensure that there is direct nutrient cycling.[19]	Habitat destruction: the soil in tropical rainforests is poor in nutrients; therefore, long term cultivation of crops cannot be sustained, resulting in the abandonment of these clearings and deforestation of new areas for cultivation.
Water purification	Rain in tropical forests does not directly reach the soil but trickles through the forest canopy. As water percolates slowly, it is purified by biological processes performed by bacteria, fungi and algae, before reaching the soil and flowing into streams.[20]	Habitat destruction: deforestation in tropical rainforests results in rapid water run-off, leading to flooding and soil erosion.
Biological and genetic resources	While domesticated plants and animals are bred and become susceptible to pests and disease, wildlife flora and fauna have diverse traits due to out-breeding. Genes of wild plants are used to strengthen varieties and to introduce disease resistance.	Deforestation and climate change affect the composition of rainforests causing the loss of genetically diverse flora and fauna.
Sequestering carbon	Tropical rainforests are vast reservoirs of carbon (carbon sinks) through CO_2 absorption and conversion to biomass by trees and plants.	Habitat destruction: deforestation in the tropics accounts for nearly 20% of carbon emissions due to human activities. This will release an estimated 87 to 130 billion tonnes of carbon by 2100, which is greater than the amount of carbon that would be released by 13 years of global fossil fuel combustion. [21]

Annex 1 contd.

Services	Description	Threats
Regulating services		
Climate regulation	Excess emission of greenhouse gases into the atmosphere results in the rise of surface temperatures, which alters major planetary weather systems. Often called the 'lungs of the earth', tropical forests help stabilise the climate through absorption of CO_2 by trees and plants. Functioning as water pumps, tropical rainforests add to local humidity through transpiration which releases water vapour to form clouds. Some of this vapour precipitates as rain over the rainforest but often, clouds are carried a great distance to precipitate as rain in the mid latitudes - as far away as Europe and Australia.	Habitat destruction: deforestation in the Amazon region of South America influences rainfall from Mexico to Texas and in the Gulf of Mexico, while forest loss in Central Africa affects precipitation patterns in the upper and lower US Midwest; deforestation in Southeast Asia was found to influence rainfall in China and the Balkan Peninsula.[7]
Flood regulation	The flora of tropical rainforests (such as epiphytes) act collectively as a giant sponge. Rain is absorbed by canopy epiphytes and percolates slowly to the bottom of the forest floor and thick layer of leaf litter. This method of precipitation prevents flooding in outer, clearer areas. In a well-forested watershed, 95% of annual rainfall is trapped and released steadily, replenishing ground water and keeping streams flowing through dry seasons.[1]	Habitat destruction: when the forest canopy is removed, the exposed soil surface bakes hard in the intense heat. Rainfall cannot penetrate easily the soil surface and is lost rapidly from the area in surface run-off, creating a flood hazard.
Cultural services		
Homes for indigenous communities	Lowland tropical rainforests support many indigenous communities. Surviving indigenous people in the Brazilian Amazon demonstrate the remarkable diversity of the rainforest because they comprise 215 ethnic groups with 170 different languages.[6] Other tropical forest groups include the *Mentawai* people of Indonesia,[22] the *Bajau* people of the Philippines[23] and the *Wanniyala-Aetto* of Sri Lanka.[24]	There were an estimated ten million Indians living in the Amazonian rainforest five centuries ago. Today, there are less than 200,000.[6] Deforestation and other factors such as the search for minerals and oil are forcing indigenous people into a steadily decreasing area. Many of the groups have to give up their original way of life, their culture and their religion, because of the destruction of rainforests.
Tourism	Tropical rainforests are of great economic value in the tourism industry. Popular tropical rainforest destinations include the Amazon Rainforest in South America, the Kerinci Sablat National Park (KSNP) in Indonesia, the Sinharaja Forest Reserve Sri Lanka and Sarawak in Malaysia.	Pollution: tourists disturb tropical rainforests by irresponsible trash disposal. Over-visitation results in habitat degradation. Intentional removal or addition of flora and fauna by uninformed tourists creates an imbalance, influencing natural species diversity.[25]

References

1. http://www.coralcay.org/science/forests/why_conserve_forests.php
2. http://www.rainforestfoundationuk.org/s-The%20Destruction%20of%20Rainforests)
3. http://rainforests.mongabay.com/20indonesia.htm
4. http://www.mongabay.com/deforestation_rate_tables.htm
5. http://www.awionline.org/wildlife/cites/press/raminprotected.htm
6. http://www.rain-tree.com/facts.htm
7. http://www.conservation.org/FMG/Articles/Pages/brazil_kayapo_ally_in_amazon.aspx
8. http://en.wikipedia.org/wiki/Veddhas
9. http://www.fao.org/docrep/003/y2783e/y2783e11.htm
10. Millennium Ecosystem Assessment (2005). *Ecosystems and Well-being Synthesis report.* Washington DC: Island Press. v+86 pp.
11. http://www.globio.org.glossopedia/article.aspx?art_id=16
12. http://www.lankalive.info/wildlife/sinharaja/sinharaja.php
13. http://cmsdata.iucn.org/downloads/species_extinction_05_2007.pdf
14. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17** (11): 930-935.)
15. http://www.ens-newswire.com/ens/feb2004/2004-02-06-11.asp
16. IPCC (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Eds. M. L. Parry, O.F. Canziani, J.P. Palutikof, P. J. Van Hanson. Cambridge, UK: Cambridge University Press. 976pp.
17. Condit, R. D. M Winsor, and S. P. Hubbell. 1996. *NPP Tropical Forest: Barro Colarado, Panama, 1969-1990. Data set*
18. Ross, S. M., J. B. Thornes and S. Nortcliff (1990). Soil Hydrology, Nutrient and Erosional Response to the Clearance of Terra Firme Forest, Maracá Island, Roraima, Northern Brazil. *The Geographical Journal* **136**: 267-282.
19. http://www.marietta.edu/~biol/102/rainfor.html
20. http://www.sciencelinks.com/lessons.cfm?DocID=275
21. rsdfsdfsdf http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2007/2007051124943.html
22. http://en.wikipedia.org/wiki/Mentawai_people
23. http://en.wikipedia.org/wiki/Bajau
24. http://en.wikipedia.org/wiki/Wanniyala-Aetto
25. http://en.wikipedia.org/wiki/Tropical_rainforests

Annex 2: At a glance: services provided by, and threats to tropical montane and sub-montane forests

Services	Description	Threats
Provisioning services (Goods)		
Timber	Seven million hectares of bamboo grow in China's mountains. In 1997, the bamboo sector generated 2.2 billion USD, including exports worth over 320 million USD and 25% of China's forest exports. This industry creates employment for 5.6 million people, including 4.5 million farmers. Bamboo is used for furniture, paper, ply-bamboo, food, medicine, and handicrafts.[1] The southwest forests of Ethiopia have served as major sources of timber for saw log, plywood, chipwood and paper industries during the last century. Over 57,987m^3, 6,273m^3 and 7,701m^3 of logs have been removed between 1982 and 1993 from the *Gera* forest, *Belete* forest and *Bonga* forest in *Oromia* and southern regions, respectively.[2]	Deforestation: cloud forests are affected by timber extraction and commercial logging in seven Asian countries, particularly in Indonesia, Malaysia and the Philippines. This reflects the presence of major logging industries in these countries. Timber harvesting was recorded for six African and six Latin American countries, principally for local construction use. Other major threats include habitat degradation and fragmentation through road construction, mining, conversion of forest area to agricultural and grazing land, fire, hunting and deforestation for drug cultivation.[3]
Non Timber Forest Products (NTFPs)	The montane forests of Thailand harbour a multitude of NTFPs, which are used by the local communities. Most of them are collected for subsistence only. These include mushrooms, honey or herbal medicine. Only few products such as the chestnuts of *Castanopsis* are sold seasonally in the market. *Camellia sinensis* grows naturally in the montane forests of Thailand.[4] The leaves of this shrub are used by villagers to produce a Thai delicacy known as *Pak Mian*g.[5] A diversity of NTFPs is exploited from cloud forests. These products include medicinal plants (extracted medicines include Quinine and Pygeum), fruits and herbs, natural gums, honey, spices, game meat and ornamental plants. Tree ferns and the abundant epiphytes such as orchids, bromeliads and mosses are extracted for horticultural markets.[3]	Clearance of cloud forests for farming is the most widely recorded threat, reported from 90% of Latin American and Asian countries and 53% of African countries. It is a major deforestation pressure in all countries with cloud forests. The cleared land is used principally for subsistence agriculture by resource poor farmers, although commercial production of temperate-zone fruits and vegetables is expanding in cloud forest areas in Asia.[3] Significant threats from planned mining operations, large dams, and high-altitude timber plantations are increasing.[6]

Annex 2 contd.

Services	Description	Threats
Supporting services		
Biodiversity	Tropical montane rainforests harbour higher levels of biodiversity than the lowland rainforests. Half of Sri Lanka's endemic flowering plants and 51% of the endemic vertebrates are limited to this ecoregion in Sri Lanka. More than 34% of Sri Lanka's endemic trees, shrubs, and herbs are found in montane rainforests. Several endemic animals - such as the Torrent toad (*Adenomus dasi*), Rhinoceros-horned lizard (*Ceratophora stoddartii*) and Sri Lanka Whistling thrush (*Myophonus blighii*) are restricted to these ecosystems.[7] Ninety of India's 484 reptile species are endemic to the montane forests of the southwestern Ghats. Almost 50% of India's 206 amphibian species are also endemic to the ecoregion.[8] More than one half of Borneo's 30 pitcher plant species are found in its montane forests. Rhododendrons are characteristic of upper montane flora, and more than twenty *Vireya* species thrive here. More than 250 bird species are also attributed to this ecoregion. Limestone forests are forests that grow on limestone hill areas. Although in southeast Asia most limestone occurs in the lowlands, Borneo has important limestone forests in the montane zone.[9, 6]	Deforestation: the primary threats to biodiversity in montane forests are from shifting cultivation, especially in the steeper slopes that people (especially in Viet Nam and Thailand) are beginning to clear because of lack of land to support increasing populations. Sub montane forests in the Knuckles Range of Sri Lanka are threatened by cultivation of cardamom and the expansion of tea plantations.[11] Large hydro projects (especially in Laos and Viet Nam) are also serious threats. Over-exploitation through illegal hunting for a huge commercial trade that supplies China; over-exploitation of eaglewood (*gaharu* - the fragrant resinous wood produced by a fungal infection in trees of the genus *Aquilaria*) and wildlife (elephant and gaur) poaching, as well as road construction are also threats to montane forests.[10] Sub montane forests in the Knuckles Range of Sri Lanka are threatened by cultivation of cardamom and the expansion of tea plantations.[11] Invasive alien species are a threat to the biodiversity of montane forests. In Sri Lanka, destructive IAS include Gorse (*Ulex europaeus*), Mistflower (*Eupatorium riparium*), *Cestrum aurantium*, Strawberry guava (*Psidium littorale*), *Naththasooriya (Tithonia diversifolia*) and the Velvet plant (*Miconia calvescens*).[12]
Watershed protection	Tropical montane cloud forests have an abundance of epiphytic plants that capture water from the condensation from clouds and fog. This 'stripping' of wind-blown fog by the vegetation becomes especially important during the non-rainy season and in areas with low rainfall but with frequent clouds. Water originating from cloud forests is also increased because water loss from vegetation wetted by rain or fog is reduced. This results in stream flows from cloud forest areas that are greater and more dependable during dry periods.[3] Montane forests are the most important catchments and watershed areas of the Knuckles range in Sri Lanka. Through the year, they play a key role in providing a water supply to sustain ecosystems and livelihoods through the year in downstream areas. They serve as the catchment for several major rivers.[11]	Of all the types of tropical forest, tropical montane cloud forests are especially vulnerable to climate change. Alterations in climate conditions will lead to the replacement of cloud forests by lower altitude ecosystems and the extinction of cloud forests currently on mountain peaks where they are unable to spread up slope. The reduction of cloudiness over the forests will result in less frequent immersion of the forest in the clouds and reduced capture of water by the vegetation, with a consequent drying out of the ecosystem. Deforestation in lowland areas also affects the hydrological role of cloud forests. Wind passing over these sparse regions lifts clouds in mountainous regions, thereby drying cloud forests.[3]

Annex 2 contd.

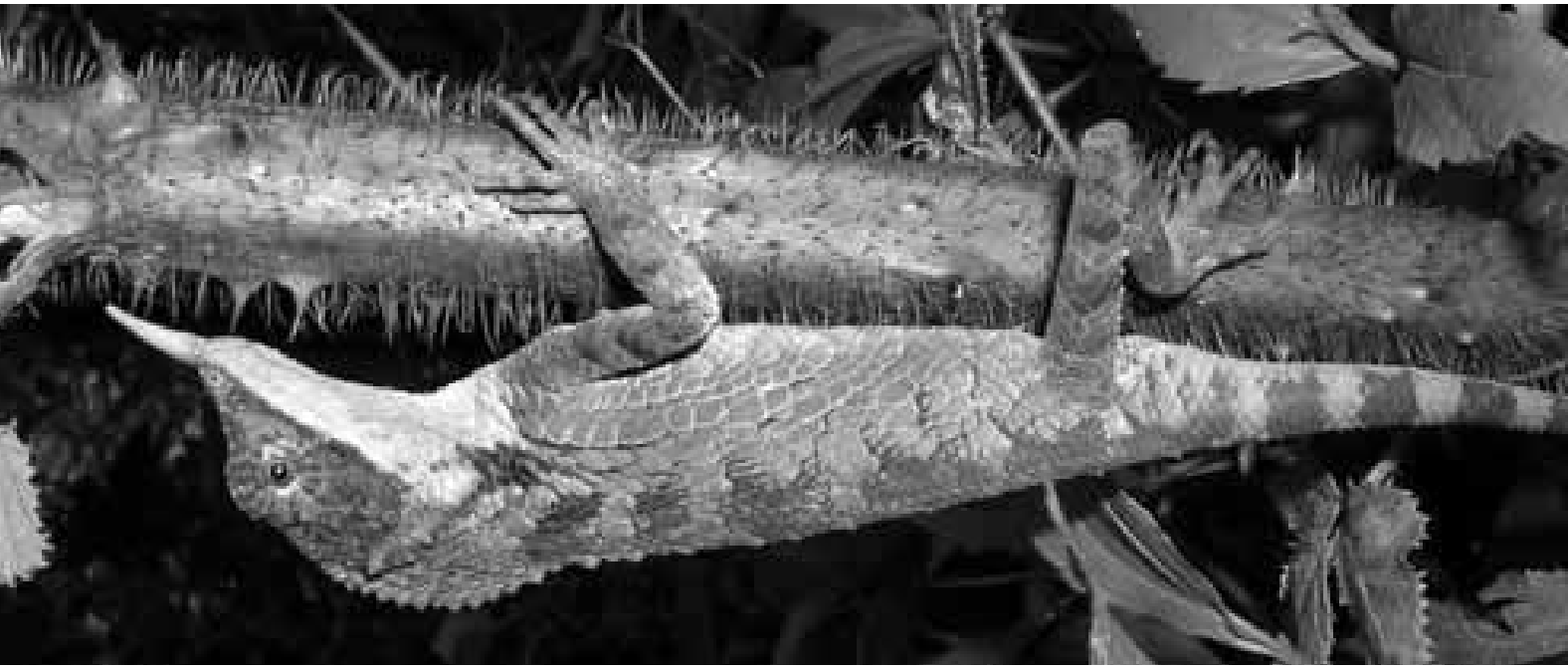
Services	Description	Threats
Supporting services contd.		
Prevention of soil erosion	Cloud forests are located on steep mountain slopes in high rainfall areas. Due to the high infiltration capacity and high organic content of their soils, cloud forests reduce soil erosion and the incidence of devastating landslides.[13]	Habitat destruction by deforestation: logging of montane forests has devastating effects on the landscape and surrounding ecosystems. Extensive erosion on surrounding deforested slopes has clogged the irrigation systems of the once fertile rice fields of Palu Valley in Indonesia.[14] Communities in the Sabaragamuwa province of Sri Lanka are vulnerable to earth slips and floods, during monsoon rains, as a consequence of the instability of hill slopes due to the loss of montane forest.[15]
Genetic resources	An important characteristic of cloud forests is that they are the natural habitat of the wild relatives of many crop species. They are, therefore, important gene pools for the continued improvement of these plants. Wild plants include relatives of papaya (*Carica papaya)*, tomato *(Lycopersicon esculentum)*, tree tomato (*Cyphomandra betacea*), species of passion fruit, avocado *(Persea americana)*, beans of the genus *Phaseolus*, the blackberry (*Rubus spp.*), cucumber (*Solanum muricatum*), potato (*Solanum spp.*) and peppers (*Capsicum spp.)*[3]	Hunting and anthropogenic fires are serious threats to the wildlife assemblages and habitats in Sulawesi, Indonesia. Hunters set fires to facilitate hunting of *Anoa*, a kind of buffalo (*Bubalus quarlesi*), creating montane meadows. Cloud forests and sub-alpine forests are subject to periods of drought, during which the oil-rich leaves of *Rhododendron, Vaccinium*, and *Gaultheria* easily catch fire destroying wild flora and fauna.[14]
Regulating services		
Sequestering carbon	Montane moist forests are also important in helping to sequester CO_2 from the atmosphere and, therefore, are major carbon sinks, helping in reducing the greenhouse effect. Current estimates have shown that the montane forests of Ethiopia sequester nearly 27,579 million kg of CO_2 per annum from the atmosphere.[2]	Climate change is the biggest threat to cloud forests, which depend on the stable position of clouds. Deforestation in lower-lying lands, even regions over 50km away, is changing the local climate, leaving cloud forests cloudless. As winds pass over deforested lowlands, clouds are lifted higher - often above the mountain tops, which dries the cloud forest - so it can no longer support the same vegetation or provide appropriate habitat for many of the rare species originally found there.[16]
Flood regulation	Cloud forests can store the water that is stripped from clouds and release it slowly to the lowland regions. In this manner, catastrophic flash floods are prevented.[13]	Deforestation of cloud forests exposes land on steep slopes which results in the incidence of floods as well as soil erosion.

Annex 2 contd.

