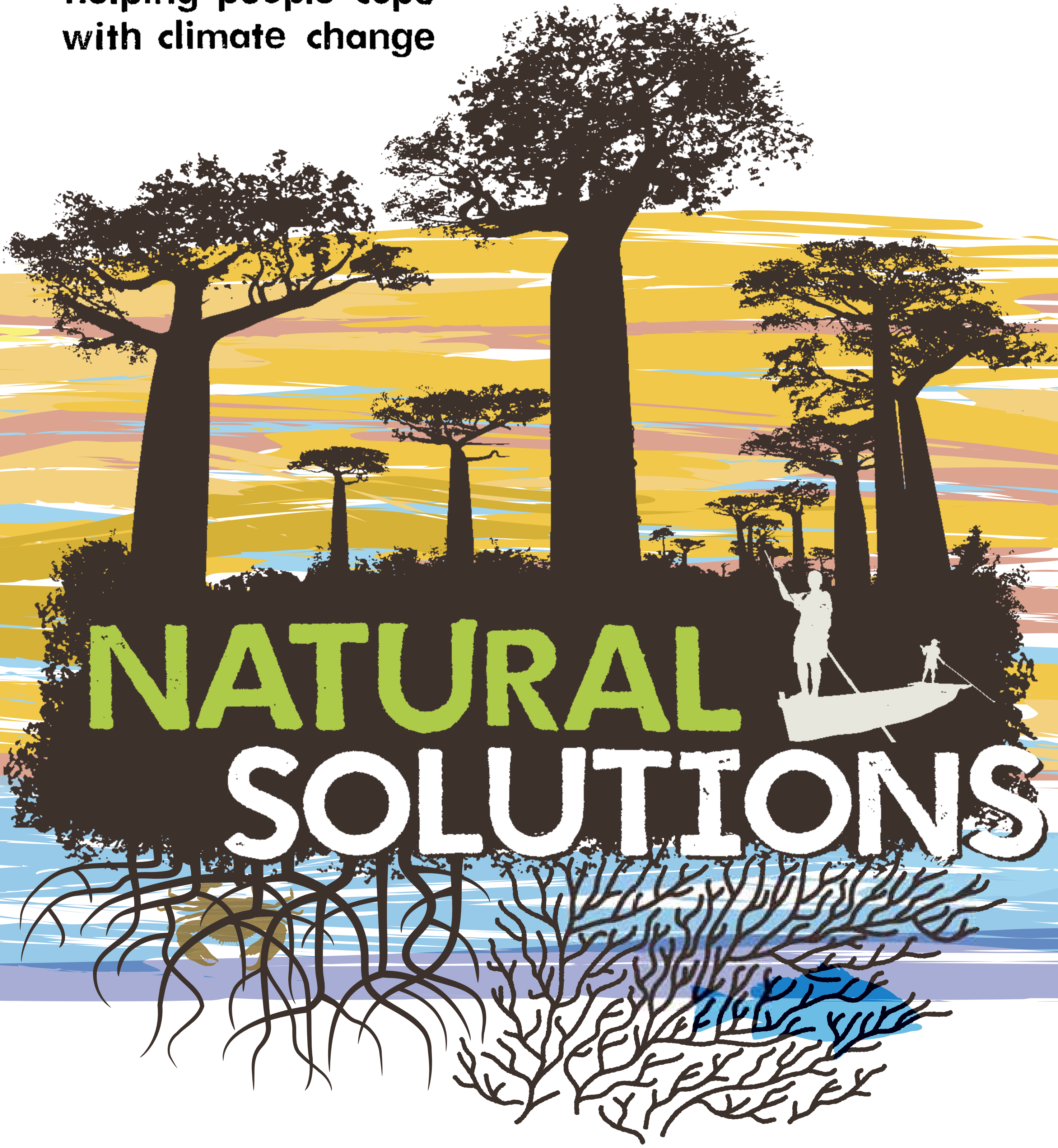
protected areas helping people cope with climate change



Preface by Lord Nicholas Stern

Arguments for Protection

In 2000 a conference organised in Bangkok by WWF and the IUCN World Commission on Protected Areas agreed that there was an urgent need to identify and quantify the wide range of social and environmental benefits offered by protected areas. The WWF **Arguments for Protection** project was developed in response. The project aims to:

- Identify and where possible quantify the wide range of benefits derived from protected areas
- Increase support for protection
- Develop new interdisciplinary partnerships
- Identify innovative financing mechanisms
- Broaden and strengthen protected area management strategies

Since 2003 the project has created the world's largest information source on the wider values of protected areas. Six reports have been published to date (see www.panda.org/protection/arguments) and a new simple-to-use tool, the **Protected Area Benefit Assessment Tool (PA-BAT)**, has been developed, field-tested and is now being implemented.

The published reports are:

- **Running Pure:** The importance of forest protected areas to drinking water
- **Food Stores:** Using protected areas to secure crop genetic diversity
- **Beyond Belief:** Linking faiths and protected areas to support biodiversity conservation
- **Safety Net:** Protected areas and poverty reduction
- **Natural Security:** Protected areas and hazard mitigation
- **Vital Sites:** The contribution of protected areas to human health

The project has worked with a number of partners including: The World Bank; UN International Strategy for Disaster Reduction; World Health Organisation; University of Birmingham; Alliance of Religions and Conservation, and many protected area agencies. This new report in the series continues the relationship with the World Bank and has been carried out in collaboration with UNDP and many members of the PACT 2020: Protected Areas and Climate Turnaround Alliance.

PACT 2020: Protected Areas and Climate Turnaround

At the IUCN Council Meeting held from 8-10 March 2008, climate change was acknowledged to be the greatest threat to biodiversity and the global system of protected areas was noted as one of the most powerful solutions. This was the genesis of **PACT 2020: Protected Areas and Climate Turnaround**, formally launched at the IUCN World Conservation Congress in 2008 and supported by IUCN's Innovation Fund.