Services	Description	Threats
Cultural services		
Tourist attractions	Tourists are attracted by the beauty of the mountain environment as well as rare species characteristic of montane rainforests. Cloud forest sites with significant tourism potential include the Monteverde cloud forest in Costa Rica, Mount Stanley in Uganda, Luquillo National Forest in Puerto Rico, Mount Makiling and Mount Pulog in the Philippines, the Cameron and Genting Highlands in peninsular Malaysia and Mount Kinabalu in Sabah, Malaysia.[3]	Pollution: tourism and recreation activities affect cloud forests through trail making and littering. Tourists also remove souvenirs from the forest. The building of attractions such as golf courses results in the destruction of cloud forests.[13]

References:

1. http://www.peopleandplanet.net/doc.php?id=1032
2. http://www.ibcet.org/?page_id=108
3. Bubb, P., May, I., Miles, L., Sayer, J (2004). *Cloud Forest Agenda*. UNEP-WCMC, Cambridge, UK.
4. P. J. Bee (1972). Economic Systems of Northern Thailand. Pp 663-665 in Structure and Change by Edward Van Roy. *Bulletin of the School of Oriental and African Studies, University of London* **35** (3).
5. http://www.fao.org/docrep/w3735e/w3735e37.htm
6. http://www.eoearth.org.article/Borneo_montane_rain_forests
7. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0155_full.html
8. http://en.wikipedia.org/wiki/Malabar_rainforests#South_Western_Ghats_montane_rain_forests
9. http://www.sabah.gov.my/htan_frc/English/Student%20Zone/Level%202/Forest%20types/limestone.htm
10. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0121_full.html
11. http://www.knucklesrange.org/biodiv.html
12. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal*, 17 (11): 930-935.
13. http://www.sciencelives.com/cloudforest1.html
14. http://www.eoearth.org/article/Sulawesi_montane_rain_forests
15. IUCN Best Practice Guidelines, After the Tsunami: Learning to prepare for natural disasters, *Information paper no. 8*. http://data.iucn.org/places/asia/coastalinfo/docs/Best_practice_guidelines_8_preparing_for_natural_distasters.pdf
16. http://cnx.org/content/m12159/latest/)



Annex 3: At a glance: services provided by, and threats to monsoon forests

Services	Description	Threats
Provisioning services (Goods)		
Timber and fuelwood	Timber extraction is an important service of monsoon forests. The principal plant species in the monsoon forests of Bangladesh is *Shorea robusta*, known commonly as *Sal*, hence these areas are also known as *Sal* forests. *Sal* is one of the most important timber yielding plant species and is used for railway sleepers, piles, beams and other load bearing parts of bridge structures, telephone poles, wheels and bodies of carts and other similar load carriers, motor trucks and structures of houses.[1] Teak (*Tectona grandis*) is found commonly as a species in monsoon forests in India and Indo-China. It is used extensively in India and prized for its durability. Teak is used to make furniture, boat decks, indoor flooring and beams in houses.[2] Approximately 16,000m^3 of wood is obtained annually from the tropical dry forests in Jalisco, Mexico.[3] Fuelwood is the only source of cooking fuel in households of the Uttara Kannada district in the Western Ghats of India. On average, each household collects about 1,900–3,300kg of fuelwood per year in the form of fallen twigs or dry branches from the moist deciduous, dry evergreen and dry deciduous forests that are characteristic of the area.[4]	Over-exploitation: of all forest regions in Bangladesh, *Sal* forests are the most threatened due to the high demand of timber, easy access and geographic location. *Sal* forests undergo rapid reduction through illicit felling, excessive leaf litter collection, encroachment and unsustainable collection of economically important plant species. The extent of forest under encroachment is approximately 0.036 million hectares with an estimated 100,000 encroachers threatening the area.[1] Teak is not considered a rare species in countries such as Thailand and India, but extraction of teak at an excessive rate has lead to forest degradation. Illegal felling of teak, particularly in the Myanmar/Thai border is of international concern.[5] Satinwood (*Chloroxylon swietenia*) and Ebony (*Diospyros ebenum*) are now rare species in the monsoon forests of Sri Lanka due to over-exploitation for timber.[6]
Non Timber Forest Products (NTFPs)	Non Timber Forest Products obtained from monsoon forests are used for food, roofing, household ornaments and utensils, fodder and for medicinal purposes. The exudates, leaves and fruits of many monsoon forest flora are prescribed by medical practitioners for ailments. Fruits from *Shorea robusta* are used to treat diarrhoeal diseases and the stem sap can be used to treat skin diseases. Serpentwood (*Rauvolfia serpentina)* is used for the treatment of snake bites and for the treatment of hypertension. Plants with medicinal properties are used to treat both humans and livestock. Garden owners and cattle farmers collect grass for use as fodder. The quantity of fodder collected in the semi evergreen zone of the Uttara Kannada district in the Western Ghats of India is 2,870 kg/household/yr.	Habitat destruction through forest-to-pasture conversion, which results in forest fragmentation; livestock grazing; slash-and-burn cultivation; and dams constructed for hydropower. Over-exploitation (excessive collection of fuelwood by indigenous people, over-exploitation of trees for timber and poaching of animals for the wildlife trade). Invasive alien species are spreading in disturbed forest areas.[7]

Annex 3: contd.

Services	Description	Threats
Provisioning services (Goods)		
NTFPs contd.	In the Uttara Kannada district, mushrooms, honey and fruits of Indian gooseberry (*Emblica officinalis)* and Bengal currant/*Karanda* (*Carissa carandas)* are collected in small quantities for use at the household level. Honey is extracted annually from the dry deciduous zone and sold commercially. Other valuable food sources include wild mangoes, lime, chilli peppers, Garcinia (*Garcinia indica)* and Ebony (*Diospyros melanoxylon)*. Gum is extracted from Axlewood (*Anogeissus latifolia*) and Soap nut (*Acacia sinuata*) is used to make shampoos. Cane, bamboo and Silver date palm *(Phoenix sylvestris)* are used to produce baskets, rooms, material for roofing, furniture and ropes.[4]	Habitat destruction through forest-to-pasture conversion, which results in forest fragmentation; livestock grazing; slash-and-burn cultivation; and dams constructed for hydropower. Over-exploitation (excessive collection of fuelwood by indigenous people, over-exploitation of trees for timber and poaching of animals for the wildlife trade). Invasive alien species are spreading in disturbed forest areas.[7]
Supporting services		
Biodiversity	The monsoon forests of Hainan Island - located in the South China Sea - support a high floral biodiversity with 4,200 plant species, 630 of which are endemic to the island. Two mammal species - the Hainan moonrat (*Neohylomys hainanensis*) and the Hainan flying squirrel (*Hylopetes electilis*) - are endemic to Hainan. Other notable mammals include the Black gibbon (*Hylobates concolor)*, the Asiatic black bear (*Selenarctos thibetanus*), and the Hainan mole (*Talpa insularis*).[8] The dry-zone dry evergreen forests of Sri Lanka are home to one of Asia's largest mammals - the Elephant (*Elephas maximus*), whose populations are estimated at 2,500 - 4,000 - as well as other large mammals such as Leopards (*Panthera pardus*) and Sloth bears (*Melursus ursinus*).[9] The Kathiarbar-Gir dry deciduous forests of India support the only surviving population of the Asiatic lion (*Panthera leo persica*).[10] The Madagascar monsoon forests are a major centre of endemism in Madagascar and have high biological importance. Endemic mammal species to the ecoregion include the Golden-crowned sifaka (*Propithecus tattersalli*), Mongoose lemur (*Eulemur mongoz*), Western forest rat (*Nesomys lambertoni)*, Golden-brown mouse lemur (*Microcebus ravelobensis*), Northern rufous mouse lemur (*M. tavaratra*), Western rufous mouse lemur (*M. myoxinus*), Perrier's sifaka (*Propithecus diadema perrieri*), Milne-Edwards's sportive lemur (*Lepilemur edwardsi*) and a species of forest mouse, *Macrotarsomys ingens*. The dry deciduous forests are one of the primary habitats for the island's largest predator, the Fossa (*Cryptoprocta ferox*).[11]	The dry deciduous forests in the Central Deccan Plateau of India are under severe threat from conversion to plantations for cash crops, over-grazing by cattle, excessive fuelwood collection and large hydroelectric projects. Habitat loss results in decreasing prey for tigers that turn to livestock as a source of food. Retaliation by the local people against these predations has affected the tiger population.[12] The primary threats to the dry-zone monsoon forests of Sri Lanka are from deforestation caused by agriculture, shifting cultivation, small-scale logging and encroachment into protected areas. Several mammals in these forests are threatened, including Asian elephants, Leopards, Sloth bears, the endemic Purple-faced leaf monkey (*Semnopithecus vetulus*) and the Sri Lanka red slender loris (*Loris tardigradus*).[13] Hunting to supply the wildlife trade has depleted wildlife biodiversity in the southeastern Indochinese dry evergreen forests, home to the Critically Endangered Javan rhinoceros (*Rhinoceros sondaicus*), one of two populations of this species on earth.[14] Invasive alien species are rampant in disturbed monsoon forests of Sri Lanka. Feral buffalo (*Bubalus bubalis*) is a common invasive animal in forest areas. Common IAS plants include Prickly lantana (*Lantana camara*), Siam weed (*Chromolaena odorata*), *Leucaena leucocephala* and the Mile-a-minute-weed (*Mikania micrantha*).[15]

Annex 3: contd.

Services	Description	Threats
Supporting services contd.		
Genetic resources	Wild species of flora and fauna found in tropical dry forests are genetically more diverse than domestic livestock and cultivated crops. Native tropical dry forest species are adapted to low and seasonal water availability. Predictions for climate change in the tropics include increasing temperatures and decreasing water availability, making tropical dry forest plant species important sources of genetic diversity which can be propagated vegetatively. Wild relatives of crops such as squash are found in dry forests in the Chamella region of Mexico.[3]	Climate change can affect genetic diversity through effects on breeding systems, plant-pollinator and plant-seed disperser interactions and species reproduction. As a consequence, genetic diversity will be lost to inbreeding and extinction of species. Over-exploitation of wild species and destruction of their natural habitat decreases surviving populations and reduces gene pools.[3]
Soil erosion	In spite of the deciduous character of monsoon forests, there is always a constant leaf litter layer on the forest floor. This protects the soil from the direct impact of raindrops which keeps high infiltration rates in the soil, preventing runoff and soil erosion.[3]	When monsoon forests are transformed into agriculture and pasture fields soil cover and infiltration rates decrease. This results in soil erosion and sediment transport which increases the incidence of flashfloods.[14]
Carbon sequestration	Carbon sequestration in the dry evergreen forests of the Kanchanaburi Province in Thailand is 70.29 tonnes C/ha.[16]	Fires during forest-to-pasture conversion in the dry forests of Mexico are a major source of CO_2 emissions to the atmosphere contributing to global warming, which further dries tropical dry forest ecosystems. Potential annual carbon emissions from the burning of biomass through slash and burn cultivation may amount to 708 million tonnes of carbon in comparison to 569 million tonnes of carbon from evergreen forests.[3]
Primary production	The net primary productivity of tropical dry forests in the Chamela region of Mexico is estimated to be 12-14 Mg/ha/yr.[3]	Teak has been shown to be sensitive to variations in climate. In India, depletion of soil moisture as a result of global warming is likely to cause teak productivity to decline from 5.40 m^3/ha/yr to 5.07 m^3/ha/yr.[17]
Maintenance of soil fertility	The strong seasonal pattern of rainfall causes nutrient leaching from forest soil. However, tropical dry forests have extremely fertile soils due to various recycling mechanisms to minimise nutrient loss from the ecosystem. The dense leaf litter layer prevents nutrient leaching by surface runoff. Further, a strong microbial population immobilises nutrients and therefore, nutrients are reabsorbed into plants prior to shedding leaves during the dry season.[18]	When forests are transformed through slash and burn cultivation, 80% of the litter layer and above ground biomass is destroyed. Forest-to-pasture conversion results in 77% of carbon and 82% of nitrogen being lost from the above ground biomass and soil erosion results in the loss of 179 and 24 kg/ha/yr of nitrogen and phosphorus respectively.[3]
Regulating services		
Climate regulation	Monsoon forests regulate the local climate by providing shade and moisture to farmers and livestock. Climate conditions on a regional and global scale are also regulated by the carbon sequestration service of these forests.[3]	Clearance of land increases the surface albedo (the direct reflection of solar radiation back to outer space) of monsoon forests. This effect, combined with increasing temperatures due to global warming, may produce some disturbances of monsoon circulation and seasonal variation in forests of the southeast Asian region. Fire - which is also influenced by fluctuations in temperature - rainfall, seasonal variation and human land use, significantly affects the structure, composition and age diversity of forests. [29]

Annex 3: contd.

Services	Description	Threats
Regulating services contd.		
Flood regulation	The Chamela region in Mexico is prone to cyclonic events with highly erosive storms. Because of the constant leaf litter layer on the forest floor, the soil has a high infiltration capacity and the occurrence of floods is reduced greatly.[30]	When monsoon forests are transformed into agriculture and pasture fields, soil cover and infiltration rates decrease resulting in soil erosion and sediment transport which increases the incidence of flash floods.[31]
Cultural services		
Home to indigenous people	Monsoon forests are home to the *Hmong* and *Yao* tribes of Thailand,[32] the *Adivasi* of Central India[33] and the *Veddas* of Sri Lanka.[34]	The biggest threat to the dry deciduous forest of the Narmada Valley in India is the construction of a series of dams along the Narmada river. Nearly 60% of the natural dry forest of this region has been cleared. These dams flood critical habitat and force large numbers of people from local communities to relocate.[35]
Tourism	Important tourism destinations in monsoon forests include the Komodo National Park in the Lesser Sunda islands of Indonesia,[36] Yala, Wasgomuwa and Minneriya National Parks in the dry-zone monsoon forests of Sri Lanka,[37] the Gir Forest National Park [38] and the Betla National Park of India.[39] The Lao system of 20 National Protected Areas covers nearly 14% of the country and is recognised as one of the best designed protected areas systems in the world. With large tracts of tropical monsoon forest, diverse wildlife populations and many ethnic minority groups, Laos' protected areas have an abundance of ecotourism attractions.[40]	Tourists disturb monsoon forests by over-visitation. This results in habitat degradation by trampling and pollution by vehicles. Removal or addition of flora and fauna by uninformed tourists creates an imbalance, influencing natural species diversity. Habituation of wildlife - such as deer and juvenile Komodo dragons - has been observed in the Komodo National Park in Indonesia. Experts project that habituation and dependency on visiting tourist adversely affects wildlife. [41] Harassment of elephants and other wild animals, off-road driving that destroys vegetation and littering by tourists threaten the Yala National Park in Sri Lanka.[42]

References

1. http://banglapedia.search.com.bd/HT/S_0035.htm
2. http://en.wikipedia.org/wiki/Teak
3. http://www.ecologyandsociety.org/vol10/iss1/art17/
4. Murthy, I. K., Bhat. P. R., Ravindranath, N. H. and R. Sukumar (2005). Financial valuation of non-timber forest product flows in Uttara Kannada district, Western Ghats, Karnataka. *Current Science Association* **88** (10): 1573-1579.
6. http://www.unep-wcmc.org/species/tree_study/asia/3-147.html
7. http://www.fao.org/DOCREP/003/W7708E/W7708E02.htm28. http://www.ecologyandsociety.org/vol10/iss1/art17/
8. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0205_full.html
9. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0169_full.html
10. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0212_full.html
11. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0206_full.html
12. http://www.worldwildlife.org/wildworld/profiles/terrestrial/at/at0202_full.html
13. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0201_full.html
14. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0212_full.html
15. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0210_full.html
16. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal*, **17** (11): 930-935.
17. www.ecology.uni-corvinus.hu/pdf/0502_093102
18. http://www.grida.no/climate/ipcc/regional/298.htm
19. www.springerlink.com/index/8237363P4J202961.pdf

Annex 4: At a glance: services provided by, and threats to scrub forests

Services	Description	Threats
Provisioning services (Goods)		
Timber and fuelwood	Trees that are important timber species such as *Palu (Manilkara hexandra),* the 'Mustard Tree' (*Salvador persica*) and Margosa/*Neem* (*Azadirachta indica*) are interspersed among the scrub vegetation in the scrub forests of Sri Lanka.[1] The *Soliga* people in the *Biligiri Rangaswarmy* Temple Wildlife Sanctuary in India depend on species such as Axlewood (*Anogeissus latifolia*), Satinwood (*Chloroxylon swietenia)*, Red Catechue *(Acacia sundra*) and *Grewia oppositifolia* for fuelwood.[2]	Over-exploitation: logging and cutting of vegetation for timber and fuelwood, excessive mining for mineral resources and over-exploitation of plant species for the ornamental plant trade. Habitat destruction: slash and burn cultivation, fires to create grazing lands and over-grazing by livestock).[3] Invasive alien species such as Mesquite (*Prosopis juliflora)*, Prickly pear (*Opuntia dillennii*) and *Lantana camara* are also spreading.[4]
Non Timber Forest Products (NTFPs)	An important NTFP of scrub forests in India is the fruit of *Nelli*/*Amla (Phyllanthus indofischeri)* which is used as a common ingredient of many medicines and tonics in traditional Indian health practices. Experimental preparations of *Nelli*/*Amla* leaf, fruit and bark extracts have properties that can be used to treat diseases such as diabetes, inflammation and age-related renal disease.[2] The *Nelli*/*Amla* fruit is used commercially to prepare pickles, jams and juices. It is also used to make hair dyes, shampoos, hair oil and tannins, which fix dyes in fabric.[5] Creole lemon (*Ampbypteryngium adstingens*), found in the open scrub forests of the volcanic complex of Colima in Mexico, is used as a cure for stomach ulcers and gastritis and *Cuachalalate (Arbutus tessellate)* is used to treat headaches.[6] Honey is a source of income and sustenance for the *Soliga* community of India.[2]	Same as above.
Mineral resources	The Jhangar Valley scrub forest of Pakistan is a site of extraction of minerals and ores such as coal, gypsum, clay and limestone. More than 100 coal mines are situated in this forest and are a source of considerable revenue for the government of Pakistan as well as the local community.[7]	Several cement factories obtain raw materials from the Jhangar Valley and destroy its scrub forest by blasting large areas to extract these raw materials. Dust particles and other pollution released by cement factories settle on scrub vegetation and block plant biological processes. Extensive coal mining has led to serious habitat degradation and erosion of fertile scrublands.[7]

Annex 4: contd.

Services	Description	Threats
Supporting services		
Biodiversity	The Deccan Thorn scrub forests of India harbour the remaining populations of Jerdon's courser (*Rhinoptilus bitorquatus*), a Critically Endangered bird species.[8] Several large mammals of conservation importance including Leopards (*Panthera pardus*), Caracals (*Felis caracal*), Indian gazelles (*Gazella bennettii*), Four-horned antelopes (*Tetracerus quadricornis*), Wild dogs (*Cuon alpinus*) and Blackbucks (*Antilope cervicapra*) find refuge in the northwestern scrub forests of India and Pakistan. These forests also harbour the Globally Threatened Indian bustard (*Ardeotis nigriceps*) and the Lesser florican (*Eupodotis indica*).[3] The Caatinga scrubland of northeastern Brazil provides habitat to over 1,200 species of vascular plants, of which 30% are endemic.[9] The Guatemalan beaded lizard (*Heloderma horridum charlesbogerti*), found in the Montagua Valley scrub forest of Guatemala, is helpful to humans as its venom is used as an effective treatment for diabetes.[10]	The Brazilian Caatinga is home to the Lear's macaw (*Anodorhynchus leari*) and the Spix macaw (*Cyanopsitta spixii*), two of the most threatened bird species in the world. More than 50% of the Caatinga has been degraded as a result of agricultural development, cattle grazing, extraction of fuelwood, extensive and uncontrolled human-induced fires and cotton cultivation.[9] The scrub forests of the Deccan Plateau are threatened by Mesquite (*Prosopis juliflora*) - an invasive alien species, which invades village pastures - resulting in the loss of grazing areas for cattle. This results in encroachment into the protected scrub forests for grazing. Other IAS include Prickly pear (*Opuntia dillennii*) and *Lantana camara*.[8] *Tillandsia xerographica*, a bromeliad endemic to the Montagua Valley scrub forest of Guatemala, is in danger of extinction because of its extraction for the ornamental plant trade. Other flora that are extracted illegally for this trade include cactus species of the genera *Mammillaria* and *Melocactus*.[11]
Carbon sequestration	Annual above ground carbon sequestration in a New Zealand scrub forest as large as 2.6 million hectares is 3.4 million tonnes of carbon.[12]	The largest potential losses of carbon from vegetation and soil are due to soil erosion, intensive grazing and over-exploitation of plant species for food and fuelwood.[12]
Regulating services		
Climate regulation	Scrub forests play a role in regulating global climate patterns through carbon sequestration. The extent of ground cover by scrub vegetation affects albedo (the amount of solar radiation that is reflected back into space) and the fraction of soil water that is transpired to the atmosphere. These effects drive atmospheric energy and water-balance processes.[13]	Over-exploitation of scrub vegetation leads to increased land albedo, reduced shade, increased surface temperatures, a rapid decrease in soil moisture which leads to reduced evaporation and reduced rainfall in the wet season.[13]
Cultural services		
Home to indigenous tribes	The scrub forests of the *Biligiri* National Wildlife Sanctuary in India are home to the *Soliga* community.[2] Other indigenous populations living in scrub forests include the *Tagbanua* of Palawan, Philippines[14] and the *Ramkokamekrá* of the Canela, Brazil.[15]	Ninety per cent of the scrub forests of the Deccan Plateau have been degraded as a result of human activities. Pastoralism is a serious cause of land degradation through heavy cattle grazing and over-exploitation of forest produce by pastoralists.[8]
Tourism	Scrub forest tourism attractions include the Biligiri National Wildlife Sanctuary of India,[2] the Montagua Valley of Guatemala[10] and the Caatingas of Brazil.[9]	Pollution through tourist activities such as irresponsible trash disposal. Over-exploitation through removal of cactus species for ornamental purposes. Habitat degradation by tourists who trample vegetation. Invasive alien species also threaten scrub forests.[16]

References

1. http://www.ias.ac.in/currsci/mar102007/586.pdf
2. Shankar. U., Murali. K. S., Shaanker. R. U., Ganeshaiah. K. N. and K. S. Bawa (1998). Extraction of Non-Timber Forest Products in the Forests of Biligiri Rangan Hills, India. Impact on Floristic Diversity and Population Structure in a Thorn Scrub Forest. *Economic Botany* **52** (3) pp: 302-315.
3. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im1303_full.html
4. Bambaradeniya, C. N. B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17** (11): 930-935.
5. Ganesan, R. and R. Siddappa Setty (2004). Regeneration of *Amla* an Important Non-Timber Forest Product from Southern India. *Conservation & Society*, **2** (2): 365-375.
6. http://www.chem.uu.nl/nws/www/publica/Studentrapporten/Studrap2006/12006-17.pdf
7. http://www.un.org.pk/undp/sgp/green-pioneers/chap-05.htm
8. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im1301_full.html
9. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt1304_full.html
10. http://www.nature.org/wherewework/centralamerica/guatemala/news/news2429.html
11. http://www.nature.org/wherewework/centralamerica/guatemala/work/art8613.html
12. http://www.rsnz.org/advisory/nz_climate/climchgwk01/tate.php
13. www.fao.org/ag/agl/agll/drylands/status.htm
14. http://www.ethnobiomed.com/content/2/1/36
15. http://www.socioambiental.org/pib/epienglish/canela/localiza.shtm
16. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0802_full.html

Annex 5: At a glance: services provided by, and threats to coniferous forests

Services	Description	Threats
Provisioning services (Goods)		
Timber	Conifers are valued for their timber as they are easy to fell, handle and saw into planks. The wood is used as building and packaging timber and in the making of chipboard and hard board.[1]	Habitat destruction: over-grazing by cattle, logging of forests to clear land for agricultural purposes and to build highways and roads. Over-exploitation: excessive resin extraction and collection of plants for their ornamental value).[2] Invasive alien species such as Crofton weed (*Eupatorium adenophorum*) and Japanese cedar (*Cryptomeria japonica*) are spreading.[3]
Non timber forest products (NTFPs)	Conifers are important sources of a wide range of non-wood products, which are derived from their foliage, bark, roots, seeds, resins and cones. Conifer wood is the main raw material for the world's paper industry and is the raw material for cellophane, viscose and wood flour used in plastics.[1] The wood, foliage and resin of conifers yield essential oils, which are important ingredients in perfumes, shampoos, disinfectants and cleaning products. Cedar wood oil obtained from *Cedrus deodara* in India has reduced the necessity to import cedar wood oil from China or the United States. Coniferous forests are home to lichens which are used as a source of dye. Some edible products from coniferous forests are eaten as delicacies. Pine nuts are an ingredient in gourmet dishes in Asian cuisine, southern Europe and the south-western United States. Juniper berries *(Juniperus communis var. depressa*) are a key ingredient of gin. Edible mushrooms harvested from coniferous forests are an important source of income. The Japanese Matsutake mushroom (*Tricholoma matsutake*), which grows in coniferous forests of *Pinus densiflora* in Japan, is an expensive delicacy.[4]	Excessive extraction of resin results in the weakening of coniferous trees which become prone to disease and die.[5] Habitat destruction: over-grazing by cattle, logging of forests to clear land for agricultural purposes and to build highways and roads. Over-exploitation: excessive resin extraction and collection of plants for their ornamental value. Invasive alien species are also spreading.[2]
Mineral resources	The Central Cordillera mountain range - in which the Luzon tropical pine forest of the Philippines is located - is famous for its mineral wealth. Its mineral resources include gold, copper, silver and zinc. Non-metallic minerals such as sand, gravel and sulphur are abundant in this region.[6]	Extensive mining of mineral resources is a major threat in the Central Cordillera and results in severe habitat destruction.[7]

Annex 5: contd.

Services	Description	Threats
Supporting services		
Biodiversity	Although they are not as rich in biodiversity as lowland tropical rainforests, tropical coniferous forests are home to many wild flora and fauna. The Sambar (*Cervus unicolor*), Barking deer (*Muntiacus muntjac*), Wild boar (*Sus scrofa*), Asiatic black bear (*Selenarctos thibetanus*) and Serow (*Capricornis sumatrensis*) are some of the species that find refuge in the northeast India-Myanmar pine forests.[5] The Sierra Madre de Oaxaca pine-oak forests of Mexico house a high diversity of reptiles and amphibians. The Canyon tree frog (*Hyla arenicolor*) and the Mexican salamander (*Ambystoma mexicanum)* find refuge in these forests. The Sierra Madre de Oaxaca is one of five centres of endemism for the Leguminosae family.[2]	Plant species of the Trans-Mexican Volcanic Belt pine-oak forests that are threatened due to selective exploitation include Mexican cedar *(Cedrela odorata)*, Mexican mahogany (*Swietenia humilis*), Shamel ash (*Fraxinus uhdei*), Arizona walnut (*Juglans major*), Basswood *(Tilia mexicana)*, Sacred fir (*Abies religiosa*), *Guayacan (Guaiacum coulteri*), *Talauma spp*. and *Magnolia iltisiana*.[8] In deforested coniferous forests, grass species - which alter the distribution and numbers of remaining flora and fauna - invade. Livestock grazing results in direct competition between native forest wildlife and livestock.[9] Invasive alien species such as Crofton weed (*Eupatorium adenophorum*) and Japanese cedar (*Cryptomeria japonica*) are critical threats in the coniferous forests of the eastern Himalayas in Nepal.[3]
Prevention of soil erosion	Coniferous forest floors have a layer of waxy pine needles, which form a dense network over the soil. This thick mat and the roots of coniferous trees provide mechanical stability of the soil. This prevents soil erosion on mountain slopes.[10]	The mountainous terrain on which coniferous forests are located favours high rates of erosion and the occurrence of landslides. The removal of vegetation by deforestation for farming, agriculture and timber increases the threat of devastating landslides and flashfloods.[8]
Source of freshwater	Tropical coniferous forests play an important role as a 'rain trap'. Rainfall percolates slowly into the soil due to the dense layer of pine needles and streams into ground-water tables and underground aquifers that supply fresh water to nearby towns.[11]	Deforestation in coniferous forests worsens the threat of soil erosion. Intense erosion of the mountain slopes contributes to poor water retention, and therefore, the lack of water availability for wildlife and humans.[8]
Carbon sequestration	Forty three percent of plantations in the tropics are of coniferous species, which are immense sinks of atmospheric carbon.[12]	Broad-leaved trees could, potentially, encroach on coniferous forests due to increasing global temperatures as a result of climate change. This will lead to a decline in coniferous species.[13]
Regulating services		
Flood regulation	The extensive root systems of conifers anchor the soil on mountain slopes and provide a mechanical barrier to surface runoff during the wet season and this minimises the incidence of flashfloods.[11]	Degeneration of the barrier provided by conifers is due to mechanical soil compaction caused by the cutting of skid trails, construction of roads, movement of logs, the pressure of heavy logging machinery and trampling by animals while working or grazing.[11]
Climate regulation	Coniferous forests sequester carbon and play a critical role in climate regulation. In Pakistan, the coniferous forests of *Murree* and *Patriata* intercept moisture laden air during the monsoon season which directly influences rainfall in surrounding regions. Coniferous forests harvest 20-25% of additional precipitation during the monsoon season.[14]	Climate change: as temperatures increase, tropical coniferous forests can be colonised by deciduous vegetation. Coniferous forests do not have an extensive microbial population due to their cold climate. An increase in temperature has the potential to alter microbial activity with unexpected results.[15]

Annex 5: contd.

Services	Description	Threats
Cultural services		
Home to indigenous cultures	Tropical coniferous forests are home to many indigenous populations. The Luzon tropical pine forest of the Philippines is a refuge for indigenous tribes such as the *Bontoc*, the *Ibaloi*, the *Ifugao*, the *Isneg*, the *Kalinga* and the *Kankana-ey*.[16]	The traditional practice of burning down most of the lower stratum of the forest to provide food for cattle is one of the most significant threats to coniferous forests. Eighty per cent of the volcanic belt pine-oak forest of Mexico has been destroyed by burning.[8]

References

1. http://www.arkiveeducation.org/resource/coniferous_forest_notes.pdf
2. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0308_full.html
3. HMGN/MFSC. August 2005. *Proceedings of the National Stakeholders' Consultation on Sacred Himalayan Landscape in Nepal.*
4. http://www.fao.org/docrep/x0453e/X0453e14.htm
5. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0303_full.html
6. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0302_full.html
7. http://www.eoearth.org/article/Luzon_tropical_pine_forests
8. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0310_full.html
9. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0309_full.html
10. Pannkuk, C. D., and P. R. Robichaud, (2003). Effectiveness of needle cast at reducing erosion after forest fires, *Water Resources Research* **39**:1333-1342
11. http://www.fao.org/docrep/x5385e/x5385e03.htm
12. http://www.actahort.org/members/showpdf?booknrarnr=615_38
13. www.grida.no/climate/ipcc_tar/biodiv/pdf/bio_eng.pdf
14. http://www.chowk.com/articles/10782
15. http://www.metla.fi/tiedotteet/2005/2005-05-23-ilmastonmuutos-en.htm
16. http://en.wikipedia.org/wiki/Igorot

Annex 6: At a glance: services provided by and threats to temperate broad-leaved and mixed forests

Services	Description	Threats
Provisioning services (Goods)		
Food	The fruits and nuts of broad-leaved trees are edible. These trees are important agricultural crops for products such as apples, pears, cherries, peaches, apricots, plums, almonds, walnuts, pecans, pistachios and olives. The nuts and fruits of temperate broad-leaved trees - such as hazelnuts, walnuts, olives and China wood oil extracted from the Asian Tung tree (*Aleurites fordii*) - are also important sources of oil.[1]	Major threats to temperate broad-leaved and mixed forests include habitat destruction (due to extensive logging, conversion of land for agriculture, clearance of land for cattle grazing and human induced fires), as well as over-exploitation (over-harvesting of tree species for non timber forest products such as cork and uncontrolled cutting of timber species).[2] Climate change and invasive alien species such as the White birch (*Betula platyphylla*) and the Dahurian birch (*Betula davurica*) are also threats.[3]
Timber	More than 70 tree species including the Korean pine (*Pinus koraiensis*), the northern Korean spruce (*Picea koraiensis*) and Mancana ash (*Fraxinus mandshurica*) are valuable timber sources in the broad-leaved and mixed forests of the Changbai mountains in China.[4]	Same as above.
Non timber forest products (NTFPs)	Temperate broad-leaved trees are a source of important NTFPs, which are derived from every part of the tree and include flowers, foliage, bark, sap, fruits and nuts. Cork - the soft, spongy inner bark of Cork oak (*Quercus suber*) - is the only product acceptable for use as a bottle stopper for fine wines and champagne. Commercially important products such as wild honey, essential oils from foliage and tannins are derived from temperate broad-leaved forests. Syrup from Maple (*Acer saccharum*) and Birch (*Betula lenta*) trees provide important sources of income. Commercially important products from organisms associated closely with temperate broad-leaved trees include edible mushrooms such as Truffles (*Tuber spp.*), Shiitake (*Lentinula edodes*) and Morels (*Morchella spp.*) produced by fungi, as well as silk produced by caterpillars feeding on the foliage of mulberry (*Morus spp.*) and Oak (*Quercus spp.*). Approximately 50,000 tonnes of Tussah silk was produced each year between 1987 and 1989 in China. Tung oil, obtained from the Asian tung tree (*Aleurites fordii*), which is native to China, is used in the manufacture of lacquer, varnishes, paints, linoleum, resins, synthetic leather, felt-based floor coverings, greases, brake linings and in cleaning and polishing compounds.[1]	Same as above.

Annex 6: contd.

Services	Description	Threats
Provisioning services contd.		
Medicine	Some organisms found in temperate broad-leaved forests have important medicinal properties. The Turkey tail mushroom (*Trametes versicolor*) is used in cancer treatments and accounts for 16% of Japan's national expenditure on anti-cancer agents. It is also used to treat pulmonary disorders and has been shown to have cholesterol lowering properties. It is also used as an immune stimulant, an antibiotic, an antiviral against hepatitis and in infections of the respiratory, urinary and digestive tract. The Chicken-of-the-woods mushroom (*Laetiporus sulphureus*) has anti-microbial and anti-oxidant properties and the Red-banded polypore (*Fomitopsis pinicola*) is used to regulate fevers and for liver and spleen support.[1]	Major threats to temperate broad-leaved and mixed forests include habitat destruction (due to extensive logging, conversion of land to agriculture, clearance of land for cattle grazing and human induced fires) and over-exploitation (over-harvesting of tree species for non timber forest products such as cork and uncontrolled cutting of timber species).[2] Climate change and invasive alien species - such as the White birch (*Betula platyphylla*) and the Dahurian birch (*Betula davurica*) are also threats.[3]
Supporting services		
Biodiversity	Temperate broad-leaved and mixed forests are hosts to diverse species of flora and fauna. From autumn to spring, the Umbrella bamboos (*Fargesia robusta* and *Yushania chungii)* attract Giant pandas to the temperate broad-leaved and mixed forests of the Sichuan giant panda sanctuary, in China.[5] The eastern Himalayan mixed forests are home to mammals such as the Endangered Golden langur (*Presbytis bieti*), Lesser panda (*Ailurus fulgens*), Clouded leopard (*Neofelis nebulosa*), Himalayan black bear (*Selenarctos thibetanus*) and Takin (*Budorcas taxicolor*). Endangered endemic plants of the broad-leaved and mixed forests of the eastern Himalayas include many orchid species such as White's Cymbidium (*Cymbidium whiteae*), Fairrie's Paphiopedilum (*Paphiopedilum fairrieanum)* and *P. wardii,* and maple species such as the Evergreen maple (*Acer oblongum*) and *Acer hookeri.*[6] The broad-leaved and mixed forests of Mount Sanqingshan in eastern China are home to rare species of flora including *Rhododendron simiarum*, the Taiwan red pine (*Pinus taiwanensis*) and the Chinese torreya (*Torreya grandis*).[7]	Same as above. Forest fires alter the composition of flora in broad-leaved and mixed forests. Tree species such as the Gmelin larch (*Larix gmelinii*) and the Scots pine (*Pinus sylvestris*) that are more tolerant of fire and need fire for seed germination will invade cleared areas and dominate the forest.[3]

Annex 6: contd.

Services	Description	Threats
Supporting services contd.		
Fertile soil	The soil of these forests is rich in organic matter derived from the annual accumulation of dead leaves from broad-leaved trees and conifer needles. A host of bacteria and fungi play a crucial role in slowly decomposing and recycling the organic matter on and within the soil, thus making it extremely fertile.[8]	Deforestation of mixed forest land for agriculture results in the loss of the leaf litter and pine needle layer and this reduces the fertility of the soil. Increased soil erosion rates - due to clearance of forest land - remove layers of soil, resulting in the loss of nutrients.[9]
Prevention of soil erosion	The forest canopy in temperate broad-leaved and mixed forests intercepts precipitation resulting in the slow percolation of rainfall to the forest floor, which is covered by a thick layer of leaf litter and pine needles. This effect minimises surface runoff. Forest tree species buttress the soil and provide a mechanical barrier to surface runoff, thus preventing soil erosion and the incidence of floods.[10]	The clearance of forest land for shifting cultivation and poppy cultivation in the Northern Triangle temperate mixed forest of Myanmar has caused severe soil erosion, loss of habitat and biological diversity.[11]
Carbon sequestration	The carbon uptake of the broad-leaved Korean pine mixed forest in the Changbai Mountains of China was 184gC/m^2 in 2003.[12] Russian temperate broad-leaved and mixed forests are huge carbon sinks because of their vast land coverage and slow rate of litter decomposition in the soil. These forests have 86.5 billion tonnes of carbon stocked in forest vegetation and 74 billion tonnes of carbon stored in the forest soil.[3]	Forest fires are a major disturbance in Russian temperate broad-leaved forests. The carbon stock in forest biomass is released by burning vegetation in forests fires, thus contributing to global warming.[3]
Source of freshwater	The forest canopy ensures that rainfall percolates slowly to the forest floor and streams into the soil and underground aquifers providing freshwater to surrounding regions. The water table depth beneath a mixed forest in southern China is 30cm deeper than beneath bare land.[10]	Deforestation of land for agriculture and cattle grazing, extensive logging and human-induced fires destroy the forest canopy and leaf litter resulting in very slow soil infiltration rates. Rainfall can no longer stream onto the forest floor and is washed off rapidly, resulting in a loss of freshwater.[13]
Regulating services		
Climate regulation	Temperate broad-leaved and mixed vegetation increase humidity and reduce maximum temperatures near the forest floor and regions surrounding the forest. Heat is absorbed by the transpiration of trees. Trees also serve as windbreaks, thereby reducing wind speeds. These forests play a role in regulating global climate conditions by sequestering carbon.[1]	Research shows that the broad-leaved and mixed forests in temperate monsoon Asia will face changes in species composition due to climate change. As air temperatures increase and rainfall decreases, the Korean pine *(P. koraiensis*) will likely disappear from the forest and the mixed forest will likely revert to predominantly hardwood forest.[14]
Flood regulation	The forest vegetation and leaf litter that intercept rainfall and the mechanical barrier provided by the roots of trees and shrubs protect the forests and surrounding regions from devastating floods.[10]	The infiltration of rain water into the soil in a medium aged mixed forest in North Carolina, USA occurs at a rate of 31.56 cm/hr, while the infiltration rate of land stripped of forest canopy and leaf litter is 11.20 cm/hr. This decrease in soil infiltration due to clearance of land can result in disastrous floods.[13]

Annex 6: contd.

Services	Description	Threats
Cultural services		
Landscape and ornamental value	Many species of temperate broad-leaved trees are important landscape and ornamental plants and are used in landscape design. Conifers and temperate broad-leaved trees are popular for bonsai culture, the technique for retaining the essential growth form of a tree but reducing it to pocket size. Popular species include the Japanese hornbeam (*Carpinus japonica*), Toringo crab apple (*Malus sieboldii*) and Yeddo spruce (*Picea Jezoensis*).[1]	Major threats to temperate broad-leaved and mixed forests include habitat destruction (due to extensive logging, conversion of land for agriculture, clearance of land for cattle grazing and human induced fires) as well as over-exploitation (over-harvesting of tree species for non timber forest products such as cork and uncontrolled cutting of timber species)[2].Climate change and invasive alien species - such as the White birch (*Betula platyphylla*) and the Dahurian birch (*Betula davurica*) are also threats.[3]

References

1. http://www.fao.org/DOCREP/005/y4351e/y4351e0e.htm.
2. www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0403_full.html.
3. Makoto. K., Nemilostiv, Y. P., Zyryanova. O. A., Kajimoto. T., Matsuura. Y., Yoshida. T., Satoh. F., Sasa, K. and T. Koike (2007). Regeneration after Forest Fires in mixed Conifer Broad-Leaved Forests of the Amur Region in Far Eastern Russia: the Relationship between species specific traits against fire and recent fire regimes. *Eurasian Journal of Forestry Research* **10**(1): 51-58.
4. http://vsia.brim.ac.cn/English/BackgroundChangbai.asp#Char3.
5. http://www.eoearth.org/article/The_Sichuan_Giant_Panda_Sanctuaries_China.
6. http://www.panda.org/about_wwf/where_we_work/ecoregions/westhimalayan_temperate_forests.cfm.
7. http://www.sqs.gov.cn/english/sw.htm.
8. http://www.zoosauvage.com/page.php/en/1/24.html.
9. Devkota. B. D., Omura. H., Kubota, T. and K. Morita (2006). State of Vegetation, Erosion Climatic Conditions and Re-vegetation Technology in Mid Hill Area of Nepal. *Journal of the Faculty of Agriculture, Kyushu University,* **51** (2): 361–365.
10. Zhou. G. Y., Morris. J. D., Yan. J. H., Yu. Z. Y. and S. L. Peng (2002). Hydrological Impacts of Reafforestation with Eucalypts and Indigenous Species: A Case Study in Southern China. *Forest Ecology and Management* **167**(1-3): 209-222.
11. www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0402_full.html.
12. http://scholar.ilib.cn/A-zgkx-ed2005z1011.html.
13. Kays. B. L. (1980). Relationship of Forest Destruction and Soil Disturbance to Increased Flooding in the Suburban North Carolina Piedmont. *Metropolitan Tree Improvement Alliance (METRIA) Proceedings* **3**:118-125.
14. Shao. G., Yan. X. and Bugmann (2003). Sensitivities of Species Compositions of Mixed Forest in Eastern Eurasian Continent to Climate Change. *Global and Planetary Change*, **37**(3):307-313.