PACT 2020 involves a partnership led by IUCN's World Commission on Protected Areas, together with the IUCN Secretariat, IUCN members and international organizations, including The Nature Conservancy, WWF International, the Wildlife Conservation Society, Conservation International, the Wild Foundation, Fauna and Flora International, the Climate, Community and Biodiversity Alliance, The World Bank, United Nations Development Programme and UNEP World Conservation Monitoring Centre.

PACT 2020 aims to "*Ensure that protected areas and protected area systems are recognised as an important contribution to climate change adaptation/mitigation strategies for biodiversity and human livelihoods*". Activities include developing:

- A situation analysis leading to the articulation of a compelling case and action plan for protected areas as an integral element of climate change adaptation/mitigation
- Guidance and project proposals are developed for regional implementation programmes
- A policy action plan championed by IUCN is agreed by key stakeholders
- Protected area and climate change policy interventions are designed and undertaken at global and national levels
- A functional communications/learning network is developed

This publication is one of the first products of this collaboration, and will be a primary input into the PACT 2020 Protected Areas and Climate Change Summit held in November 2009 in Granada, Spain, hosted by the Junta de Andalucía.

Protected areas helping people cope with climate change

Natural Solutions

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Preface

Responses to climate change must now focus on reducing greenhouse gas emissions enough to avoid runaway impacts (“avoiding the unmanageable”) and on addressing the impacts that are already with us (“managing the unavoidable”).

Managing natural ecosystems as carbon sinks and resources for adaptation is increasingly recognised as a necessary, efficient and relatively cost-effective strategy. The *Stern Review on the Economics of Climate Change* recommended that governments develop policies for “climate sensitive public goods including natural resource protection, coastal protection and emergency preparedness”.

The world’s protected area network already helps mitigate and adapt to climate change. Protected areas store 15 per cent of terrestrial carbon and supply ecosystem services for disaster reduction, water supply, food and public health, all of which enable community-based adaptation. Many natural and managed ecosystems can help reduce climate change impacts. But protected areas have advantages over other approaches to natural ecosystem management in terms of legal and governance clarity, capacity and effectiveness. In many cases protection is the only way of keeping carbon locked in and ecosystem services running smoothly.

Without the investment made in protected areas systems worldwide, the situation would be even worse. Increasing investment through a partnership of governments, communities, indigenous peoples, non-governmental organisations and the private sector would ensure greater protection of these essential services. Evidence suggests that protected areas work: even since this report was completed, a new World Bank review shows how tropical protected areas, especially those conserved by indigenous peoples, lose less forest than other management systems*.

But these co-benefits for climate, biodiversity and society are often missed or ignored. This book clearly articulates for the first time how protected areas contribute significantly to reducing impacts of climate change and what is needed for them to achieve even more. As we enter an unprecedented scale of negotiations about climate and biodiversity it is important that these messages reach policy makers loud and clear and are translated into effective policies and funding mechanisms.

Lord Nicholas Stern

Chair of the Grantham Research Institute on Climate Change and the Environment,
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* Nelson, A. and K. Chomitz (2009); *Protected Area Effectiveness in Reducing Tropical Deforestation: A global analysis of the impact of protection status*, Independent Evaluation Group, Evaluation Brief 7, The World Bank, Washington DC

Contents

Acronyms, abbreviations and formula

CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CH^4	Methane
C	Carbon
CO^2	Carbon dioxide
EBA	Ecosystem-based adaptation
GEF	Global Environment Facility
GHG	Greenhouse gases
Gt	Gigatonne (1,000,000,000 tonnes or 1 million metric tonnes)
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
Mg	Megagram (1,000,000 grams)
Mt	Megatonne (1,000,000 metric tonnes)
REDD	Reducing Emissions from Deforestation and Degradation
PoWPA	Programme of Work on Protected Areas (of the CBD)
Tg	Teragram (1,000,000,000,000 (one trillion) grams)
TNC	The Nature Conservancy
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WCPA	World Commission on Protected Areas (of IUCN)
WCS	Wildlife Conservation Society
WWF	World Wide Fund for Nature

Glossary

Adaptation: Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned[1].

Additionality of emission reductions: Reduction in emissions by sources or enhancement of removals by sinks that is additional to any that would occur in the absence of a project activity designed to mitigate greenhouse gas emissions[2]. Joint Implementation or a Clean Development Mechanism project activity as defined in the Kyoto Protocol Articles on Joint Implementation and the Clean Development Mechanism[3].

Carbon sequestration: Carbon sequestration is a biochemical process by which atmospheric carbon is absorbed by living organisms, including trees, soil micro-organisms, and crops, and involving the storage of carbon in soils, with the potential to reduce atmospheric carbon dioxide levels[4].

Ecosystem-based adaptation: The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change[5].

Ecosystem services (also ecosystem goods and services): the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfilment; and supporting services such as soil formation, photosynthesis, and nutrient cycling[6].

Equivalent CO_2 concentration (carbon dioxide): The concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other greenhouse gases[7].

Leakage: the situation in which a carbon sequestration activity (e.g., tree planting) on one piece of land inadvertently, directly or indirectly, triggers an activity, which in whole or part, counteracts the carbon effects of the initial activity[8]. The net change of anthropogenic emissions by sources of greenhouse gases (GHG) which occurs outside the project boundary, and which is measurable and attributable to a project activity designed to mitigate greenhouse gas emissions[9].

Mitigation: Technological change and substitution that reduces resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks[10]. An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks[11].

Permanence: The longevity of a carbon pool and the stability of its stocks, given the management and disturbance environment in which it occurs[12]

Resilience: The amount of change a system can undergo without changing state. Resilience is a tendency to maintain integrity when subject to disturbance[13].

Vulnerability: The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity[14].

Natural Solutions: the argument

The following section is a summary and an associated policy analysis. The main text includes references and data supporting the case.

Protected areas are an essential part of the global response to climate change. They are helping address the cause of climate change by reducing greenhouse gas emissions. They are helping society cope with climate change impacts by maintaining essential services upon which people depend. Without them, the challenges would be even greater, and their strengthening will yield one of the most powerful natural solutions to the climate crisis.