Annex 7: At a glance: services provided by and threats to grasslands

Services	Description	Threats
Provisioning services (Goods)		
Food (Grain)	The world's major grains such as rice, wheat, rye, oats, barley corn, millet, and sorghum originated in grasslands. These grains are important commercially as they are part of the staple diet in many countries and are important for their nutritional value. Approximately 218g of 40% protein dehydrated grass supplies 18,600 units of vitamin A, 113mg of Vitamin C and 5.7g of protein.[1]	Conversion to agricultural areas has caused the greatest loss of the world's grasslands. Native vegetation is removed and replaced with farm crops, soil is exposed and is made vulnerable to wind and water erosion. Pesticides and fertilisers that affect soil composition are added and the water holding capacity of the soil is lessened, reducing the moisture available to plants and animals supported by the grasslands.[2]
Forage for domestic livestock	Grasslands provide livestock with fodder for consumption, thereby supporting human livelihoods associated with meat, milk, wool and leather products. Grasslands contribute 78 billion USD annually to the economy of the United States by supporting an estimated 60 million cattle and eight million sheep.[3] Dominant forage species in grasslands of Sri Lanka include *Arundinella spp*. and *Pollinia spp*. in montane grasslands, *Panicum spp*. and *Themeda triandra* in the lowland savannahs and *Cynodon dactylon, Stenotaphrum secundatum* and *Bothriochloa glabrain* in wet grasslands (*villu* grasslands).[4]	Humans start fires in grasslands to maintain good grazing conditions for livestock, to clear away debris and control pests. However, intense and frequent fires induced by humans destroy vegetation and increase soil erosion. Over-grazing is a significant threat to grasslands. It is most acute when livestock numbers are high, animals are confined to small grazing plots without rotation. Then soils are eroded easily and vegetation becomes sparse.[2]
Supporting services		
Biodiversity	Grasslands contribute 19% of the world's centres of plant diversity, 15% of the endemic bird areas and 30% of the World Wildlife Fund's unique ecoregions.[5] The alpine grasslands of the Qinghai province in China are home to fauna such as the Plateau pika (*Ochotona curzoniae*), Vlangal's toad-headed lizard (*Phrynocephalus vlangalii*), Hume's ground tit (*Pseudopodoces humilis*), several species of Snow finches (*Montifringilla spp.*), Asian polecats (*Mustela eversmanni*), Tibetan sand foxes (*Vulpes ferrilata*), Black kites (*Milvus migrans*), Upland buzzards *(Buteo hemilasius*), Grey wolves (*Canis lupis*) and Brown bears (*Ursus arctos*).[6] The wet grasslands of the Terai belt of the India/Nepal border host the Vulnerable Swamp francolin (*Francolinus gularis*). The Endangered Great Indian bustard (*Ardeotis nigriceps*) and the Lesser florican *(Sypheotides indica*) are key bird species characteristic of Indian grasslands.[7] Plant species characteristic of grasslands in the Republic of Palau include *Pennisetum polystachium*, Wild sugarcane (*Saccharum spontaneum*), Signal grass (*Brachiaria decumbens*), Para grass (*Brachiaria mutica*) and Congo grass (*Brachiaria ruziziensis*).[8]	Over-grazing by livestock affects the composition and structure of grasslands, as palatable and productive species decrease in abundance, while poisonous species will increase and dominate the area.[9] The Plateau pika (*Ochotona curzoniae*) - an important keystone species in the grasslands of the Qinghai province - is being poisoned over large areas to increase forage for livestock. This adversely affects a number of other species - such as Asian polecats (*Mustela eversmanni*) and Upland buzzards (*Buteo hemilasius*) - dependant on the Pika as prey. Pikas provide nesting sites in their burrows for other species, and their burrowing recycles nutrients which enhances plant species richness. Their elimination affects diverse ecological processes of the grassland ecosystem.[6] Invasive alien species that threaten grasslands in Sri Lanka include Gorse (*Ulex europaeus*), Cocklebur (*Xanthium indicum*) and the Erect Prickly pear cactus (*Opuntia stricta*) which invade coastal grasslands in south eastern Sri Lanka.[10]

Annex 7: contd.

Services	Description	Threats
Supporting services contd.		
Carbon sequestration	Grasslands store approximately 34% of the global stock of carbon in terrestrial ecosystems, while forests store 39% and agrosystems store approximately 17%. Unlike forests, where carbon is stored primarily in vegetation, most of the carbon stock in grasslands is in the soil.[11] Rehabilitation of over-grazed grasslands can result in 45 million tonnes of carbon being sequestered each year.[12]	The future capacity of grasslands to store carbon will decline if their soils are over-grazed, cleared through frequent cultivation and eroded.[12] Burning biomass in grasslands is the source of nearly 40% of gross CO_2 and tropospheric ozone. Much of these emissions originate in Africa, referred to as the 'burn centre' of the planet because of extensive burning in its savannas.[2]
Prevention of soil erosion	Grasslands such as savannahs go through periodic drought conditions, hence a majority of plants live more 'in' the soil than above it. Under the surface of the soil is a tangled web of roots and rhizomes. Some grass roots grow down to the depths of a metre in the soil, while the tap roots of soft stemmed plants reach as far as 5m to acquire water. This system of horizontal and vertical roots anchors the soil protecting it from erosion by wind and water.[9]	Over-grazing will reduce grasslands to sparse shrub lands and soil erosion will be a serious threat. Soil formation is a slow process and it takes 100-1000 years to form a 2.5cm layer of soil, which can be eroded easily when the web of roots in over-grazed grasslands wither and can no longer anchor it.[9]
Genetic resources	Agriculturally important grains originated in grasslands and these ecosystems are the primary source of genetic resources for improving crops. Research in wild grass species in grasslands will, therefore, improve genetic variation in crop species such as sorghum, whose genetic diversity is eroding significantly.[13] Plant species that are valuable forage genetic resources include False brome (*Brachypodium sylvaticum*), *Bromus himalaicus* and *Medicago spp.* Ten wild relatives of Alfalfa (*Medicago sativa*) have been found in grasslands. Many forage species from the Steppes are of interest for resistance to cold, arid and saline or alkaline conditions.[14]	Desertification results when land is degraded severely in arid, semiarid, and dry sub-humid areas. Increased pressure on dry grasslands - such as over-grazing, intensive fires and climate change - leads to desertification, which will decrease grassland productivity and water availability and threaten flora and fauna.[2] Over-grazing by livestock is rampant in grasslands. Satellite data revealed that the grasslands in *Talala Taluka* in India can support sustainably only 589 cattle. The actual cattle population size is 49,737 which is 84 times larger than the carrying capacity of *Talala Taluka*.[9]
Fertile soil	Grasslands grow in soils that are nutrient rich, due to the abundance of soil microorganisms that recycle nutrients and decompose plant tissue. Small grassland mammals - such as Pikas (*Ochotona spp.*) and Zokors (*Myospalax spp.*) - found in the Tibetan regions of China - transport organic matter between the subsoil and the surface and their burrows and provide channels to transport water and essential nutrients to underground plant stems and fibrous root systems. Wet grasslands are particularly rich in nutrients that are churned up and brought in to the ecosystem during the flooding season.[15]	The fertile soils (characteristic of grasslands) result in their conversion to agricultural land. The productive alluvial grasslands of the *Terai-Duar* savannah in Nepal, which provide habitat to the world's tallest grass species, have been converted to agricultural terrain. No more than 2% of the alluvial grassland of the Gangetic floodplain remains intact.[16]

Annex 7: contd.

Services	Description	Threats
Supporting services contd.		
Primary production	The net primary productivity of dry grassland forages in Sri Lanka is estimated to be between 68,000 and 111,000 kg/ha/yr.[17]	Desertification results when land is degraded severely in arid, semi-arid, and dry sub-humid areas. Increased pressure on dry grasslands such as over-grazing, intensive fires and climate change leads to desertification, which will likely decrease grassland productivity and water availability and threaten flora and fauna.[2]
Regulating services		
Climate regulation	Grasslands contribute to the regulation of global temperatures by sequestering carbon into their soils.[11]	Increased global temperatures degrade grassland ecosystems, decreasing their productivity and expediting desertification. Climate models predict hotter summers and warmer, wetter winters in montane grasslands, affecting species composition. Livestock grazing is a significant source of carbon emissions, contributing to global warming.[18]
Water regulation	Wet grasslands are important in flood alleviation because they retain water during the flood seasons. Due to this retention of water, surrounding regions are protected from devastating floods. The retention of water by wet grasslands within watersheds allows groundwater tables to be replenished. Riparian wet grasslands (grasslands near rivers) retain nutrients, toxic substances and sediment, thereby improving the quality of water entering watercourses.[19]	Wet grasslands are exposed to significant threats including agricultural practices such as the increased use of fertiliser, which leads to eutrophication. Land drainage practices modify natural hydrological regimes resulting in low water levels in drainage channels and ground water tables. Increased use of herbicides affects and destroys flora and fauna. Fragmentation of wet grasslands for agriculture results in isolation of species restricted to wetlands and makes them vulnerable to extinction.[19]
Cultural services		
Tourism	Grasslands are popular tourist attractions for viewing game animals, hiking, fishing, trophy hunting, observing large mammalian herbivores, diverse plant life and open-air landscapes.[14] Grassland tourism attractions include the Royal Chitwan National Park in Nepal,[16] the wet grasslands of the Knuckles range in Sri Lanka,[21] the Masai Mara[22] and the Serengeti of Kenya[23] and the Emas National Park of Brazil.[24]	Irresponsible tourism causes pollution (through irresponsible trash disposal); habitat destruction (through clearance of grassland areas to build hotels and lodges); habitat degradation (through off-road driving); and over-exploitation (through poaching of wild animals).

References

1. http://www.tuberose.com/Grasses.html.
2. http://earthtrends.wri.org/features/view_feature.php?fid=8&theme=9.
3. www.ducks.org/Conservation/Habitat/1572/EconomicBenefits.html.
4. http://www.fao.org/ag/AGP/agpc/doc/Counprof/srilanka/srilanka.htm#natural.
5. http://www.philipallan.co.uk/images/743-T2.
6. Foggin, J. M. and A. T. Smith (1996). *Rangeland Utilization and Biodiversity on the Alpine Grasslands of Qinghai Province, People's Republic of China: Conserving China's Biodiversity (II*) J. S. Peter, S. Wang and Y. Xie eds. Beijing: China Environmental Science Press. 247-258 pp.
7. http://www.rrcap.unep.org/reports/soe/sa_part2_5.pdf.
8. http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/palau.htm.
9. http://www.gisdevelopment.net/application/nrm/forestry/mi04068abs.htm.
10. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17**(11): 930-935.
11. http://www.wri.org/publication/content/8273.
12. Conant, R. T. and K. Paustian (2002), Potential soil carbon sequestration in overgrazed grassland ecosystems, *Global Biogeochemical Cycles* **16**(4):1143, doi:10.1029/2001GB001661.
13. http://www.cirad.fr/en/presse/communique.php?id=273.
14. http://www.fao.org/docrep/008/y8344e/y8344e0f.htm#bm15.4.
15. http://www.usembassy-china.org.cn/sandt/final3.htm.
16. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0701_full.html.
17. Amarasinghe. A. and M. A. Pemadasa (1983). The ecology of a montane grassland in Sri Lanka, VII, Biomass production, *Ceylon Journal of Science* **16**: 15-21.
18. http://www.grasslands-trust.org/page.php?pageid=5.
19. http://www.ramsar.org/key_guide_under-represented_e.htm.
20. http://archive.wri.org/item_detail.cfm?id=1073&section=pubs&page=pubs_content_text&z=?.
21. www.knucklesrange.org/biodiv.html.
22. www.kilimanjaro.com/kenya/mara.htm.
23. en.wikipedia.org/wiki/Serengeti.
24. www.geocities.com/TheTropics/Cabana/6292/emas.html.
25. http://www.wri.org/publication/content/8273.

Annex 8: At a glance: services provided by and threats to deserts

Services	Description	Threats
Provisioning services (Goods)		
Petroleum	Deserts are renowned for the provision of biologically derived, but non-renewable energy resources which dramatically boost the political standing and per capita GDP of several desert countries. The petroleum sector of Saudi Arabia accounts for 75% of budget revenues, 35% of GDP and 90% of its export earnings.[1] Deserts contribute more than 50% of world oil production and contain 75% of its reserves, while 28% of the world's natural gas reserves are found in the deserts of West Asia, North Africa and Central Asia.[2]	Over-exploitation of oil and natural gas reserves threatens the deserts of the Middle East. Oil extraction causes air pollution, spills and chronic leakages that affect desert surface and subsurface organisms, as well as human populations supported by deserts.[2]
Mineral resources	Deserts are rich in non-renewable mineral resources in quantities much larger than are required to support local populations. Water soluble salts such as gypsum, borates, saltpetre (potassium nitrate), table salt and sodium are exported to non-desert regions. The saltpetre and salt beds of the Atacama desert of South America contain 40% of the world's reserves of lithium, used extensively in medicine and technology. In 2004, 33% of the world's diamonds were extracted in the dry lands of Botswana and Namibia and 35% of the world's production of gold was accounted for by northwestern China, South Africa, Australia, Uzbekistan and Mali. The most important contribution of deserts to mineral wealth is their deposits of soda, boron and nitrates, which are not found in other ecosystems.[2]	Over-exploitation of mineral resources: the unsustainable mining of diamonds and copper threatens a significant area of the Namib desert, an extremely diverse habitat. When a mine reaches the end of its life, the site is abandoned and remains a mixture of deteriorated materials, mining by-products and unproductive rubble, which is coarse and chemically toxic. These sites cause pollution of land and groundwater.[2] Human induced degradation through over-grazing, clearance of woody vegetation, farming, irrigation-induced salinity, soil and water pollution by agrochemicals and groundwater exploitation also threaten deserts. As global temperatures increase due to climate change, desert regions become drier, water resources are depleted and productivity decreases further.[2]
Renewable biological resources	Desert countries such as Turkmenistan and Uzbekistan practise irrigation agriculture and export their produce such as cotton. Because of mild winter temperatures of many deserts, proper water resource management results in intensive production of vegetables, fruits and cut flowers, which are sold at high prices in non-desert regions, where temperatures are significantly lower and therefore unsuitable for the production of such crops. Dates, vegetables and cut flowers of the Negev desert of Israel are exported to Israel's non desert markets serving 90% of its population.[2]	Military activities and off-road vehicles cause extensive, lasting damage to the fragile desert cover. The Mesopotamian shrub desert - located in the Tigris and Euphrates River valleys - is an ecologically and culturally important desert. It has been degraded greatly by the recent Iraq wars.[2]

Annex 8: contd

Services	Description	Threats
Provisioning services contd.		
Medicine	Countries with large deserts such as China and India export herbal and medicinal plants. Germany imports 1,500 plant species from the deserts of China and India for medicinal purposes. Ninety five per cent of disease treatments of the Thar desert in India are provided through the use of 85 desert plant species.[2] Derived chemicals from *Hoodia gordonii* of the Kalahari desert are components of commercially marketed dietary supplements. *Hoodia* is used by desert tribesmen who use it to control their appetite when they go into the deserts for several weeks to hunt. Desert plants are adapted to the stressful environmental conditions of their habitat. Recent findings - including compounds with anti - oxidative and anti-herbivory action found in desert plants - have shown that these adaptations are chemically based. Bio-prospecting of desert flora could catalyse the pharmaceutical industry. Screening of plants in the Negev desert of Israel identified desert plant species with cytotoxic and anti-malarial properties. Further development of the medicinal potential of desert plants could, therefore, revolutionise modern medicine.[2]	The Thar desert is known to be one of the most densely populated deserts in the world. Grazing of livestock - such as sheep and goats - is intensive and affects soil fertility and destroys native vegetation. Many edible plant species are being replaced with inedible plants, thus changing the vegetation composition and ecosystem dynamics of the desert.[3]
Supporting services		
Cooling the global atmosphere	Deserts habitually cool the adjacent global atmosphere due to the desert albedo effect. (Desert albedo is the direct reflection of solar radiation by the desert's surface back to outer space.) The typical hot desert albedo is 20-35% of solar radiation reflected back to space (much higher than the 15% of the savannah and 5% of the rainforest). The albedo of snow in cold deserts - such as Antarctica - can be as high as 80%. Desert albedo cools the air in the troposphere and this cool air is dispersed by winds over great distances away from deserts to non desert dry lands, which become cooler and drier.[2]	Global warming is projected to increase desert albedo, through reducing desert vegetation cover. This will further amplify the effect of cooling the non-desert atmosphere and drying adjacent non desert drylands. Thus, whereas global climate change makes deserts drier, deserts make the global atmosphere cooler, and the drier the desert becomes, the more its cooling effect will increase. This phenomenon not only worsens desertification in deserts, but will alter the climate of non-desert regions with unpredictable consequences.[2]

Services	Description	Threats
Supporting services contd.		
Biodiversity	Although plant and species richness is low, deserts contain large numbers of ancient and relic species. Many plants occurring in Chinese deserts are relics of the Cretaceous period. The ancientness of its flora and fauna, combined with the harsh ecological conditions, determines the uniqueness of the biotic elements of deserts. China's Junggar Basin plain and Ga Shun Gobi desert are home to many endemic plant genera such as *Tetraena, Potaninia, Tugarinovia, Stilpnolepis* and *Synstemon*.[4] The Mesopotamian shrub desert is transitional between the deserts to the south and the Steppes to the north and harbours a unique biodiversity. The flora includes Umbrella-thorn acacia (*Acacia tortillis*), Shrubby rock-rose species (*Cistus spp.*) and many dwarf shrubs. Reeds and rushes grow in the wetland areas, while Poplar (*Populus euphratica*) and Tamarisk (*Tamarix*) grow along river channels. Among the plants that are unique to the deserts of Africa are *Welwitschia mirabilis* of the Namib, which is considered to be a living fossil. There is also a great variety of woody legumes and succulent (plants with thick, fleshy tissues that can store water) stemmed species such as Baobabs (*Adansonia spp.*), Commiphoras (*Commiphora spp.*), Bottle-trees (*Pachypodium spp.*), Phantom-trees (*Moringa spp.*) and Quiver trees *(Aloe dichotoma*). The Madagascar thorny thickets represent a unique, very diverse assemblage of plants and animals - such as the local baobabs and the Octopus tree (*Didierea madagascariensis*) - most of which are found nowhere else.[2] The Succulent Karoo - which is known as the world's most extraordinary desert - is the world's only plant hotspot that is found completely within the desert biome and is entirely arid. The number of plant species in the region is unparalleled anywhere else in the world for an area of its size. At least 40% of these species are endemic. Most are succulents. One-third of the world's 10,000 species of succulent plants grows in this desert.[5]	Over-grazing of livestock is a persistent threat and catalyst for desertification. Illegal hunting is a serious threat in the South Iran Nubo-Sindian desert. Egg collection and nest disturbance affect nesting migratory waterfowl. Significant portions of the Azerbaijan shrub desert and the Central Asian northern deserts are farmed under irrigation, causing water and soil pollution by the use of fertilisers and pesticides. Currently, the desert biome holds on average an abundance of original species of 68%, but the rate of biodiversity loss in deserts may double in the coming decades. A decline in original species to a mean of 62.8% by 2030 and 58.3% by 2050 is expected, as a result of the new pressures and impacts brought forward by agriculture and human land use (41% of the loss), fragmentation associated with infrastructure (40%), and climate change (6% in 2000 and 14% by 2050).[2] Climate change and increased levels of soil nitrogen caused by atmospheric nitrogen deposition may increase the dominance of invasive alien plants and decrease the diversity of plant communities in desert regions because they are tougher competitors. Dominant IAS of the Mojave desert include the grasses *Bromus madritensis ssp. rubens* and *Schismus arabicus and S. barbatus,* as well as the forb *Erodium cicutarium.*[6]
Prevention of soil erosion	Desert soil is covered by a biological crust composed of a highly specialised community of cyanobacteria, fungi, mosses and lichens. In deserts, these soil crusts perform many functions, such as the stabilisation of sand and dirt, promotion of moisture retention and the fixation of atmospheric nitrogen. The most prominent of these functions is the prevention of soil erosion as crust-forming cyanobacteria have an extensive network of filaments that secrete a sticky polysaccharide sheath that cements soil particles together. Fungi, lichens and mosses assist in soil stability through their hyphae and rhizoids, improving the resistance of soil to erosion by wind and water action.[5]	Soil crusts are adapted poorly to physical disturbances. Domestic livestock grazing, tourist activities - such as biking - and military activities affect the strength of the soil crust by breaking the sheaths and filaments of the microorganisms in the soil. This reduces the capability of the soil organisms to provide soil stability which increases the rate of soil loss sixfold.[7]