Protected areas can contribute to the two main responses to climate change through:

Mitigation
- **Store**: Prevent the loss of carbon that is already present in vegetation and soils
- **Capture**: Sequester further carbon dioxide from the atmosphere in natural ecosystems

Adaptation
- **Protect**: Maintain ecosystem integrity, buffer local climate, reduce risks and impacts from extreme events such as storms, droughts and sea-level rise
- **Provide**: Maintain essential ecosystem services that help people cope with changes in water supplies, fisheries, disease and agricultural productivity caused by climate change

Protected area systems have the advantage that they are already established as efficient, successful and cost effective tools for ecosystem management, with associated laws and policies, management and governance institutions, knowledge, staff and capacity. They contain the only remaining large natural habitats in many areas. Opportunities exist to increase their connectivity at landscape level and their effective management so as to enhance the resilience of ecosystems to climate change and safeguard vital ecosystem services.

Opportunities to use protected areas in climate response strategies need to be prioritised by national and local governments. At a global level, the Convention on Biological Diversity's (CBD) Programme of Work on Protected Areas should be deployed as a major climate change mitigation and adaptation tool. The role of protected areas as part of national strategies for supporting climate change adaptation and mitigation should also be recognised by the UN Framework Convention on Climate Change (UNFCCC). This means:

- **UNFCCC**: recognise protected areas as tools for mitigation and adaptation to climate change; and open up key climate change related funding mechanisms, including REDD and adaptation funds, to the creation, enhancement and effective management of protected area systems
- **CBD**: renew the Programme of Work on Protected Areas at COP10 to address more specifically the role of protected areas in responses to climate change, in liaison with other CBD programmes
- **National and local governments**: incorporate the role of protected area systems into national climate change strategies and action plans, including for mitigation by reducing the loss and degradation of natural habitats, and for adaptation by reducing the vulnerability and increasing the resilience of natural ecosystems

A unique challenge

Climate change poses an unprecedented level of threat to life on the planet. In addition, predictions about the scale and speed of impact are continually being revised upwards, so that what was already a serious situation continues to look even more threatening. The facts are well known. Atmospheric greenhouse gases are creating warmer temperatures, ice melt, sea-level rise and an unpredictable climate, with a range of extremely serious and hard-to-predict consequences. Recent research shows an increasingly bleak picture. During the period of writing this report new information suggests that: we may already be too late to prevent widespread collapse of coral reef systems due to ocean acidification; climate change adaptation will cost US$75-100 billion a year from 2010 onwards for developing countries according to the World Bank; and climate change may move faster than expected with average temperatures rising 4°C by 2060 compared to pre-industrial levels according to the UK Meteorological Office. But serious as the situation has now become, much can still be done to reduce the problems created by climate change. This report focuses on the role that protected areas can play in mitigating and adapting to climate change; a set of options that hitherto has been under-represented in global response strategies. In the rush for "new" solutions to climate change, we are in danger of neglecting a proven alternative.

Why protected areas?

A protected area is defined by IUCN as a *"clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"*.

Various land use management strategies will be needed to combat greenhouse gas emissions from land use change, and to sustain ecosystem services vital to climate change adaptation. But protected areas are uniquely positioned to support national climate change mitigation and adaptation strategies as they benefit from existing policies, laws, and institutions that govern their management and on-the-ground capacities and expertise. In particular, protected area systems at national scale:

Governance and safeguards

- Have defined borders, which can be used to measure carbon sinks and storage and ecosystem services
- Operate under legal or other effective frameworks, which provide a stable, long-term mechanism for managing land and water ecosystems
- Have agreed governance structures to meet a wide range of social and cultural requirements
- Are backed by a range of supportive conventions and agreements (CBD, World Heritage, Ramsar, Man and the Biosphere, CITES etc) and regional agreements such as Natura 2000 to provide policy frameworks, tools and political support
- Recognise cultural and social values of protected areas and have experience in implementing accessible, local approaches involving people in a legitimate and effective way in management

Permanence

- Are based around a commitment to permanence and long-term management of ecosystems and natural resources
- Focus local, national and international attention on a particular protected area, adding to the area's protection

Effectiveness

- Are proven to work as an effective way of retaining natural ecosystems and ecosystem services especially through protected area systems at the landscape/seascape scale
- Are supported by management plans, which can facilitate rapid responses to new information or conditions related to climate change
- Have staff and equipment which provide management expertise and capacity, including understanding of how to manage ecosystems to generate a range of ecosystem services vital for climate change adaptation
- Provide opportunities to bring the experience developed in planning and managing protected areas to bear on developing broader landscape and seascape scale approaches to climate change mitigation and adaptation
- Can draw on existing funding mechanisms, including government budgetary appropriations, and funding from the GEF and LifeWeb
- Are backed up by networks of experts ready to provide advice and assistance, including particularly the IUCN World Commission on Protected Areas and conservation NGOs

Monitoring, verification and reporting

- Are supported by government commitments under the CBD to establish ecologically-representative protected area systems
- Have organised and populated data sources to set baselines and facilitate monitoring, such as the IUCN management categories, governance types and Red List, and the UNEP World Conservation Monitoring Centre (UNEP-WCMC) World Database on Protected Areas (these systems would need some strengthening to meet UNFCCC needs)

Well managed protected areas can provide a cost effective option for implementing climate change response strategies because start-up costs have already been met and socio-economic costs are offset by other services that protected areas supply. Protected areas are most effective when they have good capacity, efficient management, agreed governance structures and strong support from local and resident communities. Ideally protected areas and conservation needs should be integrated into wider landscape and seascape strategies.

Protected areas already cover over 13.9 per cent of the world's land surface and a growing (although still inadequate) area of coasts and oceans. In many places where population or development pressures are particularly strong, protected areas safeguard the only remaining natural ecosystems. The best protected areas are inspirational models for the management of natural ecosystems.

What protected areas can do to respond to the climate change challenge

Mitigation

Store: Prevent the loss of carbon that is already present in vegetation and soils

Challenge: Ecosystem loss and degradation are major causes of greenhouse gas emissions. The Intergovernmental Panel on Climate Change estimates that 20 per cent of greenhouse gas emissions come from deforestation and other forms of land use change.