Annex 8: contd

Services	Description	Threats
Regulating services		
Climate regulation	Recent findings linking desert dust to climate regulation suggest that dust carried over oceans blocks and reflects incident sunlight, thereby causing a decrease in oceanic temperatures. The chilling effect of dust was responsible for one-third of the drop in North Atlantic sea surface temperatures between June 2005 and 2006, possibly contributing to the difference in hurricane activity between the two seasons (five hurricanes in 2006 compared to 15 hurricanes in 2005).[8]	Climate change: in deserts where rainfall is predicted to increase, desert dust flux will be reduced, sustaining, in turn, wet conditions away from deserts. Yet, due to uncertainties, projections of dust emissions for the next 100 years range between a 60% decrease to a 50% increase in dust emissions.[2]
Cultural services		
Supporting modern societies and indigenous populations	Currently, approximately 500 million people live in deserts and desert margins, totalling 8% of the world's population. Deserts support indigenous tribes such as the Bedouin tribes of the Sahara, Negev and Arabian Desert, the *San* people of southern Africa, the *Herero* people of the Kalahari Desert the *Ugyur* people of the Gobi Desert and the *Bishnois* of the Thar Desert.[2]	More than 90% of the original habitat of the Madagascar thorny thickets has disappeared through extraction of wood for firewood and charcoal, grazing and clearance for farming. Livestock browsing and human firewood collection also threaten the deserts around the Horn of Africa and in the southern Arabian Peninsula, from the Red Sea to the Gulf of Oman.[2]
Tourism	Many desert areas south of the Mediterranean basin are popular destinations for tourists from northern countries who are attracted by the balmy climate of the desert. Eleven per cent of Egypt's gross national income is from tourism. Services for the desert tourism industry also create new jobs and attract immigration into the growing desert cities.[2]	Land degradation in deserts is increased through tourist activities. Trampling causes a disturbance of the fragile desert surface; irresponsible trash disposal affects desert wildlife; increased use of water resources threatens the availability of an already scarce resource and the introduction of exotic flora and fauna by uninformed tourists disrupts and threatens desert biodiversity.[2]
Knowledge of the early history of animals, people and earth	The sparse vegetation cover, lack of thick soils and aridity of deserts provide large areas of exposed rock. The lack of precipitation that reduces chemical leaching by groundwater promotes the preservation and detection of fossils that allow deciphering the evolutionary history of plants, animals and of early man. Deserts have been treasures of paleontological findings. In the badland terrains of the cold Gobi Desert, a great diversity of late Cretaceous (65 million year old) dinosaurs and mammals have been unearthed. Egypt's Fayum Desert has preserved important Eocene-age (40 million year old) fossil treasure of early cetaceans (whales and dolphins) and sirenians (dugongs and manatees).[2]	Human induced degradation through over-grazing, clearance of woody vegetation, farming, irrigation-induced salinity, soil and water pollution by agrochemicals and groundwater exploitation threatens deserts.[2]

References

1 http://en.wikipedia.org/wiki/Economy_of_Saudi_Arabia
2. http://www.unep.org/Geo/gdoutlook/
3. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im1304_full.html
4. http://english.biodiv.gov.cn/images_biodiv/ecosystems/deserts-en.htm
5. http://www.nationalgeographic.com/wildworld/profiles/terrestrial/at/at1322.html
6. http://www.blackwell-synergy.com/doi/abs/10.1046/j.1365-2664.2003.00789.x
7. http://en.wikipedia.org/wiki/Soil_crust
8. http://www.nasa.gov/topics/earth/features/cooling_dust.html

Annex 9: At a glance: services provided by and threats to rivers and streams

Services	Description	Threats
Provisioning services (Goods)		
Food (Fish)	Fish are a rich source of protein, vitamins and minerals. Rivers and streams provide humans with fish species such as Salmon, Trout, Carp, Eel (primarily *Anguilla anguilla* and *A. japonica)*, *Ayu* (*Plecoglossus altivelis*), Milkfish (*Chanos chanos*), Tilapia (*Oreochromis niloticus*), Pickerel (*Esox niger*) and Whitefish (*Coregonus huntsmani*).[1] The Mekong River system produces 1.3 million tonnes of fish per year.[2] Freshwater fisheries in the Mekong River basin have a commercial value exceeding 1.7 billion USD and provide 80% of the animal protein consumed by 55 million people.[3] Freshwater shrimp (*Macrobrachium spp*.) found predominantly in the Indus river delta are important food species.[4]	Threats to freshwater species in rivers, streams and deltas include over-fishing, climate change, pollution by agricultural run-off and waste, water extraction for irrigation[5] and invasive alien species such as Rainbow trout (*Oncorhynchus mykiss*), Clown knife fish (*Chitala chitala*), Water hyacinth (*Eichhornia crassipes*) and Salvinia (*Salvinia molesta*).[6] Over-exploitation and the use of destructive fishing practices and methods such as derris roots, poisons, explosives, small mesh nets and fish traps lead to a reduction in populations of most fish species.[5]
Freshwater	Less than 3% of the earth's water is fresh and most of that water is frozen in the North and South poles. Rivers and streams are an important source of freshwater required for human consumption, sanitation, agriculture, the survival of terrestrial organisms and in industries.[7] The Amazon river forms the largest basin in the world and contains approximately 20% of the world's freshwater.[8] The Brahmaputra river accounts for nearly 30% of the total water resources in India.[9]	Pollution is the largest threat to rivers. Sources of pollution include effluents from livestock farms, domestic and industrial sewage, chemicals from manufacturing and agro-based industries, suspended solids from mining, domestic waste, road construction waste and heavy metals from factories. Sewage pollution causes outbreaks of water borne diseases such as cholera, typhoid and Hepatitis A that affect humans.[5]
Hydro-electric power	Many countries dependent on hydropower as an energy source rely on rivers. Hydro-electricity is generated by turbines that extract energy from fast flowing water from rivers. Major hydropower plants in Asia include the Ertan hydropower plant in China which generates 3,300 million watts annually[10], the Kukule Ganga hydropower plant in Sri Lanka[11] and the Darjeeling and Shimsa plants in India.[12]	Channelisation of rivers running through urban areas, river diversion, deepening, straightening and widening of rivers and the clearance of riverine vegetation are required to build dams, control floods and store water in reservoirs and affect rivers. These activities affect rivers, streams and the aquatic life by causing shifts in flow regimes, sediment deposition, changes in river water chemistry and processes, thereby altering the natural river ecology and hydrology.[5]

Annex 9: contd.

Services	Description	Threats
Supporting services		
Biodiversity	Rivers and streams support diverse plant and animal life, adapted differently to various water environments. Key species that are dependent on the Amazon river basin include Pink river dolphins (*Inia geoffrensis*), Manatees (*Trichechus manatus*), Jaguars (*Panthera onca*), Pumas (*Puma concolor*), River otters (*Lutra canadensis*), Tapirs (*Tapirus terrestris)*, Capybaras (*Hydrochaeris hydrochaeris*), Peccaries (*Tayassu tajacu*), Harpy eagles (*Harpia harpyja)* and one of the largest scaled freshwater fishes in the world, *Arapaima gigas*, which can reach nearly 2.5m in length.[8] The Euphrates river is home to species such as Basra reed warblers (*Acrocephalus griseldis*), Iraq babblers (*Turdoides altirostris*), Eurasian otters (*Lutra lutra*), Smooth-coated otters (*Lutra perspicillatamaxwelli*), Pygmy cormorants (*Phalacrocorax pygmaeus*), Lesser white-fronted geese (*Anser erythropus*), and Red-breasted geese (*Branta ruficollis*).[13] The Mekong river in southeast Asia is the tenth largest river in the world with a biological diversity comparable to that of the Amazon. It is home to species such as Mekong Giant catfish (*Pangasianodon gigas*), Mekong Giant carps (*Arapaima gigas*), Mekong stingrays (*Dasyatis laosensis)*, Irrawaddy dolphins (*Orcaella brevirostris)*, Giant ibis (*Thaumatibis gigantean*) and Siamese crocodiles (*Crocodylus siamensis*).[14] The Indus river delta is home to one of few species of freshwater dolphin, the Endangered Indus River dolphin (*Platanista minor*). A number of fish including the Indus baril (*Barilius modestus*), Indus garua (*Clupisoma naziri*) and Rita catfish (*Rita rita*) are endemic to this ecoregion.[4]	Rivers and streams contaminated by waste contain high levels of organic pollutants that result in eutrophication and the spread of harmful bacteria and viruses that can cause mass deaths and loss of reproductive ability of freshwater species.[5] Invasive alien fauna that threaten rivers and streams in Sri Lanka include the Rainbow trout (*Oncorhynchus mykiss*), Clown knife fish (*Chitala chitala*), Plectosomus catfish (*Hypostomus plecostomus*), Walking catfish (*Clarias batrachus*), Western mosquito fish (*Gambusia affinis)*, Tilapia (*Oreochromis mossambicus*) and Guppies (*Poecilia reticulate*).[6] Invasive alien flora that threaten rivers and streams in Sri Lanka include the Water hyacinth (*Eichhornia crassipes*), Salvinia (*Salvinia molesta*), Hydrilla (*Hydrilla verticillata*) and Canadian pondweed (*Egiria densa*).[6] Warmer temperatures as a result of global warming will lead to higher metabolic rates of species which will contribute to the proliferation of IAS in rivers and streams. Cold water species will likely become extinct in regions where water temperatures are too high to tolerate. Commonly cultured freshwater species such as carp and Tilapia may grow faster at higher temperatures, but more food is required for their growth and there is an increased risk of disease.[15]
Movement of sediment and nutrients	Fast moving water in rivers can pick up, suspend and move soil, sand and debris. This transport of sediment carries important minerals and nutrients such as nitrogen and phosphorus. These particles and nutrients are carried and deposited in river deltas, banks and floodplains making the land extremely fertile.[16] Replacing the soil nutrients carried out to sea by rivers each year with fertiliser would cost 1,000 million Indian Rupees.[17]	Dams reduce the flow of water in lower regions of rivers and limit the transport of fertile sediment downstream into deltas.[4] Climate change affects rainfall and therefore, affects river flow and underground water supplies. Some river basins will experience increased flooding while others will become progressively drier. This will have severe effects on freshwater species.[18]

Annex 9: contd.

Services	Description	Threats
Supporting services contd.		
Prevention of soil erosion	During rainstorms, unanchored soil washes into rivers affecting turbidity, composition as well as flora and fauna. Riverine vegetation stabilises the riverbank by anchoring the soil in place and preventing the erosion of soil.[22]	Deforestation of riverine and forest vegetation results in river bank erosion. The soil particles deposit on the riverbed in slow moving regions, thereby increasing water levels and the incidence of floods.[18]
Water table replenishment	Most of the earth's freshwater is underground and collects in aquifers, which store 97% of the world's unfrozen freshwater. Water from rivers and streams travels through layers of sand and gravel to recharge aquifers, renewing the underground water supply. People dig wells into these aquifers to pump out water for drinking, irrigation and industrial use.[23]	The lack of sustainable agricultural practices harms the environment by severely depleting water in rivers, lakes and underground water sources, increasing soil salinity and destroying its quality. Pollutants and pesticides washing into rivers, in turn, destroy downstream ecosystems such as coral reefs.[24]
Regulating services		
Flood regulation	Floodplains are flat areas of land that lie adjacent to rivers or streams that are periodically or occasionally flooded. During wet seasons and intense storms, these floodplains are inundated with the water that overflows from rivers. This water is retained in the plains and this prevents the occurrence of floods in regions of lower altitude. This periodic flooding brings in nutrients and minerals making flood plains very fertile and suitable for agriculture.[25]	The construction of dams, dikes, levees and physical alterations of river flow by straightening, deepening and widening river courses disrupts the natural flooding cycles, reduces flows, drains wetlands, cuts off rivers from their floodplains and flood riparian habitats, resulting in the destruction of species and the intensification of floods.[18]
Cultural services		
Supporting civilizations	Rivers have been very important to the development of civilizations and many historically important civilizations have flourished around them because of the supply of water for agriculture. The Sumerians built the first cities of the world between 4000 and 3000BC on the Tigris and Euphrates rivers. The Indus river valley was the location of the first civilization of India in 2500 - 1500BC and China's earliest civilizations were around the three large rivers, the Yellow River, the Yangtse and the West River.[26] The population of Egypt has depended on the Nile river for more than 5,000 years. Currently, the Nile delta is home to virtually all of Egypt's 78 million people.[27]	The lack of sustainable agricultural practices harms the environment by severely depleting water in rivers, lakes and underground water sources, increasing soil salinity and destroying its quality. Pollutants and pesticides washing into rivers, in turn, destroy downstream ecosystems such as corals reefs.[24] Agriculture wastes 60% or 1,500 trillion litres, of the 2,500 trillion litres of water it uses each year, which is 70% of the world's accessible water.[28]

Annex 9: contd.

Services	Description	Threats
Cultural services contd.		
Transport	Rivers were used to transport commuters and goods long before roads and railways were built.[19] Rivers are used as a cheap and efficient method of transporting logs from forests to nearby paper mills and other logging industries. Other goods transported using rivers include dry bulk cargo such as grain, cement, coal and liquid bulk cargo such as petroleum, gasoline, chemicals and liquefied natural gas.[20] Rivers form a critical link between land and sea and provide transportation routes for humans and make it possible for fish to migrate between marine and freshwater systems.[18]	Inland shipping infrastructure projects alter natural river function and habitats, as they involve water pumping, channelling, dredging and gravel and sand extraction to make deep, straight and uniformly banked waterways that cut the river off from its floodplain. Vessel operations create waves that disturb habitats and ecological processes. Also, spills and ship collisions pollute and severely damage freshwater species and habitats by the release of oil and hazardous substances such as cadmium, lead, mercury and DDT.[21]
Tourism	Rivers and streams are important tourist attractions for recreational activities such as fishing, boating, water sports, camping and their historical and cultural importance. Popular tourist destinations include the Amazon river[8], the Mekong river[3], the Ganges[29], the Nile[27] and the Congo river.[30]	Tourist actions such as irresponsible trash disposal in the river, camping and construction of toilet pits close to rivers and oil pollution and disturbance of wildlife by boating and fishing and inadvertent introduction of exotic species threaten rivers and streams.[31]

References

1. http://www.answers.com/topic/freshwater.
2. http://www.oceansatlas.org/world_fisheries_and_aquaculture/html/ecosys/inland/nateco/rivers_and_streams.htm.
3. http://www.panda.org/about_wwf/what_we_do/freshwater/problems/river_decline/10_rivers_risk/mekong_lancang/index.cfm.
4. http://www.panda.org/about_wwf/where_we_work/ecoregions/indus_river_delta.cfm.
5. http://www.wwf.org.my/about_wwf/what_we_do/freshwater_main/freshwater_conserving_river_basins/threats_to_rivers/index.cfm .
6. Bambaradeniya, C. N. B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17**(11): 930-935.).
7. www.bbc.co.uk/nature/environment/conservationnow/global/freshwater/.
8. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/amazon/index.cfm.
9. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/brahmaputra/index.cfm.
10. http://www.power-technology.com/projects/ertan/#adEnd.
11. www.water-technology.net/projects/kukule/.
12. http://en.wikipedia.org/wiki/Electricity_in_India#Hydro_Power.
13. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/euphrates/index.cfm.
14. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/mekong/index.cfm.
15. http://www.grida.no/climate/ipcc_tar/wg2/261.htm.
16. http://ga.water.usgs.gov/edu/earthriverssed.html.
17. www.iespanchayat.net.in/pdf/vol_vi-no_iv-2003.pdf.
18. http://www.panda.org/about_wwf/what_we_do/freshwater/problems/river_decline/index.cfm.
19. http://www.kented.org.uk/ngfl/subjects/geography/rivers/RiverArticles/riversfortransport.htm.
20. http://en.wikipedia.org/wiki/Bulk_cargo.
21. Wong, C. M., Williams, C. E., Pittock, J., Collier, U. and P. Schelle (2007). *World's top 10 rivers at risk*. Gland, Switzerland: WWF International.
22. http://nature.ca/rideau/e/e2c-e.html.
23. http://www.ramsar.org/info/values_groundwater_e.htm.
24. assets.panda.org/downloads/wwfbookletthirstycrops.pdf.
25. http://en.wikipedia.org/wiki/Floodplain.
26. http://library.thinkquest.org/3950/
27. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/nile/index.cfm.
28. Clay, J. (2004). *World agriculture and the environment: A Commodity-by-Commodity Guide to Impacts and Practices*. Washington DC: Island Press.
29. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/ganga/index.cfm.
30. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/rivers/congo/index.cfm.
31. http://www.boloji.com/environment/175.htm.

Annex 10: Ecosystem services provided by and threats to lakes and ponds

Services	Description	Threats
Provisioning services (Goods)		
Food (Fish)	Lakes and ponds provide humans with fish, which are highly nutritious and are the primary source of protein in developing countries. Fish obtained from lakes and ponds include *Ka tle (Acrossocheilus hexagonolepis), Mahseer* (*Tor tor* and *T. putitora*), Brown trout (*Salmo trutta*), *Lenok (Brachymystax lenok*), Arctic grayling (*Thymallus arcticus*), Common carp (*Cyprinus carpio*), *Marinka (Schizothorax argentatus*), Silver perch (*Leiopotherapon plumbeus*), White goby (*Glossogobius giurus*) and Bighead carp (*Aristichthys nobilis*).[1] The Tonle Sap lake in Cambodia is one of the most productive inland fisheries in the world, supporting over three million people and providing over 75% of Cambodia's annual inland fish catch and 60% of the Cambodians' protein intake.[2]	More than half of the world's five million lakes are threatened by human activities.[3] Threats to lakes and ponds include pollution, eutrophication, excessive water extraction, invasive alien species such as Janitor fish (*Hypostomus plecostomus*), Thai catfish (*Clarias batrachu*s) and the Golden apple snail (*Pomacea canaliculata*) in the Laguna lake basin in the Philippines. Climate change and the practice of destructive fishing methods destroy breeding and feeding areas of fish.[4]
Freshwater	Only 3% of the water on earth is fresh. Approximately 0.3% of water is found on earth's surface and lakes contain 7/8th of this freshwater. Freshwater obtained from lakes and ponds is essential for drinking, sanitation, agriculture, industry, recreation and as a habitat for freshwater flora and fauna.[5] Lake Baikal, in Russia is the world's deepest lake and holds 20% of the earth's freshwater.[6] Lake Biwa is the largest lake in Japan and supplies water for 14 million people.[7]	Pollution by heavy metals, chemical waste and pesticides from agricultural run-off, sewage and industrial waste products pose severe threats to lakes and ponds. Nitrogen and phosphorus are added to lakes from domestic sources, livestock and poultry, industries and fertilisers causing eutrophication.[8] Other threats include excessive water extraction; invasive alien species such as Janitor fish (*Hypostomus plecostomus*), Thai catfish (*Clarias batrachus*) and the Golden apple snail (*Pomacea canaliculata*) in the Laguna lake basin in the Philippines; mining activities; climate change and the use of destructive fishing gear that destroy breeding and feeding areas of fish.[4]
Medicine	The Yunnan Lake is host to 15,000 species of plants, including 60% of the plants used in Traditional Chinese Medicine.[9]	Pollution by heavy metals, chemical waste and pesticides from agricultural run-off, septic pit and industrial waste products pose severe threats to lakes and ponds. Nitrogen and phosphorus are added to lakes from domestic sources, livestock and poultry, industries and fertilisers causing eutrophication.[8]

Annex 10: contd.