Role of protected areas: Protected areas are the most effective management strategy known to avoid conversion to other land uses and loss of carbon and to secure carbon in natural ecosystems: research by the UNEP-WCMC shows that tropical forests inside protected areas lose far less carbon than those outside. There are opportunities to protect additional "high carbon" ecosystems and to manage, and in some cases restore, habitats for carbon retention; such as increasing water levels in peat. Data from the UNEP-WCMC suggests that there are already 312 Gt of carbon stored in the world's protected area network, or 15 per cent of the world's terrestrial carbon stock.

Implications: Carbon storage provides arguments for increasing protected area coverage and for changing management in some protected areas to retain more carbon.

Examples of storage and capture

- **Madagascar: around 6 million ha of new protected areas are being created, responsible for 4 million t of avoided CO_2 a year**
- **Tanzania: the Eastern Arc Mountains store over 151 million t C, 60 per cent of which is in existing forest reserves**
- **Belarus: on-going restoration and protection of degraded peatlands is leading to an annual reduction of greenhouse gas emissions equivalent to 448,000 t CO_2 from peatland fires and mineralization**
- **Russian Federation: the protection of 1.63 million ha of virgin taiga forests and peat soils in the Komi Republic is ensuring that their store of over 71.5 million t C is protected**
- **Bolivia, Mexico and Venezuela: protected areas contain 25 million ha of forest, storing over 4 billion t C, estimated to be worth between US$39-$87 billion**
- **Canada: 4,432 million t C is sequestered in 39 national parks, at a value of between US$72-78 billion**
- **Brazil: protected areas and indigenous lands in the Brazilian Amazon are likely to prevent an estimated 670,000 km² of deforestation by 2050, representing 8 billion t of avoided carbon emissions**

New protected areas may soon be chosen partly for their carbon storage potential, suggesting a need for new selection tools. Management operations within individual protected areas, such as prescribed burning, will also need to consider carbon emissions implications and the relationship of such practices to any agreed UNFCCC rules.

Capture: Sequester further carbon dioxide from the atmosphere in natural ecosystems

Challenge: Most natural and semi-natural ecosystems sequester carbon dioxide, thus reducing greenhouse gases. Some of these services are at risk due to habitat destruction and degradation: if these trends persist, under credible scenarios, some ecosystems could switch from carbon sinks to carbon sources over the next few years and specialised management responses are needed to address this threat.

Role of protected areas: Protection of ecosystems usually secures their sequestration potential. When climate change or other factors continue to undermine carbon dioxide capture, even inside protected areas, there is the potential to modify management specifically to increase sequestration; this includes active restoration and encouragement of natural regeneration. Degraded forests can have less than half the carbon value of intact forests.

Implications: Management of some protected habitats, especially inland waters, estuaries and peatlands, may have to be tailored to maintain sequestration potential. The role of restoration will increase in some protected areas, in particular for forests, mangroves and within natural and managed grasslands.

Adaptation

Protect: Maintain ecosystem integrity, buffer local climate, reduce risks and impacts from extreme climatic events such as storms, droughts and sea-level rise

Challenge: The Millennium Ecosystem Assessment estimates that 60 per cent of global ecosystem services are degraded, which: "*…contributed to a significant rise in the number of floods and major wild fires on all continents since the 1940s*". Economic losses from climate disasters have increased ten-fold in 50 years, and "natural" disasters from floods, storms, tidal surges, droughts and avalanches will continue to increase in frequency and intensity.

Role of protected areas: Protected areas can help to reduce the impact of all but the largest natural disasters:

- **Floods**: providing space for floodwaters to disperse and absorbing impacts with natural vegetation
- **Landslides**: stabilizing soil and snow to stop slippage and slowing movement once a slip is underway
- **Storm surges**: blocking storm surges with coral reefs, barrier islands, mangroves, dunes and marshes
- **Drought and desertification**: reducing grazing pressure and maintaining watersheds and water retention in soil
- **Fire**: limiting encroachment into fire-prone areas, maintaining traditional management systems

Implications: The integrity of ecosystems, communities and species, and of the processes that confer resilience in ecosystems, is an essential factor in protecting against increasingly variable climatic extremes. A revised protected area gap analysis should consider other vital ecosystem services as well as biodiversity, and some management approaches may need to be modified. Recognition of disaster reduction options will add impetus to increasing protected areas, in particular for mountains, steep slopes and coastal and inland wetlands.

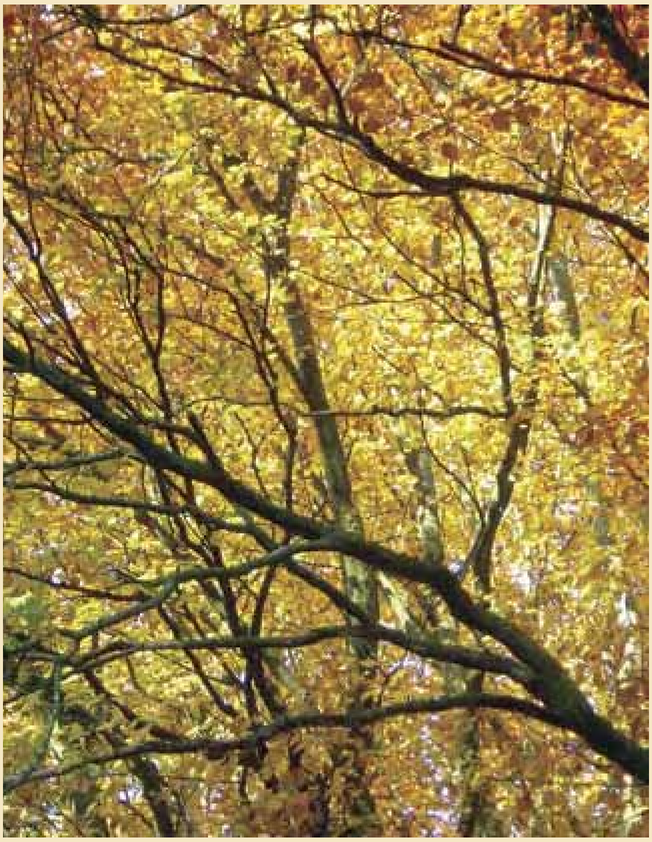
Provide: Maintain essential ecosystem services that help people cope with changes in water supplies, fisheries, incidence of disease and agricultural productivity caused by climate change

Challenge: Climate change is likely to exacerbate shortages of food, potable water and traditional medicines and to increase the spread of certain disease vectors and thus the need for alternative sources and new products. Food and water resource shortages will likely be unpredictable and sometimes severe, increasing the costs of humanitarian assistance for the most vulnerable.

Role of protected areas: Protected areas are proven tools for maintaining essential natural resources and services, which in turn can help increase the resilience and reduce the vulnerability of livelihoods in the face of climate change:

- **Water**: both purer water and (especially in tropical montane cloud forests) increased water flow
- **Fish resources**: marine and freshwater protected areas conserve and rebuild fish stocks
- **Food**: by protecting crop wild relatives to facilitate crop breeding and pollination services; providing sustainable food for communities
- **Health**: ranging from habitat protection to slow the expansion of vector-borne diseases that thrive in degraded ecosystems to access to traditional medicines

Implications: Protected area specialists need to work closely with relevant national and local level governments and technical agencies responsible for managing ecosystem services to ensure that they continue to support livelihoods under conditions of climate change. In some cases, investments in restoring ecosystems within and adjacent to protected areas may be necessary to enhance ecosystem services that serve to reduce the vulnerability of human societies to climate change.



Autumn leaves in a temperate forest © Nigel Dudley

Examples of protection and provision

- **Global: 33 of the world's 105 largest cities derive their drinking water from catchments within forest protected areas**
- **Global: 112 studies in marine protected areas found that they increased size and population of fish**
- **Kenya: improved fishery health through protection of coral reefs is providing dual benefits for coral reef conservation and per capita income for local people**
- **Papua New Guinea: in Kimbe a locally-managed marine protected area network is being designed, focusing on resilience to climate change, to protect coral reefs, coastal habitats and food security**
- **Global: over 100 studies in protected areas have identified important crop wild relatives**
- **Colombia: the *Alto Orito Indi-Angue Sanctuary* was set up explicitly to protect medicinal plants**
- **Trinidad and Tobago: the restoration and conservation of the Nariva wetlands recognises their importance as a carbon sink, a high biodiversity ecosystem and a natural buffering system against coastal storms**
- **Sri Lanka: the Muthurajawella protected area has flood protection valued at over US$5 million/year**
- **Australia: management of Melbourne's forested catchments (almost half of which are protected areas) is being adapted in the face of climate change scenarios to minimise water yield impacts**
- **Switzerland: 17 per cent of forests are managed to stop avalanches, worth US$2-3.5 billion per year**

Next steps in building and strengthening protected area systems

Protected areas are already providing vital climate change mitigation and adaptation benefits. But their potential is still only partially realised and their integrity remains at risk; indeed research shows that unless protected area systems are completed and effectively managed they will not be robust enough to withstand climate change and contribute positively to response strategies. Increasing protected area size, coverage, connectivity, vegetation restoration, management effectiveness and inclusive governance would enable a scaling up of the potential of the global protected areas system as a solution to the challenge of climate change and as a model for other resource management programmes. Two issues are critical:

- **Finances**: despite some welcome funding initiatives, analysis shows that support for the global protected area network is far less than half that needed for maximum efficiency and that some governments are reducing net support at the moment. Further resources are needed to maintain and enable an expanded role for protected areas, including extra capacity development to meet new challenges and opportunities presented by climate change.
- **Policy**: currently national and international policy instruments aimed at the twin environmental crises of biodiversity loss and climate change are often not sufficiently coordinated, wasting resources and missing valuable and complementary policy opportunities.

Financial and policy instruments are needed to address six important responses, summarised in the box below.

The two key multilateral environmental agreements – the UNFCCC and the CBD – are responsible for climate change mitigation and adaptation and ecosystem conservation and management respectively. The UNFCCC explicitly recognises the relationship between ecosystem resilience and the vulnerability and resilience of human communities, and the decisions taken within the context of the CBD have highlighted the threat of climate change on biodiversity and ecosystems. Several steps are needed to improve the effectiveness of protected areas as a significant tool for climate change mitigation and adaptation within the implementation programmes of both conventions, thus enhancing their potential to achieve targeted outcomes at country level, and collectively for the global community. Several initiatives are also required from national governments.

Six key policy and management developments are needed for protected areas to function more effectively as a climate change response mechanism

- **More and larger protected areas:** particularly in ecosystems where much carbon is stored and/or captured and is likely to be lost without protection, or where important ecosystem services are under threat – particularly tropical forests, peatlands, mangroves, freshwater and coastal marshes and seagrass beds, as well as marine ecosystems
- **Connecting protected areas within landscapes/ seascapes:** using management of natural or semi-natural vegetation outside protected areas or intervening waters. This can include buffer zones, biological corridors and ecological stepping stones, which are important to build connectivity to increase ecosystem resilience to climate change at the landscape/seascape scale and to increase the total amount of habitat under some form of protection
- **Recognition and implementation of the full range of governance types:** to encourage more stakeholders to become involved in declaring and managing protected areas as part of community climate response strategies, particularly through indigenous and community conserved areas and private protected areas
- **Improving management within protected areas:** to ensure that ecosystems and the services that they provide within protected areas are recognised and not degraded or lost through illegal use or unwise management decisions
- **Increasing the level of protection for carbon stores within protected areas:** by recognising protection and management aimed at specific features that have high value in carbon storage, for example to maintain old-growth forest, avoid ground disturbance or drying out of peat and also using restoration in protected areas where vegetation has been degraded
- **Focusing some management specifically on mitigation and adaptation needs:** including modification of management plans, selection tools and management approaches as necessary

Evenke reindeer breeder, Siberia, Russian Federation © Hartmut Jungius / WWF-Canon