Services	Description	Threats
Supporting services		
Biodiversity	Lake Baikal supports 2,500 species of known plants and animals, of which 1,500 are endemic. This lake has hydrothermal vents at a depth of 400m that support reefs of living sponges, bacterial mats, snails, transparent shrimp and fish. The endemic Baikal seal (*Phoca sibirica*) is the only landlocked seal species in the world.[6] Lake Biwa hosts a number of endemic fauna such the Biwa trout (*Oncorhynchus masou rhodurus*), *Wataka (Ischikauia steenackeri), Honmoroko (Gnathopogon caerulescens)*, *Biwa higai (Sarcocheilichthys variegatus microoculus)*, *Abura higai (Sarcocheilichthys biwaensis)*, *Sugomoroko (Squalidus chankaensis biwae*), and the *Gengorou crucian* carp (*Carassius cuvieri*).[7] Lake Ganga in Mongolia is of great importance for breeding and stop-over water birds such as White-naped Crane (*Grus vipio*), Swan Geese (*Anser cygnoides*) and Great Bustards (*Otis tarda*).[10] Lake Inle in Myanmar is home to the endemic Inle swamp eel (*Chaudhuria caudata*) and Inle barb (*Sawbwa resplendens*).[11] Lake Victoria in Africa housed nearly 400 species of cichlid fishes, all of whom evolved with astonishing rapidity from five ancestral species, making this lake a living laboratory.	Pollution by heavy metals, chemical waste and pesticides from agricultural run-off, septic pit and industrial waste products pose severe threats to lakes and ponds. Nitrogen and phosphorus are added to lakes from domestic sources, livestock and poultry, industries and fertilisers causing eutrophication.[8] Invasive alien fauna that threaten lakes and ponds in Sri Lanka include the Clown knife fish (*Chitala chitala*), Plectosomus catfish (*Hypostomus plecostomus*), Guppies (*Poecilia reticulata*) and the Golden apple snail *(Pomacea canaliculata*).[12] Invasive alien flora that threaten lakes and ponds in Sri Lanka include the Water hyacinth (*Eichhornia crassipes*), Salvinia (*Salvinia molesta*), Hydrilla (*Hydrilla verticillata*) and the Leafy elodia (*Egiria densa*).[12] China's Hebei province has lost 969 of its 1,052 lakes as a result of water extraction. Diverting river water for crops in dry areas and dry seasons reduces the flow of water to lakes and when excessive groundwater extraction exceeds recharge from precipitation, water tables and lake levels fall.[3] Introduction of the Nile Perch (*Lates niloticus*) has caused the death of nearly 200 species of cichlid fishes in Lake Victoria, because it preyed on these cichlids.
Water purification	The vegetation in lakes and ponds have the capacity to remove high levels of nutrients especially phosphorus and nitrogen from agricultural run-off. The vegetation along the edge of Lake Victoria in East Africa was found to have phosphorus retention of 60-92%. *Typha* and *Phragmite* species (a species of reed) can filter and purify lakes from heavy metals such as cadmium, zinc, mercury and vanadium from mining areas.[13] Entire lakes and ponds have a natural capacity to cleanse themselves. These ecosystems have interlinked food webs in which organisms assimilate incoming nutrients, moving nutrients up from the simplest single cell bacteria to large fish. This process cleanses lakes and ponds from excess nutrients.[9]	Excessive nutrient loading overwhelms the ability of the entire ecosystem to assimilate nutrients. The addition of nitrogen and phosphorus leads to eutrophication and the rapid growth of algae which use up the lake resources thus depriving other freshwater species of oxygen and nutrients. The lake-wide algal bloom of *Microcystis sp*. in Laguna lake in the Philippines killed five million milkfish (*Chanos chanos*) in 1973.[4] Acid rain, caused by hydrated sulphur and nitrogen released by burning fossil fuels, is destroying thousands of lakes. Approximately 12,000km^2 of lakes in Norway have been acidified resulting in the loss of fish stocks. Sweden has 4,000 acidified lakes while in Canada, 14,000 lakes are acidified severely, threatening aquatic life.[3]
Water replenishment	Most of earth's freshwater is underground and collects in aquifers, which store 97% of the world's unfrozen freshwater. Water from lakes and ponds filters through layers of sand and gravel to recharge aquifers, renewing the underground water supply. People dig wells into these aquifers to pump out water for drinking, irrigation and industrial use.[14]	The lack of sustainable agricultural practices harms the environment by severely depleting water in lakes, rivers and underground water sources, increasing soil salinity and destroying its quality.[15]

Annex 10: contd.

Services	Description	Threats
Regulating services		
Flood regulation	Lakes and ponds fluctuate in volume according to rainfall and climate changes, thereby preventing floods. Floodplains are flat areas of land that lie adjacent to large lakes and are flooded with overflowing water during rainy seasons, thereby reducing the incidence of floods.[16] During the monsoon season, the Tonle sap river reverses its flow and pushes water into the Tonle sap lake increasing its area and depth and filling the floodplains. This process brings in nutrients and sediment to the floodplain providing a perfect breeding ground for fish.[17]	Deforested areas and farmland erode into lakes, increasing sediment and silt. This reduces the storage capacity of lakes and increases the risk of floods. The Hamoun Lakes in Iran are losing their ability to mitigate floods as they are drying from the damming of the Helmand River and years of drought.[3] The devastating flooding of China's Yangtze River in 1998, which wreaked more than 30 billion USD in damages, was attributed largely to deforestation and the loss of more than 13,000km^2 of lake area along the Yangtze's middle and lower reaches. The loss of 800 lakes deprived the river of water storage capacity and flood protection.[3]
Climate regulation	Lakes affect weather patterns by cooling surrounding regions. Within a 50-80km zone around Lake Victoria the climate is cooler, never exceeding 27^{o}C, compared to further regions.[18] Lakes stabilise regional climates by absorbing heat. Freshwater has a high specific heat capacity and so requires a large amount of heat energy for a small increase in temperature. Conduction, convection and currents mix this energy over a thick layer of water thus maintaining cool weather conditions. Exchanges of heat and moisture above lakes modify weather patterns.[19]	Increasing global temperatures will cause the ice cover in lakes to decrease with large changes in lake water levels. As increasing temperatures thin ice sheets on lakes, light which was blocked previously will penetrate surface waters causing shifts in the lake biota.[20] Nutrient cycling will be altered by climate change in ways that could worsen nutrient loading threats such as eutrophication. Wetter climates will likely increase the export of nutrient and sediment to lakes and a warmer climate will likely allow the invasion of new species of fish that will upset the ecological balance of biota.[21]
Cultural services		
Tourism and recreation	Lakes generate income as they are popular tourist attractions for fishing, camping, angling and boating activities. Important lakes in tourism include the Tonle sap lake in Cambodia,[22] Lake Inle in Myanmar,[23] the five Great Lakes in the US (Ontario, Huron, Erie, Michigan and Superior)[24] and Lake Baikal.[25]	Tourism threatens the well-being of lakes because of over-visitation, irresponsible trash disposal, increased extraction of freshwater from lakes for use by tourist lodges, oil pollution of lakes and disturbance of aquatic wildlife by tourist activities such as boating and fishing and inadvertent introduction of invasive alien species.[26]

References

1. http://www.fao.org/docrep/003/x2614e/x2614e09.htm#P5_0
2. http://en.wikipedia.org/wiki/Tonle_Sap
3. http://www.earth-policy.org/Updates/2005/Update47.htm
4. http://www.millenniumassessment.org/documents_sga/Philippine%20SGA%20Report.pdf
5. http://www.panda.org/about_wwf/what_we_do/freshwater/about_freshwater/index.cfm
6. http://www.panda.org/about_wwf/where_we_work/ecoregions/lake_baikal.cfm

7. http://www.panda.org/about_wwf/where_we_work/ecoregions/lake_biwa.cfm
8. http://www.waterencyclopedia.com/Oc-Po/Pollution-of-Lakes-and-Streams.html
9. http://www.panda.org/about_wwf/where_we_work/ecoregions/yunnan_lakes_streams.cfm
10. http://www.ramsar.org/wn/w.n.mongolia_five.htm
11. http://www.panda.org/about_wwf/where_we_work/ecoregions/lake_inle.cfm
12. Bambaradeniya, C. N. B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17** (11): 930-935.
13. www.millenniumassessment.org/documents/document.289.aspx.
14. http://www.ramsar.org/info/values_groundwater_e.htm
15. assets.panda.org/downloads/wwfbookletthirstycrops.pdf
16. http://en.wikipedia.org/wiki/Floodplain
17. http://en.wikipedia.org/wiki/Tonle_Sap
18. http://www.panda.org/about_wwf/where_we_work/ecoregions/rift_valley_lakes.cfm
19. Ackerman, S. A. and J. A. Knox (2003). *Meteorology: Understanding the Atmosphere*. Pacific Grove, California: Thompson Brooks Cole. 486 pp.
20. http://www.ipcc.ch/ipccreports/sres/regional/046.htm
21. http://www.grida.no/climate/ipcc_tar/wg2/262.htm
22. http://www.wcs.org/globalconservation/Asia/Cambodia/Cambodia_Eco-tourism
23. en.wikipedia.org/wiki/Inle_Lake
24. www.great-lakes.net/tourism/
25. en.wikipedia.org/wiki/Lake_Baikal
26. Hadwen. W. L., Arthington, A. H. and T. D. Mosisch (2003). The impact of tourism on dune lakes on Fraser Island, Australia. *Lakes & Reservoirs: Research and Management* **8**(1) 15-26.

Annex 11: Ecosystem services provided by and threats to swamps, marshes and peatlands

Services	Description	Threats
Provisioning services (Goods)		
Timber	Forested swamps and peat swamps are a source of timber species such as *Ramin* (*Gonystylus bancanus*), Paper bark tree (*Melaleuca cajeputi*), Red Balau (*Shorea balangeran*), *Jelutong* timber (*Dyera costulata*), Ant rattan *(Korthalsia flagellaris*) and Wild durian (*Durio carinatus*).[1]	*Ramin* is a valuable light hardwood species and is threatened severely by over-exploitation. Its distribution is restricted to Indonesia and Malaysia, whose peat swamp forests have been depleted severely.[2] Peat swamp forests are threatened by the expansion of forestry operations, which could lead to the over-exploitation of important species for timber and pulp such as Red Balau.[3]
Food (finfish, shellfish)	Common edible fish species in the east Kalimantan peat swamp forests include the Climbing Perch *(Anabas testudineus*), Snakehead murrel *(Channa striata),* Catfish *(Clarias sp*.) and Helicopter catfish *(Wallago leerii*). Prawn species - such as the Giant freshwater prawn *(Macrobrachium rosenbergii)* - are also a source of nourishment.[4] Fish species such as Tilapia (*Oreochromis esculentus and O. variabilis*) are found in the Yala swamp in Kenya and are used to meet the protein requirements of its human population.[5]	Over-exploitation of fish and shrimp species threatens the freshwater swamps in Irrawady, Myanmar.[1] The use of dynamite and toxic chemicals to capture either live or dead fish destroys habitats and kills other non-target organisms in swamps, peatlands and marshes.[6]
Non timber forest products (NTFPs)	Tube sedge (*Lepironia articulata*) - a reed found in the peatlands of Thailand - is woven to make baskets, mats, hats and sacks.[8] Forested swamps, marshes and peatlands are important sources of fruits - particularly berries - as well as mushrooms, latex, resins, tannins and fodder for animals.[9]	Viewed conventionally as wastelands, a vast number of swamps, marshes and peatlands have been destroyed and converted to agricultural lands for their nutrient rich fertile soil. In Indonesia, peat swamps forests are being cleared for timber plantations and cultivation of oil palm and other commercial crops.[10]
Peat (fuel)	Peat soil has been mined extensively in western Europe and South America for domestic and industrial fuel. Peat mining for use in the horticulture industry is a multi-million dollar industry in Europe.[11]	Human induced fires for the clearance of peatland for agriculture destroy peat, release stored carbon into the atmosphere - adding to global warming. They eliminate seed banks and destroy soil. All of this may take thousands of years to be replaced naturally.[12]
Medicine	Medicinal plants obtained from the east Kalimantan peat swamp forest have an economic value of 1,750 USD. Indigenous tribes in the peat swamps of east Kalimantan rely on traditional herbs such as *Kacip Fatimah (Labisia pumila*) and *Tongkat Ali (Eurycoma longifolia*).[13] Medicinal plants found in South American include *Chapeu de couro (Echinodorus macrophyllus*), which is used as a diuretic[14] and in Africa, *Ngoka (Thomandelsia laurifolia),* which is used to treat colic, fever and diarrhoea.[15]	Viewed conventionally as wastelands, a vast number of swamps, marshes and peatlands have been destroyed and converted to agricultural lands for their nutrient rich fertile soil. In Indonesia, peat swamps forests are being cleared for timber plantations and cultivation of oil palm and other commercial crops.[16]

Annex 11: contd.

Services	Description	Threats
Supporting services		
Biodiversity	Peat swamps are extreme habitats and support an array of diverse species adapted to living under such harsh conditions. The North Selangor Peat Swamp Forest of Malaysia is home to the Fighting fish (*Betta livida*), Blackwater snakehead (*Channa bankanensis*), Licorice gouramy (*Parosphromenus anjunganensis and P. ornaticauda*) and the Peat swamp barb (*Puntius rhomboocellatus*).[10] The peat swamp forests in Borneo are key habitats for the endangered Proboscis monkey (*Nasalis larvatus*), which is endemic to Borneo and the Asian arowana (*Scleropages formosus*), a popular aquarium fish.[3] The Irrawady freshwater swamp forests are important wetlands for migratory birds such as the Mongolian plover (*Charadrius mongolus*), Spoon-billed sandpiper (*Eurynorhynchus pygmeus*), Black-tailed godwit (*Limosa limosa*), Eurasian curlew (*Numenius arquata*), Temminck's stint (*Calidris temminckii*) and the Asian openbill stork (*Anastomus oscitans*).[1] Freshwater marshes support fauna such as the Vietnamese pond turtle (*Mauremys annamensis)* and flora such as reeds (*Phragmites australis*), prostrate grasses (*Aeluropus littoralis*) and Sawgrasses (*Cladium spp*).[11]	Viewed conventionally as wastelands, a vast number of swamps, marshes and peatlands have been destroyed and converted to agricultural lands for their nutrient rich fertile soil. In Indonesia, peat swamps forests are being cleared for timber plantations and cultivation of oil palm, rice and other commercial crops.[3] Invasive alien flora that threaten freshwater swamps and marshes in Sri Lanka include Salvinia (*Salvinia molesta*), Water hyacinth (*Eichhornia crassipes*), Canadian pondweed (*Elodia canadensis*) and Giant Mimosa (*Mimosa pigra*).[12] Invasive alien fauna that threaten swamps and marshes in Sri Lanka include the Clown knife fish (*Chitala chitala*), Plectosomus catfish *(Hypostomus plecostomus*), Guppy (*Poecilia reticulata*) and Western mosquito fish (*Gambusia affinis*).[12] Illegal hunting and habitat loss has led to the extinction of key species such as Swamp deer (*Cervus duvaucelii*) in the freshwater swamp forests of the Sunderbans.[13]
Absorption of pollutants	As water moves slowly through a marsh, sediment and other pollutants settle on vegetation and the marsh bed. Marsh vegetation and microorganisms absorb pollutants and excess nutrients - such as nitrogen and phosphorus - that would otherwise pollute the surface water. Cypress swamps in Florida, USA can remove 98% of the nitrogen and 97% of the phosphorus that would otherwise have entered the groundwater.[7]	Viewed conventionally as wastelands, a vast number of swamps, marshes and peatlands have been destroyed and converted to agricultural lands for their nutrient rich fertile soil. In Indonesia, peat swamps forests are being cleared for timber plantations and cultivation of oil palm and other commercial crops.[3]
Supplying water aquifers	Swamps and marshes replenish underground aquifers with freshwater and moderate stream flow by providing water to streams, which is a very important function in periods of drought. A 223,000ha swamp in Florida has been valued at 25 million USD per year for its role in storing water and recharging the aquifers.[15]	Same as above.
Carbon sequestration	Peatlands and swamps regulate and affect regional climates by sequestering carbon.	In addition to releasing carbon into the atmosphere and contributing to global warming, peat fires affect human health. In areas where peat fires are common, 30% of children under the age of five have respiratory illnesses and linked growth inhibition.[14]

Annex 11: contd.

Services	Description	Threats
Regulating services		
Flood regulation	The presence of marshes in watersheds prevents flooding by slowing down flood water and retaining it during wet seasons. Peatlands function as sponges and can soak up rainwater during rainy seasons and control water levels in rivers.[16]	Destruction of swamps, marshes and peatlands for agriculture destroys the natural water retention capacity of the land and results in the rapid release of water during wet seasons leading to devastating floods.[17]
Climate regulation	Swamps, marshes and peatlands that cover large areas contribute to local climates by absorbing heat and maintaining regional evapo-transpiration thus contributing to rainfall.[18]	Viewed conventionally as wastelands, a vast number of swamps, marshes and peatlands have been destroyed and converted to agricultural lands for their nutrient rich fertile soil. In Indonesia, peat swamps forests are being cleared for timber plantations and cultivation of oil palm and other commercial crops.[3]
Cultural services		
Home to indigenous people	Indigenous communities dependent on peat swamps include the *Orang Asli* and the *Orang Jakun* tribes living near the boundaries of the south east *Pahang* Peat Swamp Forest in Peninsular Malaysia.[4]	Same as above.

References

1, http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0116_full.html.
2. http://www.abc.net.au/4corners/content/2002/timber_mafia/resources/resources_ramin.htm.
3. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0104_full.html.
4. http://www.peatsociety.org/user_files/files/ramakrishna.
5. http://www.jaluo.com/wangwach/1106/Leo_Odera_Omolo112306.html.
6. http://www.adb.org/Documents/Policies/Fisheries/fish420.asp?p=policies.
7. http://www.millenniumassessment.org/documents/document.289.aspx.
8. http://www.iracambi.com/english/downloads/med_brief.pdf.
9. http://www.shc.usp.ac.jp/kuroda/medicinalplants.html.
10. http://www.dbs.nus.edu.sg/biodiversitii/bio/peat.htm.
11. http://en.tourduvalat.org/la_tour_du_valat/les_zones_humides/la_vegetation_et_la_faune.
12. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal.* **17** (11): 930-935.
13. http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0162_full.html.
14. http://www.biofuelwatch.org.uk/peatfiresbackground.
15. http://www.ramsar.org/info/values_groundwater_e.htm.
16. http://www.epa.gov/owow/wetlands/types/swamp.html.
17. http://www.ramsar.org/info/values_floodcontrol_e.htm.
18. http://www.nwri.ca/threats2full/ch13-1-e.html.

Annex 12: Ecosystem services provided by and threats to mangroves

Services	Description	Threats
Provisioning services (Goods)		
Food (fin fish, shellfish, vegetables and other plant parts)	Mangroves are permanent or temporary habitats for many aquatic animals and are also hatching and nursery grounds for many marine fish. It is estimated that up to 80% of global fish catches are directly or indirectly dependent on mangroves.[1]	Over-exploitation (shrimp and other aquaculture, unsustainable fishing practices, overharvesting); habitat destruction though coastal development and land reclamation; and inland freshwater extraction.[2,3]
Timber and fuelwood	All over the world, the timber of mangrove flora is used to build houses, make furniture, rafters, fences, bridges, poles and boats. Mangrove wood is also used as fuelwood and still provides 90% of the fuel used in Viet Nam.[4]	Same as above.
Medicines	About 70 different mangrove flora are listed as having traditional medicinal uses for treatment of various ailments and diseases. In parts of Indonesia, traditional use of mangrove products contributes up to a half of income among the poorest households, and in southern Thailand is thought to generate products worth almost a quarter of per capita GDP among coastal villages.[4]	Same as above.
Other Non Timber Forest Products (NTFPs)	The leaves of species such as Water Palm (*Nypa)* and Screwpine (*Pandanus)* are used for thatching and weaving and light woods such as *Cerbera manghas* used to carve masks and puppets. The breathing roots of various *Sonneratia spp.* are used to make corks and fish floats. Mangrove plants are sources of sodium and the ash of some species such as *Avicennia* is used as soap. The barks of many species produce gums and tannins, which are still used in the Indian subcontinent for curing leather and fish nets. In the Bangladesh and India, honey from mangroves is an important local industry. Mangrove leaves, fruits, shoots and roots serve as vegetables and edible fruits in many parts of the region and other non-timber forest products such as sugars and drinks are extracted from different species.[4]	Same as above.

Annex 12: contd.