UNFCCC

- Recognise the role of protected areas as tools for permanent carbon storage and sequestration and call for the implementation of robust protected areas systems as a core component of national strategies to achieve land-based emissions reductions
- Emphasise the role of ecosystems in climate change adaptation and incorporate protection of natural ecosystems within national adaptation strategies and action plans (including National Adaptation Programmes of Action – NAPA) for protection of natural ecosystems as a cost-effective alternative to technology- and infrastructure-based adaptation measures and to avoid mal-adaptation
- Permit nationally appropriate mitigation and adaptation actions that involve the enhancement of protected areas or national protected area networks to receive financial and technical assistance through climate-related financial mechanisms

CBD

- Renew the Programme of Work on Protected Areas at COP 10 to address more explicitly climate change impacts and response strategies, in liaison with other CBD programmes
- Encourage development of tools and methods to support countries to evaluate climate impacts and increase resilience of their protected areas systems, and ensure that their role in mitigation and adaptation is fully explored
- Emphasise the importance of increasing connectivity among national protected areas and transboundary protected areas to further enhance the benefits of protected area networks as a climate change response strategy
- Cultivate political urgency for the development of marine protected areas and protected areas in under-represented biomes

National and local governments

- Incorporate the role of protected area systems into national climate change strategies and action plans
- Address mitigation by reducing the loss and degradation of natural habitats
- Strengthen adaptation by reducing the vulnerability and increasing the resilience of natural ecosystems
- Ensure effective management of protected areas to provide benefits to biodiversity and climate change mitigation and adaptation

Section 1
Introduction

The Intergovernmental Panel on Climate Change has laid out in considerable detail the likely trends in climate and the expected ecological responses. The first part of this section summarises the latest IPCC thinking on issues that relate most closely to protected areas.

The second part looks at how intergovernmental processes, particularly the UN Framework Convention on Climate Change and the Convention on Biological Diversity, have dealt with mitigation and adaptation in relation to protected areas. Some examples of national government responses are also included.

Next, protected areas are introduced as a concept. The range of different management models and governance approaches is described, along with some basic statistics about coverage and area.

Finally, and most importantly, this section explains why protected areas are uniquely placed to help confront climate change.

The consequences of climate change for nature, natural resources and the people who depend on them

KEY MESSAGES

It is highly probable that climate change is *already* adversely affecting terrestrial and marine ecosystems and that these changes will increase in rate and severity during the century. This means that food and water will be less available, natural disasters more frequent, human health put at risk, species will be lost and ecosystems destroyed or degraded. Ecosystems and species in protected areas will not be exempt from these affects.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published in 2007 draws on more than 29,000 observational data series from 75 studies[15]. The results show significant changes in many physical and biological systems; more than 89 per cent are consistent with the projected effects of climate change on natural systems. Overall the analysis led the IPCC to conclude: *"Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases."*

The following section summarises some IPCC conclusions relating to natural ecosystems and natural resources and outlines the consequences for human communities. Impacts on protected areas, and possible management responses, are discussed further in section 5.

Current impacts

The IPCC assesses that there is very high (i.e. 90 per cent) confidence* that recent warming is strongly affecting **terrestrial biological systems**, including:

- Earlier timing of spring events, such as leaf-unfolding, egg-laying and bird migration
- Plants and animals shift ranges polewards and upwards

There is high (80 per cent) confidence that natural systems related to **snow, ice and frozen ground** (including permafrost) are affected, including the:

- Enlargement and increased numbers of glacial lakes
- Increasing ground instability in permafrost regions and rock avalanches in mountain regions
- Changes in Arctic and Antarctic ecosystems, including those in sea-ice biomes, and affecting top predators

There is also high confidence of the effects on **hydrological systems** including:

- Increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers
- Warming of lakes and rivers in many regions, with effects on thermal structure and water quality

There is high confidence that changes in **marine and freshwater biological systems** are associated with rising water temperatures and related changes in ice cover, salinity, oxygen levels and circulation including:

- Shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans
- Increases in algal and zooplankton abundance in high-latitude and high-altitude lakes
- Range changes and earlier fish migrations in rivers

There is increasing evidence of climate change impacts on coral reefs. However it is difficult to separate these from other stresses (e.g. over-fishing and pollution). Sea-level rise and human development are also contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding.

Assessment of **managed and human systems** is particularly difficult given that the drivers of change are so complex, and the confidence the IPCC attaches to reports assessing the impacts on these systems is therefore lower (50 per cent):

- In the higher latitudes of the Northern Hemisphere agricultural and forest management impacts include earlier spring planting of crops, and alterations in disturbances of forests due to fires and pests
- Some impacts on human health, such as excess heat-related mortality in Europe, changes in infectious disease vectors in parts of Europe, and earlier onset of and increases in seasonal production of allergenic pollen in the high and mid-latitudes of the Northern Hemisphere
- Impacts on human activities in the Arctic, in relation to hunting activities and shorter travel seasons over snow and ice, and in lower-elevation alpine areas, such as changes in mountain sports activities

* As with all IPCC reports, a standardised framework for the treatment of uncertainties is used when discussing the effects of climate change

Green Sea Anemones, Olympic coast, Washington DC, USA © Fritz Pölking / WWF

Future impacts: The fourth IPCC report has a higher level of confidence about the projected impacts during the 21st century than earlier reports. It concludes that warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean (near Antarctica) and northern North Atlantic. It projects that:

- It is very likely that extreme hot weather, heat waves and heavy precipitation events will be more frequent
- Increases in precipitation are very likely in high-latitudes
- Decreases in precipitation are likely in most subtropical land regions
- Tropical cyclones (typhoons and hurricanes) are likely to become more intense

It is very likely that increased global average temperature exceeding 1.5 to 2.5°C with related atmospheric CO_2 concentrations will create: *"major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply"*. Specifically, during this century:

- The resilience of many ecosystems is likely to be exceeded by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and other factors (e.g. land-use change, pollution, fragmentation of natural systems, overexploitation of resources)
- The net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change
- Approximately 20-30 per cent of plant and animal species are likely to be at increased risk of extinction

Other significant impacts include:

- Coastal areas exposed to erosion due to climate change and sea-level rise, which will result in many millions of people experiencing annual flooding events by the end of the century
- The health of millions of people affected through increases in malnutrition, diarrhoeal diseases, and cardio-respiratory diseases (the last due to higher concentrations of ground-level ozone); more extreme weather events; and impacts related to the changing distribution of some infectious diseases
- Overall the negative impacts of climate change on freshwater systems will outweigh benefits. Changes in precipitation and temperature will lead to altered runoff and water availability. Although runoff is projected to

CASE STUDY

Fires … hotter, more severe and more frequent in Australia

Climate change is influencing the nature and intensity of Australian bushfires such as the disastrous Victorian fires of 7th February 2009 according to bushfire management experts, research organisations16 and researchers17. The situation will get worse. Climate change forecasts identify that the number of extreme fire days will increase between 15 per cent and 65 per cent by 2020 (relative to 1990) for high global warming estimates and the number of catastrophic fire weather events will increase from 12 sites from 1973 (over 36 years) to 20 sites between 2009 and 202018.

I have been involved in bushfire management in Australia since the 1970's as an on-ground fire fighter, a fire strategist and as an incident controller for many, many fires, and the intensity and ferocity of the February 2009 Victorians exceeded the hottest of the fires I have ever experienced. When we look at the conditions in which the fire burnt, it is not surprising this was the case. The fires were preceded by a severe and protracted drought which is without historical precedent. In central Victoria, the 12-year rainfall totals were 10-13 per cent below the lowest on record for any 12 year period before 1997[19]. For the capital city Melbourne, a record breaking heat wave meant maximum temperatures were above 30 degrees Celsius every day of the 11 days prior to the 7th February (called Black Saturday). This caused extensive drying and curing of vegetation matter and forest fuels. On Black Saturday, the highest ever recorded temperature was recorded for Melbourne (46 degrees Celsius) and the humidity was less than 10 per cent for many hours. Even worse, atmospheric instability provided an opportunity for massive convection columns to develop, and consequently severe fire weather phenomena. Of the 100 fires that started on Black Saturday, those fires influenced by an upper atmosphere trough were the worst. Apart from a fire in South Australia in 2005, these were the most extreme fire weather conditions in the recorded history of Australia. The average spread of the fire was 12 km/hr (and faster in localised situations), however fire brands ahead of the fire, driven by the 100 km/hr winds were causing spot fires up to 35 kilometres down wind. This extreme spotting effect was unprecedented. Flames of over 100 metres in length were observed, and the total amount of heat released has been estimated to equal 1500 atomic bombs the size of the one used in Hiroshima[20]. Regrettably, there were 173 fatalities and 2029 homes lost in the fires. It was fire weather behaviour influenced by climate change, something more severe than I have ever encountered before and a portent of fire behaviour for Australians for the future.

Source: Graeme L. Worboys

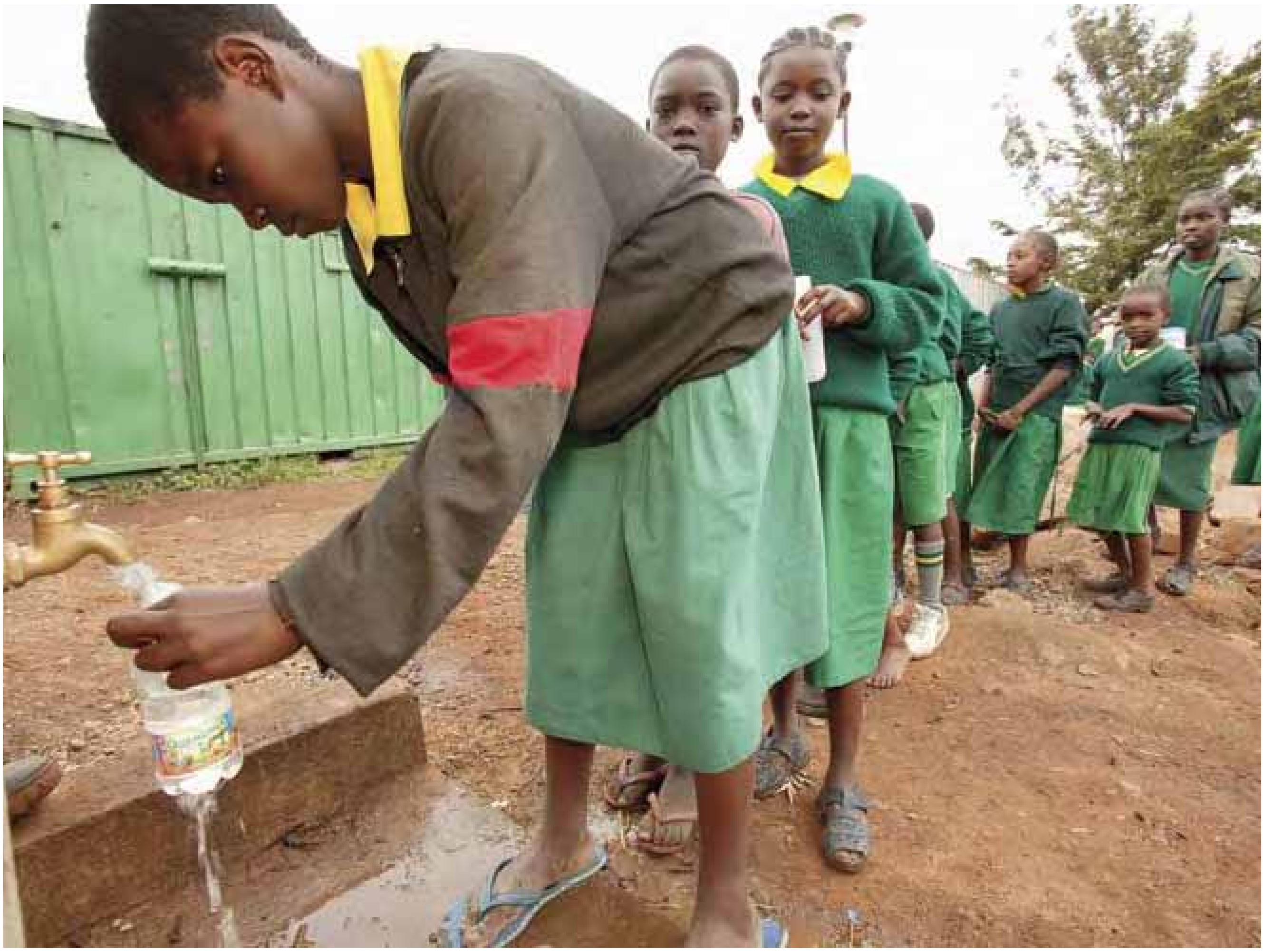
increase by 10-40 per cent by mid-century at higher latitudes and in some wet tropical areas, beneficial impacts are expected to be offset by the negative effects of increased variability in precipitation and runoff. Up to 20 per cent of people will live in areas where river flood potential could increase by the 2080s
- Conversely, there is likely to be a decrease in runoff of between 10-30 per cent in some dry regions at mid-latitudes and in the dry tropics, due to reduced rainfall and higher rates of evapotranspiration. Many semi-arid areas (e.g. the Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources. Finally, increased temperatures will affect the physical, chemical and biological properties of freshwater lakes and rivers, with predominantly adverse impacts
- Slight increases in crop productivity in mid- to high latitudes; but decreases at lower latitudes