Services	Description	Threats
Supporting services		
Biodiversity	Because mangroves grow between the land and the sea, mangrove species are adapted uniquely to live in extreme and variable conditions. Mangroves, therefore, carry an unique assemblage of flora and fauna found in no other ecosystem.[5]	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, overharvesting); coastal development and land reclamation; inland freshwater extraction; pollution[2,3]; and spread of IAS are serious threats. Mangroves in the southwestern Sri Lanka are being affected by the spread of Alligator/Pond apple *(Annona glabra*) and *Wormia suffruticosa.*[5]
Protecting the shoreline	Mangroves act as physical buffers between the elements and the shore, and can absorb at least 70-90% of the energy of the waves, depending on their ecological condition.[6]	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation.[2,3]
Promoting accretion	Mangroves function much like a living groyne to build up sediment, stabilising the ground and fixing mud banks. Therefore, they prevent erosion. They also protect coral reefs from sedimentation.[7]	Same as above.
Primary production	Estimated net primary productivity values of up to 7.5g C/m/day for mangrove forests in Florida, USA. In comparison, a heavily fertilised and managed sugarcane field has a maximum net productivity of 10g C/m/day.[8]	Same as above.
Enriching nutrients	It is estimated that every time the tide goes out, it takes with it as much as 12,500 tonnes of food for marine life each year.[8]	Same as above.
Regulating services		
Sequestering carbon	Mangroves are important carbon sinks, and sequester approximately 25.5 million tonnes of carbon every year.[8] They also provide more than 10% of essential dissolved organic carbon that is supplied to the global oceans from land.[9]	Same as above.
Trapping pollutants	Mangrove roots that help trap sediments also function as filters to sift out pollutants reaching the sea from inland waters.[6]	Same as above.
Reducing floods	Mangroves provide physical buffering to prevent floods.[6]	Same as above.
Cultural services		
Tourism	The foreign visitor recreational value of a mangrove ecosystem in the western coast of Sri Lanka is estimated at 1196 USD/ha/year.[5]	Over-visitation: user conflicts with traditional fishing practices (i.e, damage to by motor boats): irresponsible trash disposal.[5]
Supporting traditional fishing	Brush pile fisheries (traditional fishing methods in Bangladesh and Sri Lanka) and other traditional fisheries in south Asia are being sustained because of mangroves.	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation.[2,3]

References

1. Sullivan, C (2005). The importance of mangroves www.vi<?> shandwildlife.com/ Education/FactSheet/PDF_Docs/28 Mangroves.pdf
2. Valiela, I, Bowen, J. L. and J. K. York (2001). Mangrove Forests: One of the World's Threatened Major Tropical Environments. *BioScience*, **51** (10): 807-815.
3. Environmental Justice Foundation (2005). *Mangroves: Nature's defence against Tsunamis - A report on the impact of mangrove loss and shrimp farm development on coastal defences.* London, UK: Environmental Justice Foundation. 32 pp.
4. Bandaranayake, W. M (1998) Traditional and medicinal uses of mangroves. M*angroves and Salt Marshes* **2**(3):133-148.
5. Bambaradeniya, C. N. B, Ekanayake, S. P., Kekulandala, L. D. C. B., Fernando, R. H. S. S., Samarawickrama, V. A. P. and T. G. M. Priyadharshana (2002). An Assessment of the Status of Biodiversity in the Maduganga Mangrove Estuary. *Occasional Papers of IUCN Sri Lanka (No. 1)*. Colombo: IUCN Sri Lanka.
6. UNEP-WCMC (2006) *In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs*. Cambridge: UNEP-WCMC, UK. 33 pp.
7. Broom, S.W., Seneca, E.D. and W.W. Jr. Woodhouse (1981). *Planting marsh grasses for erosion control*. North Carolina: North Carolina University Sea Grant Program.11 pp.
8. Ong, J. E (1993) Mangroves – a carbon source and sink. *Chemosphere,* **27**: 1097-1107.
9. Dittmar, T., N. Hertkorn, G. Kattner, and R. J. Lara (2006), Mangroves, a major source of dissolved organic carbon to the oceans. *Global Biogeochemical Cycles* **20**. GB1012, doi:10.1029/2005GB002570.

Annex 13: Ecosystem services provided by and threats to coral reefs

Services	Description	Threats
Provisioning services (Goods)		
Lime	Lime is extracted from coral and used for construction. Largely illegal, large-scale mining of coral is ongoing in the region.[1,2]	Over-exploitation and damage to the entire coral reef because the reef is blasted for removal of calcium carbonate.[1,2]
Fish and other species for food	Every square kilometre of well-managed coral reef can yield an average of 15 tonnes of fish and other seafood every year.[3] The demand for fish has doubled in the last 50 years, and fish production would have to double again in the next 25 years to keep up with demand and population growth. In Southeast Asia, the live food trade (both as food fish and ornamentals), estimated at over a billion USD per year in mostly illegal trade.[4]	Over-exploitation: more than 25% of the world's fisheries are over-exploited, 50% are being fished to their full capacity and 75% need immediate action to ensure future supplies.[5] The Giant grouper (*Epinephelus lanceolatus*) and Humphead wrasse (*Cheilinus undulatus*) are listed in the 2006 IUCN Red List as Vulnerable and Endangered respectively as a direct consequence of over-fishing.[6] Spiny lobsters and sea cucumbers are over-harvested in Sri Lanka.[1] Activities such as coral mining and destructive fishing practices such as purse seining, fine-mesh fishing, 'moxy' nets, cyanide fishing and blast fishing are also depleting fish stocks.[5,7]
Aquarium fish	Harvest of coral, fish and other organisms for the aquarium is a major form of trade now.[7]	Same as above and large-scale mortality during transport.[5,7]
Medicines	Many species are collected for traditional medicine. In addition, bio-prospecting is ongoing for novel remedies in allopathic medicine.[8]	Over-harvesting of certain species (such as seahorses and some croakers) for traditional medicine, as well as other species by bio-prospectors.[8]
Curios/ornaments	Molluscs and marine turtles are collected for making curios or trinkets. Molluscs, dried sea stars and sea urchins, dried fish (seahorses and puffer fish) and dried lobsters are collected as souvenirs.[9]	Several species such as *Corallium* (a group of red coral) are now threatened with extinction due to over-harvesting.[10] Molluscs (chanks) (*Turbinella pyrum*) are over-exploited in Sri Lanka for export to Bangladesh.[1] Six out of seven species of marine turtles are listed as Endangered or Critically Endangered, partly as a result of over-exploitation for the use of their shells in the trinket trade.[6]
Supporting services		
Biodiversity	Coral reefs are extremely productive ecosystems and are called 'the rainforests of the sea.' Despite this, they are extremely delicate and their balance is disrupted easily and productivity decreases when species are over-harvested.[5]	Climate change and associated coral bleaching is a serious threat to coral reef ecosystems.[11] Sediment, nutrient and chemical pollution from inland development, coastal development including land reclamation and irresponsible tourism are also serious threats to the biodiversity of coral reefs.[5,12] Over-exploitation of certain species disrupts the balance of coral reef ecosystems, often with a decrease in species diversity.[13]

Annex 13: contd.

Services	Description	Threats
Supporting services contd.		
Primary production	Coral reefs have a primary productivity as high as that of tropical rain forests.[14]	Climate change[11], habitat destruction, pollution[5, 12] invasive alien species[15] and predator outbreaks[16] all affect the productivity of coral reefs.
Prevention of coastal erosion	Coral reefs dissipate the energy of waves and currents. Without the protective wall of coral reefs, the shoreline becomes more vulnerable to coastal erosion.[5]	Habitat change in the form of coral mining (including mining of inland deposits) and blast fishing destroys reefs.[1] Irresponsible coastal development is also a threat.
Beach accretion	Coral pieces are broken into smaller and smaller pieces and eventually become part of the beach.	Habitat change such as sand mining (both coastal and inland) and collection of corals and shells is reducing the amount of accretion, resulting in changes in beach morphology and wave hydraulics.[17]
Regulating services		
Protection from storms and tidal surges	Coral reefs provide a physical barrier – a wall – against tidal surges, extreme weather events, ocean currents, tides and winds.[5]	Coral mining (including mining of inland deposits) and blast fishing destroys reefs, as does irresponsible coastal development. Mining of inland resources such as sand is also destroying coral reefs and reducing their protective service function.[5,12]
Cultural services		
Recreation/tourism	Because of their easy access, visiting coral reefs is an important recreation for snorkellers, scuba divers, recreational fishermen and beach lovers.	Snorkelling, diving and boating can cause direct physical damage to reefs. Over-exploitation of reef species as food, for aquaria and as curios can threaten the survival of species. Careless and irresponsible building of infrastructure - sometimes directly onto reefs or too close to beaches, river mouths and lagoons - results in increased sedimentation and leaves the infrastructure vulnerable to damage from extreme weather events. Another indirect effect of tourism is often the irresponsible disposal of sewage and solid waste.[5, 18]

References

1 Rajasuriya, A., Zahri, H., Venkataraman, K., Islam, Z and J. Tamelander (2004). Status of coral reefs in South Asia: Bangladesh, Chagos, India, Maldives and Sri Lanka. Pp 213-233 in D. Souter and O. Linden (eds.) *Coral reef degradation in the Indian Ocean Status Report 200*4, Sweden: CORDIO.

2 Brown, B. E. Dunne, R. P. and T. P. Scofim (1995). Coral rock extraction in the Maldives, central Indian Ocean - limiting the damage, *Coral Reefs* **14**: 236.

3 http://www.panda.org/about_wwf/what_we_do/marine/blue_planet/coasts/coral_reefs/coral_importance/index.cfm

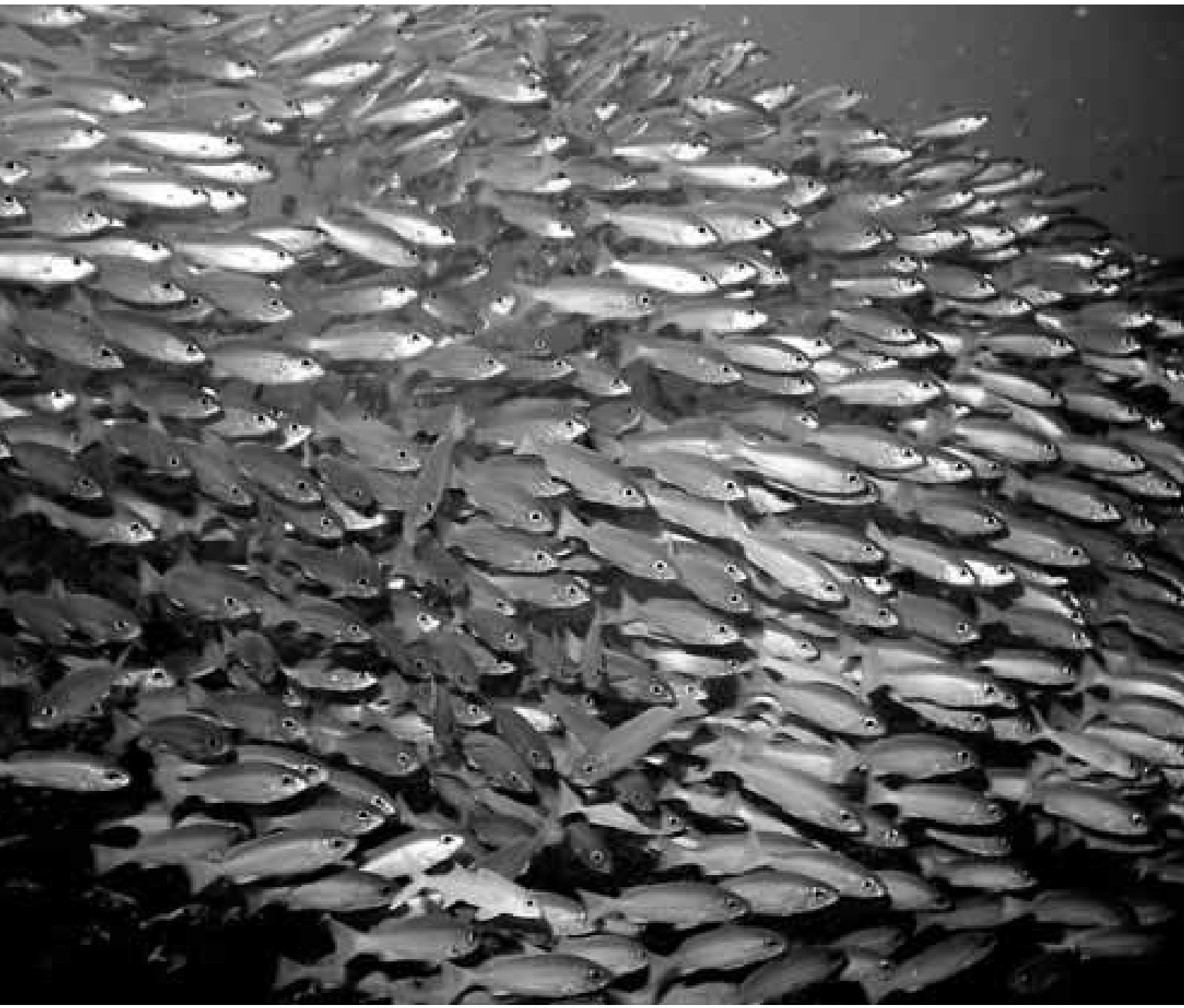
4 Sham, 1997 in TRAFFIC (1999). *The Hong Kong trade in live reef fish for food*. TRAFFIC East Asia and WWF.

5 Burke, L., Selig, L. and M. Spalding (2002). *Reefs at Risk in Southeast Asia*. Washington, DC.: World Resources Institute. 72 pp.

6 Baillie, J., and B. Groombridge (Compilers and Editors) (2007). *2007 IUCN Red List of Threatened Animals*. Gland, Switzerland and Cambridge, UK: IUCN.

7 Wabnitz, C., Taylor, M., Green, E. and T. Razak (2003). *From Ocean to Aquarium*. Cambridge, UK: UNEP-WCMC.

8 Hunt, B. and A. Vincent (2006). The use of marine organisms in traditional and allopathic medicine pp. 64-75 in S. Miththapala (ed.) *Conserving Medicinal Species: securing a healthy future*. Colombo: Ecosystems and Livelihoods Group Asia, IUCN. 184 pp.
9 Vincent, A (2006). Live food and non-food fisheries in coral reefs and their protection management. Pp 183-236 in *Coral Reef Conservation* I. M Côté and J. D. Reynolds (eds.). Cambridge: Cambridge University Press.
10 http://www.iucn.org/
11 Wilkinson, C (2004). *Status of Coral Reefs of the World, 2004* (Vol 1) Townsville, Australia: Australian Institute of Marine Science. xiv + 301 pp.
12 Nybakken, J. W (1993). *Marine Biology: an Ecological Approach*, 3rd ed. New York: Harper Collins. 579 pp.
13 Jackson, J. B. C and 18 others (2001). Historical over-fishing and the recent collapse of coastal ecosystems. *Science* **293** (5530):629 - 637.
14 Sorokin, Y. I (1995). *Ecological Studies Coral Reef Ecology* Vol. 102. Berlin: Springer- Verlag.
15 ten Hallers-Tjabbes, C (2004). Marine Biodiversity threatened by ballast water transported by ships; curbing the threat. In subtheme, Coping with Aliens, in Proceedings of *Biodiversity loss and species extinctions, managing risk in a changing world*. A global synthesis workshop convened at the IUCN World Conservation Forum 18-20 November 2004, Bangkok, Thailand.
16 Forbes, E (2006). C*oral Reefs and the Crown-of-Thorns Starfish*. http://jrscience.wcp.muohio.edu/fieldcourses06/Papers MarineEcologyArticles/CoralReefsandtheCrown-of-.html
17 http://www.icsf.net/icsf2006/uploads/publications/proceeding/pdf/english/issue_10/chapter84.pdf
18 Mastny, L (2001). *Travelling light*. www.gttp.org/docs/lisamastny.pdf



Annex 14: Ecosystem services provided by and threats to seagrass meadows

Services	Description	Threats
Provisioning services (Goods)		
Food	Seagrass meadows are nursery areas for many commercial fin and shell fish species as well as other species.[1] Fish, clams and mussels are harvested as a source of protein from seagrass meadows all over the world.[2]	Inland and coastal pollution, causing sedimentation and turbidity[3]; dredging and coastal development; eutrophication[4] - as a result of industrial and domestic pollution; port, jetty and harbour development[5]; mooring, propellers and jet skis[6]; invasive alien species (IAS)[7]; disease[7]; over-grazing[7] and climate change.[8]
For the aquaculture and aquarium trades	Polychaete worms are harvested from seagrass meadows as broodstock feed for aquaculture. Aquarium fish are also harvested.[9]	Over-exploitation and damaging collection practices.[9] Other threats same as above.
Housing insulation and thatching, stuffing and packing	Until the last century, in Europe, dried seagrass material was used as housing insulation. Until recently, sea-grasses were also used to thatch roofs in rural coastal areas in Europe and the UK as a substitute for straw. Before the advent of plastic, seagrasses were used as stuffing for pillows and upholstery and for packing.[10]	Not used currently.
For preventing erosion	Seagrasses were used to bind soil in embankments, such as in the dikes of the Netherlands. Presently, seagrasses are being used in sand dune restoration in Australia.[10]	No immediate threat.
Regulating services		
Preventing pollution and sedimentation of coastal waters	The leafy 'canopy' of seagrasses slows down water currents, trapping particles, nutrients and pollutants washed from inland waters to coastal seas.[11]	Over-exploitation and damaging collection practices;[9] inland and coastal pollution – causing sedimentation and turbidity[3]; dredging and coastal development; eutrophication[4] – as a result of industrial and domestic pollution; port, jetty and harbour development[5]; mooring, propellers and jet skis[6]; IAS[7]; disease[7]; over-grazing[7] and climate change.[8]
Stabilising the floor of coastal seas	The underground stems of seagrasses help stabilise the sea meadows preventing sand from being washed away and churned up by wave action.[12]	Same as above.

Annex 14: contd.

Services	Description	Threats
Supporting services		
Supporting coastal biodiversity	Because of their three-dimensional structure in the water, seagrass meadows provide protection for juvenile fish and many marine larvae. They house hundreds of other species as well, such as algae, sponges, round worms, marine worms and even threatened species such as manatees and dugongs that feed directly on them.[13, 14]	Over-exploitation and damaging collection practices;[9] inland and coastal pollution – causing sedimentation and turbidity[3]; dredging and coastal development; eutrophication[4] – as a result of industrial and domestic pollution; port, jetty and harbour development[5]; mooring, propellers and jet skis[6]; IAS[7]; disease[7]; over-grazing[7] and climate change.[8]
Primary production	Seagrasses rank with coral reefs and mangroves in their productivity.[14]	Same as above.
Enriching nutrients in coastal waters	Seagrasses are important in the detrital food chain. When all the organisms found in the three dimensional habitat of seagrasses, as well as the seagrasses die, the released nutrients enter the marine system as carbon and other nutrients.[3]	Same as above.
Cultural services		
Supports traditional fishing practices	In many countries, traditional fishing practices are supported by seagrass meadows. In Australia and Polynesia, Aboriginal and Polynesian traditional fishing and hunting techniques and rituals are associated with seagrass meadows.[14]	Mooring, propellers and jet skis are emerging as a major threat to seagrass meadows.[6] When boats – either for fishing or recreation – enter into areas where there are seagrass meadows, their propellers can slash leaves as well as the rhizomes of seagrass, leading to fragmentation of the habitat, which, in turn, leads to erosion.[3] Similarly irresponsible mooring and recreation can endanger these habitats. Blue crab dredging in Chesapeake Bay eastern USA has caused significant declines in seagrass cover.[6] Trampling or using fishing gear that rakes up the seagrasses is also damaging. For example, push nets and drag nets cause immense damage to seagrass meadows in coastal wetlands in Sri Lanka.[15]
Other services		
'Biological sentinels' and 'coastal canaries'	Like canaries that were taken into coal mines to test the quality of the air, seagrasses respond to changes in the quality of water, indicating deterioration of the environment by declining. What is important is that these changes are visible and very quickly so that it is possible to take management action.[7]	Over-exploitation and damaging collection practices;[9] inland and coastal pollution – causing sedimentation and turbidity[3]; dredging and coastal development; eutrophication[4] – as a result of industrial and domestic pollution; port, jetty and harbour development[5]; mooring, propellers and jet skis[6]; IAS[7]; disease[7]; over-grazing[7] and climate change.[8]

References

1. Heck, K. L., Hays, C., and R. J. Orth (2003). A critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series* **253**: 123–136.
2. Green E. P. and F. T. Short (2003). *World Atlas of Seagrasses*. xii+298 pp. Berkeley, CA: UNEPWCMC, University of California press.
3. http://www.sms.si.edu /IRLspec/ Seagrass _Habitat.htm.
4. Short, F. T., Kock, E. W., Magalhães, K. M., Fernandez, E. and J. L. Gaeckle (2006). Seagrass monitoring across the Americas: case studies of seagrass decline. *Marine Ecology* **27**: 277–289.
5. Spalding, M., Taylor, M., Ravilious. C., Short, F and E. Green (2003). The distribution and status of seagrasses. Pp 5- 26 in Green E. P. and F. T. Short (2003) *World Atlas of Seagrasses*. Berkely, CA: UNEP-WCMC, University of California press. xii+298 pp.
6. Fonseca, M. S., Kenworthy, W. J. and G. W. Thayer (1998). Guidelines for the Conservation and Restoration of seagrasses in the United States and Adjacent Waters. *Decision Analysis Series* **No. 12**. U.S.A: National Oceanic and Atmospheric Administration, Coastal Ocean Program.
7. Orth, R. J. and 14 others (2006) A global crisis for seagrass ecosystems. *BioScience* **56(**12):987-996.
8. Short, F. T. and H. A. Neckles (1999). The effects of global climate change on seagrasses. *Aquatic Botany* **63:** 169–196.
9. Kallesøe, M. F., Bambaradeniya, C. N. B., U. A. Iftikhar, Ranasinge, T. and S. Miththapala (2008). *Linking Coastal Ecosystems: and Human Well-Being Learning from conceptual frameworks and empirical results*. Colombo: Ecosystems and Livelihoods Group, Asia, IUCN. viii + 49 pp.
10. Hurley, L. M (1990). U.S. *Fish and Wildlife Service Field Guide to the Submerged Aquatic Vegetation of Chesapeake* Bay. Annapolis, MD: Chesapeake Bay Estuary Program. 51pp.
11. Short, F. T. and C. A. Short (1984). The seagrass filter: purification of estuarine and coastal water. Pp. 395–413. In V. S.Kennedy (ed.) T*he Estuary as a Filter*. Orlando: Academic Press.
12. Dahm, J., Jenks, G., and D. Bergin (2005). *Community-based Dune Management for the Mitigation of Coastal Hazards and Climate Change Effects: A Guide for Local Authorities*. www.lgnz.co.nz/projects/ClimateChange/Community Based DuneMangementpart1.pdf
13. Ruppert, E. E., Fox, R. S. and Robert D. Barnes (2003) *Invertebrate Zoology: A Functional Evolutionary Approach.* USA: Brooks Cole. 1008 pp.
14. Coles, R. G., McKenzie, L. J. Rasheed, M, Mellors, J. E., Taylor, H., Dew, K., McKenna, S., Sankey,T. L., Carter, A. B. and A. Grech (2007). *Status and Trends of seagrass habits in the Great Barrier Reef World Heritage Area*. Report to the Marine and Tropical Research Science Facility. Cairns: Reef and Rainforest Centre Limited. Pp 122.
15. Bambaradeniya personal communiation.

Annex 15: Ecosystem services provided by and threats to sand dunes

Services	Description	Threats
Provisioning services (Goods)		
Sand and other minerals	Sand is mined heavily in many parts of the region. Beach sand mining in the east coast of Sri Lanka is estimated at 500-1000m^3/km/year.[1]	Over-exploitation of both sand and river sand results in coastal erosion.[1]
Regulating services		
Stabilising the shoreline	The store of sediment in sand dunes protects the land behind them from storm erosion and potential sea level rise. Sand dune vegetation traps and prevents sand being blown further inland.[2]	Sand mining – inland or at the coast and resultant erosion[1]; beach infrastructure[3], artificial erosion defence structures, afforestation and other human influences – such as ports and jetties – are damaging or reducing the extent of sand dunes and with it, nesting habitats of endangered species.[4] Tourist infrastructure often destroys sand dunes.[3] Climate change is also a threat.
Flood protection	When there are storm surges and waves, sand dunes prevent flooding inland. Intact sand dunes were the most effective barrier against tsunami waves that affected the coastal zone of Sri Lanka in 2004.[5]	Same as above.
Supporting services		
Biodiversity	Sand dunes are essential components of coastal vistas and coastal biodiversity. They also harbour endangered species such as marine turtles – who must lay their eggs on sandy beaches and return to the sites where they were born. Coastal sand dunes with natural vegetation such as Goat's Foot (*Ipomea pescaprae)* and *Spinifex littoreus* are ideal nesting sites.[4]	Same as above. Excessive trampling of sand dune vegetation by tourists causes death of the flora and can result in erosion of dune sites. Species such as Prickly Pear (*Opuntia dillenii*) and Mesquite (*Prosopis juniflora*) are spreading in sand dunes and beaches and destroying natural vegetation.[5]
Cultural services		
Recreation	Beaches are popular for recreation and many people enjoy walking on the beach and paddling on beach fronts. Sand dunes can provide source sand for the maintenance of beaches. In many countries, coastal tourism relies on intact sand dunes and beach fronts as part of their marketing packages. Seventy percent of all hotels registered with Sri Lanka Tourist Board are located in the coastal zone.[1]	Tourist infrastructure often destroys sand dunes. A by-product of such development is the increase of sedimentation, solid waste and marine pollution.[4]
Supporting traditional fishing practices	In many countries, traditional fishing practices are supported by sand dunes. Because sand dunes can provide source sand for the maintenance of beaches, they indirectly support traditional fisheries. Traditional stilt fishery and beach seine fishery are supported indirectly in Sri Lanka by the combination of the presence of sand dune ecosystems and sandy sea beds.[6]	Sand mining – inland or at the coast – and resultant erosion[1]; beach infrastructure[3], artificial erosion defence structures, afforestation and other human influences – such as ports and jetties – are damaging or reducing the extent of sand dunes and with it, nesting habitats of endangered species.[4] Tourist infrastructure often destroys sand dunes.[3] Climate change is also a threat.

References

1. CCD (2004). *Revised Coastal Zone Management Plan, Sri Lanka*. Colombo, Sri Lanka: Coast Conservation Department, Ministry of Fisheries and Aquatic Resources. xiv+182 pp.
2. Dahm, J., Jenks, G., and D. Bergin (2005). *Community-based Dune Management for the Mitigation of Coastal Hazards and Climate Change Effects: A Guide for Local Authorities.* http://www.lgnz.co.nz/projects/ClimateChange/CommunityBasedDuneMangementpart1.pdf
3. UK Biodiversity Group (1999). *Tranche 2 Action Plans - Volume V: Maritime species and habitats.* http://www.ukbap.org.uk/ukplans.aspx?ID=66.
4. Choudury, B. C., Pandav, B., Tripathy, B., and H. V. Andrews (2003). *Sea turtle conservation: Eco (turtle) friendly coastal development. A GOI-UNDP project manual*. Tamil Nadu, India: Centre for Herpetology/Madras Crocodile Bank Trust. 44 pp.
5. Bambaradeniya, C.N.B., Perera, M. S.J. and V.A.M.P.K. Samarawickrama (2006). A rapid assessment of post-tsunami environmental dynamics in relation to coastal zone rehabilitation and development activities in Hambantota District of southern Sri Lanka. *IUCN Sri Lanka Occasional Paper No. 10*. Colombo, Sri Lanka: IUCN. 27pp.
6. Kallesøe, M. F., Bambaradeniya, C. N. B., Iftikhar, U. A., Ranasinghe, T and S. Miththapala (2008). *Linking Coastal Ecosystems: and Human Well-Being Learning from conceptual frameworks and empirical results*. Colombo: Ecosystems and Livelihoods Group, Asia, IUCN. viii + 49 pp.

Annex 16: Ecosystem services provided by and threats to lagoons and estuaries

Services	Description	Threats
Provisioning services (Goods)		
Food (Fish)	Lagoons and estuaries are important sources of fish and provide employment for coastal residents in the aquaculture industry and ornamental fisheries. The average annual fish production in the Rekawa lagoon, Sri Lanka, is 40kg/ha.[1] The Negombo lagoon has a high productivity for fisheries producing 150 kg/ha/yr and involving more than 3,000 families from 26 villages.[2] Estuaries - often called 'the nurseries of the sea' - are particularly important as nursery areas for fisheries because they are extremely fertile due to the abundance of nutrients brought in from upstream and tidal sources.[3] The most abundant and commercially important prawn species in the Rekawa lagoon is the White shrimp (*Penaeus indicus*).[1]	Major threats to lagoons and estuaries include pollution by wastewaters from urban areas, industries and agricultural run-off; eutrophication, which results in oxygen depletion and death of flora and fauna; invasive alien species; climate change and habitat destruction.[4] The construction of the Kapuhenwala causeway in the Rekawa lagoon has reduced greatly the volume of water entering and leaving the lagoon. The causeway impedes sea water entering the lagoon reducing the production and quality of shrimp and fish, thus affecting the livelihoods of fishermen.[1]
Timber and fuelwood	Estuaries provide timber resources for building houses, making furniture, rafters, fences, bridges and boats and fuelwood for populations living in coastal areas.[3]	Major threats to lagoons and estuaries include pollution by wastewaters from urban areas, industries and agricultural run-off; eutrophication, which results in oxygen depletion and death of flora and fauna; invasive alien species; climate change and habitat destruction.[4]
Supporting services		
Biodiversity	Organisms found in lagoons and estuaries are unique as they can tolerate both freshwater and varying levels of salinity. The five lagoons of the Bundala wetland in Sri Lanka are important internationally as homes to large populations of migratory birds, that visit from regions as far away as Siberia.[5] Resident and migratory birds include the Greater flamingo (*Phoenicopterus ruber*), the Spot-billed pelican (*Pelecanus philippensis*), the Lesser adjutant (*Leptoptilos javanicus*) and the Black-necked stork (*Xenorhynchus asiaticus*).[6] Fish species found in the lagoons of Bundala National Park include the Short-finned Eel (*Anguilla bicolor*), the Snake-head glass perchlet (*Ambassis gymnocephalus)*, Milk fish (*Chanos chanos*) and Murrel (*Channa striata*). The Bundala lagoons are also home to the largest reptiles in Sri Lanka, the Mugger crocodile (*Crocodylus palustris*), the saltwater crocodile (*C. porosus*), the Indian Python (*Python molurus*) as well as the Leatherback Turtle (*Dermochelys coreaceae)*.[7]	Invasive alien species that threaten the lagoons and estuaries of Sri Lanka include Pond weed (*Najas marina*), Cattail (*Typha angustifolia*) and Pond apple (*Annona glabra)*.[8] In New Zealand, invasive species have displaced commercially important mussel beds, causing significant economic losses to mussel farmers.[3] Global warming and climate change will result in the rise of sea levels. Salinity in lagoons and estuaries will increase and affect species composition, favouring some species while damaging others.[9] Estuaries in close proximity to urban areas are affected by land alterations such as infilling, dredging, channelling and installations of harbor works including seawalls and groynes.[3]

Annex 16: contd.

Services	Description	Threats
Provisioning services (Goods) contd.		
Trapping nutrients and filtering pollutants	Estuaries trap nutrients brought in from the ocean, inflowing rivers and land. These nutrients are dispersed throughout the estuary by tidal movement, wind and currents and this constant mixing of nutrients creates a productive habitat for flora and fauna.[10] Estuary plants and microorganisms filter pollutants and sediments by filter feeding activity and break down of heavy particles.[4]	The dredging and diversion of rivers decreases the volume of water entering lagoons. When lagoons are not flushed periodically, deposited silt and sediment builds up creating an acidic environment. Shrimps require a habitat with a pH of 8 and a sandy bed for growth. Most organisms in lagoons are adapted to saline, basic conditions and the increase in acidity is unsuitable for their growth.[1]
Primary production	Coastal lagoons are extremely productive aquatic ecosystems and can reach net primary production values of 7000g carbon/m2/yr. The primary productivity of lagoons and estuaries is supported by phytoplankton and large plants.[11]	Major threats to lagoons and estuaries include pollution by wastewaters from urban areas, industries and agricultural run-off; eutrophication, which results in oxygen depletion and death of flora and fauna; invasive alien species; climate change and habitat destruction.[4]
Carbon sequestration	The productive phytoplankton and large plants in lagoons and estuaries sequester carbon. Rivers bring organic rich sediments that accumulate on the beds of estuaries which function as an important carbon sink.[12]	Higher temperatures caused by global warming will change patterns of phytoplankton growth, affecting productivity and ecosystem balance. They will lead to eutrophication in lagoons and estuaries damaging the quality of water and causing a reduction in fish yields. This will affect food security and livelihoods.[9]
Regulating services		
Flood regulation	Wetlands that fringe many estuaries act as natural buffers between land and the ocean, absorbing flood waters and dissipating storm surges. Estuarine plants stabilise shorelines preventing soil erosion and flood damage.[4]	Rising sea levels due to climate change can also flood lagoon banks. The loss of protective and regulative function of lagoons and estuaries will leave coastal communities more vulnerable to natural disasters.[9]
Climate regulation	Estuaries and lagoons regulate the climate by their capacity to sequester carbon and their high primary productivity.[12]	Increased precipitation caused by climate change will increase flooding of lagoons and estuaries and reduce their protective and regulatory functions.[9]
Cultural services		
Tourism	Estuaries and lagoons are important tourist attractions for recreational activities. Popular tourist destination associated with lagoons and estuaries include the Bundala National Park,[6] the Hooghly River Estuary in India[13] and the Meghna River Estuary in Bangladesh.[14]	Tourist activities - such as irresponsible trash disposal, introduction of exotic species, over-visitation and disturbance of wildlife, pollution from jet-skis and boats - threaten lagoons and estuaries.[15]

References

1 janathakshan.net/files/Kapuhenwala.pdf

2. www.iucn.org/dbtw-wpd/edocs/2005 047.pdf
3. http://www.millenniumassessment.org/documents/document.288.aspx.pdf
4. http://www.epa.gov/nep/about1.htm
5. http://www.iwmi.cgiar.org/About_IWMI/Strategic_Documents/Annual_Reports/1998/Bundala.pdf
6. http://www.info.lk/srilanka/srilankanature/srilanka_parks/bundala.htm
7. http://www.pdn.ac.lk/socs/zaup/reptiles/images/ruchira/bundala.pdf
8. Bambaradeniya, C. N. B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17** (11): 930-935.

9 http://www.ipcc.ch/

10. http://public.metrovancouver.org/about/publications/Publications/BiodiversityFactSheetEstuary.pdf
11. http://www.eoearth.org/article/Coastal_lagoon
12. Brevik, E. C. and J. A. Homburg (2004). A 5000 year record of carbon sequestration from a coastal lagoon and wetland complex, Southern California, USA. *Catena* **57** (3): 221-232.
13. www.britannica.com/EBchecked/topic/271249/Hooghly-River
14. www.britannica.com/EBchecked/topic/373096/Meghna-River
15. http://www.aaee.org.au/docs/WAbugs/cs5.pdf

Photocredits

Page number	Caption	Credit
Frontpiece	Reefscape.	© Jerker Tamelander/IUCN
iv & v	Prawn fishing, Sri Lanka.	© Vimukthi Weeratunge
4	Mangroves in northwestern Sri Lanka.	© Sriyanie Mththapala
7	Top to bottom: Musk deer, the musk of which is used in Traditional Chinese Medicine; deforestation in Sri Lanka; solid waste accumulation, Sri Lanka; *Pistia stratiotes*, as invasive alien species in Viet Nam; floods in the Philippines.	Top to bottom: © Susan Earle; © Gehan de Silva Wijeyeratne; © Ranjit Galappatti; © Alvin Lopez; © Efren Mariano, CARE Sri Lanka
8	Vendors in the northwestern coast of Sri Lanka.	© Sriyanie Mththapala
11	Water palm (*Nypa*) in the Sunderbans, Bangladesh.	© Raquibul Amim
12	Lowland tropical rain forest, Sri Lanka.	© Vimukthi Weeratunge
14	Destruction of tropical rain forests in Sri Lanka.	© Gehan de Silva Wijeyeratne
15	Montane forests, Sri Lanka.	© Vimukthi Weeratunge
16	Broad-leaved deciduous forest, India.	© Eric Wikramanyake
17	Scrub forest, Sri Lanka.	© Nadeera Weerasinghe/Jetwing Hotels
18	Tropical coniferous forest, Nepal.	© Eric Wikramanyake
21	Subtropical grasslands, Nepal.	© Eric Wikramanyake
24	River in central Sri Lanka.	© Vimukthi Weeratunge
25	Tonle Sap lake, Cambodia.	© Sun Visal, Ministry of Environment, Cambodia
26	Coral reef, Similan island, Thailand.	© Nishan Perera
27	*Corallium* necklace for sale in Hanoi, Viet Nam.	© Sriyanie Mththapala
28	Mangroves, Sri Lanka.	© Vimukthi Weeratunge
30	Seagrass meadows in Sanur, Bali, Indonesia.	© Rudi Yoshida, Seagrass-Watch HQ
31	Sand dunes in southern Sri Lanka.	© Thushan Kapurusinghe
33	Top to bottom: Hotel extended to beach front, sothern Sri Lanka; groyne, southwestern Sri Lanka; coastal erosion, Sri Lanka; speeding jet ski, Sri Lanka; Prickly Pear (*Opuntia dillenii*) spreading in southern Sri Lanka.	© Channa Bambaradeniya; © CRMP; © CRMP, © Luxmanan Nadaraja; © Channa Bambaradeniya
34	Fishermen in northwestern Sri Lanka.	© Sriyanie Mththapala
38	Floods and landslides in Mt. Pinatubo, Central Luzon Philippines.	© Nico Sepe
46	Dried lava from a volcano forming a mountain, Yogyakarta, Indonesia.	© Sriyanie Mththapala
54	Earthquake damage in Pakistan.	© Karl Schuler/ IUCN
57	Top to bottom: Earthquake damage in Pakistan, 2005; tsunami damage to sand dunes southern coast, Sri Lanka; floods in Bangladesh; typhoon damage in the Philippines, 2006; salinisation of fresh water after the tsunami, Thailand.	© Karl Schuler/IUCN; © Asanka Abayakoon/ IUCN Sri Lanka; © CNRS, Bangladesh; © Efren Mariano /CARE; © IUCN, Thailand
58	Cleaning up the Tasman Spirit oil spill, Pakistan.	© Ali Raza Rizvi
60	Coastal scene Sibolga, Indonesia.	© Nishan Perera
69	Woman collecting firewood from a mangrove, Sri Lanka.	© Sanjeewa Lellwalla
78	*Rafflesia arnoldii*, which produces the largest single flower in the world, is endemic to the rainforests of Indonesia and insular Malaysia.	© Karl Lehmann
82	Rhinoceros-horned lizard (*Ceratophora stoddartii*),endemic to montane regions of Sri Lanka.	© Nadeera Weerasinghe, Jetwing Hotels
89	Leopard (*Panthera pardus kotiya*) in scrub forest, Sri Lanka.	© Luxmanan Nadarajah
92	Asiatic black bear *(Ursus thibetanus*) threatened by trade for its gall bladder for use in Traditional Chinese Medicine.	© TRAFFIC East Asia
96	Lesser panda (Ailurus fulgens) found in the temperate mixed forests of China.	© Ann Batdorf, Smithsonian's National Zoo
100	Plateau Pikas (*Ochotona curzoniae*) in Qinghai Province, China.	© Andrew T. Smith
112	Fishermen in Tonle Sap lake, Cambodia.	© Sun Visal, Ministry of Environment, Cambodia
118	The wood of Native frangipani (*Cerbera mangus*) - found in mangroves - is used to make traditional masks in Sri Lanka.	© Sriyanie Mththapala
121	Shoal of fish, Koh Bon, Thailand.	© Nishan Perera
124	Hawksbill turtle (*Eretmochelys imbricata*).	© Peter Richardson, MCS
126	Sand dunes, Palatupana, Sri Lanka.	© Gehan de S. Wijeyeratne

The IUCN Asia region covers 23 countries, stretching from Pakistan in the West to Japan in the East, Indonesia in the South to Mongolia in the North. IUCN maintains offices in Bangladesh, Cambodia, China, Lao PDR, Nepal, Pakistan, Sri Lanka, Thailand and Viet Nam. The Asia Regional Office is in Bangkok, Thailand.

IUCN's seven regional thematic programmes, known collectively as the Ecosystems and Livelihoods Group (ELG), are based in two clusters: one in Colombo, Sri Lanka (environmental economics, marine and coastal, species conservation), and one in Bangkok, Thailand (environmental law, forests, protected areas, wetlands and water resources).

Ecosystems and Livelihoods Group Asia

IUCN
4/1 Adams Avenue
Colombo 4
Sri Lanka
Phone: + 94 11 2559634
Fax: +94 11- 2559637
E-mail: coastalinfo@iucnsl.org
http://data.iucn.org/places/asia/coastalinfo/