Regional impacts are also reported. The IPCC attaches high or very high confidence to all of the impacts below, although the magnitude and timing of impacts will vary with the amount and rate of climate change.

Africa
- By 2020, 75-250 million people are projected to be exposed to increased water stress
- By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50 per cent
- Towards the end of the century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10 per cent of GDP
- By 2080, arid and semi-arid land is projected to increase by 5-8 per cent

Asia
- By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease
- Coastal areas, especially heavily populated mega-delta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers
- Climate change is projected to compound pressures associated with rapid urbanisation and industrialisation
- Endemic morbidity and mortality due to diarrhoeal disease, primarily associated with floods and droughts, are expected to rise in East, South and South-East Asia

Australia and New Zealand
- By 2020, significant loss of biodiversity is projected to occur in some ecologically rich sites, including the Great Barrier Reef and the Wet Tropics in Queensland
- By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions
- By 2030, agriculture and forestry production is projected to decline over these area, due to drought and fire
- By 2050, ongoing coastal development and population growth in some areas is projected to exacerbate risks



Water is a precious resource in Nairobi, Kenya © Martin Harvey / WWF-Canon

Europe
- Climate change is expected to magnify regional differences in the quantity and quality of natural resources and assets
- Negative impacts will include increased risk of flash floods, coastal flooding and erosion
- Mountainous areas will face glacier retreat, reduced snow cover, and extensive species losses
- In southern Europe, climate change is projected to reduce water availability, hydropower potential, summer tourism and crop productivity

Latin America
- By mid-century, increases in temperature and associated decreases in soil water are projected to lead to a gradual replacement of tropical forest by savannah in eastern Amazonia
- Similarly, areas of semi-arid vegetation will tend to be replaced by arid-land vegetation
- There is a risk of significant biodiversity loss through species extinction in many areas
- Changes in precipitation and disappearance of glaciers are projected to significantly affect water availability

North America
- Warming in western mountains is projected to cause decreased snow-pack, more winter flooding and reduced summer base stream flows, exacerbating competition for water resources
- The number, intensity and duration of heat waves are predicted to result in adverse health impacts in cities
- Coastal communities and habitats will be stressed by climate change, development and pollution

Polar Regions
- Changing snow and ice conditions will harm infrastructure and traditional indigenous ways of life
- In both polar regions specific ecosystems and habitats are projected to be vulnerable to species invasions
- Reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems will damage many organisms including migratory birds, mammals and higher predators

Small Islands
- Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards
- By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, so that they become insufficient to meet demand during low-rainfall periods
- With higher temperatures, increased invasion by non-native species is expected to occur

Glacier carving, Spitsbergen, Norway © Steve Morello/WWF-Canon

SOLUTIONS

Addressing climate change requires major and fundamental changes in the way that we live, do business and interact with each other. The overwhelming priority is to reduce emissions of greenhouse gases and to increase rates of carbon sequestration.

This report looks at one important part of any rational response strategy: **the use of protected areas as a tool to conserve natural and semi-natural systems; both to capture and store carbon from the atmosphere and to help people and ecosystems adapt to the impacts of climate change.**

Of course protected areas are not a complete solution, nor should reliance on them be used to replace or undermine efforts to reduce emissions at source. But they are an essential – though so far often neglected – part of the strategy.

International and national responses – how policy makers view the role of protected areas

KEY MESSAGES

The IPCC has identified protected areas as essential in mitigating and adapting to climate change. Other intergovernmental bodies have repeated this message, particularly the CBD. National governments are already starting to include protected areas as tools within their own climate response strategies. But there is much, much more to do.

Protected areas have already been widely recognised as a practical mitigation and adaptation strategy by governments and inter-governmental bodies. This chapter reviews some existing responses from policy makers.

Intergovernmental Panel on Climate Change: The IPPC calls for the use of protected areas as an element in enhancing both mitigation and adaptive capacity, and in reducing emissions and vulnerability to climate change[21]. The IPPC report focused in particular on the role of forest protection and management in terms of limiting climate impacts, proposing that some 65 per cent of the total mitigation potential is located in the tropics and about 50 per cent of the total could be achieved by reducing emissions from deforestation[22]. The report identified that forest-related mitigation activities are likely to be relatively low cost and can create important synergies with climate change adaptation and sustainable development, with substantial co-benefits in terms of employment, income generation, biodiversity and watershed conservation, renewable energy supply and poverty alleviation[23]. The IPCC report on forestry concluded: *"While **regrowth of trees due to effective protection will lead to carbon sequestration, adaptive management of protected areas also leads to conservation of biodiversity and reduced vulnerability to climate change**. For example, ecological corridors create opportunities for migration of flora and fauna, which facilitates adaptation to changing climate"*[24] (our emphasis). In terms of mechanisms to achieve these win-win situations, the IPCC notes that the forest policies, measures and instruments shown to be environmentally effective include:

- Financial incentives (national and international) to increase forest area, to reduce deforestation, and to maintain and manage forests
- Land use regulation and enforcement[25]

This combination of agreed approaches to land management backed up by financial incentives is precisely the model advocated in the current report.

UN Framework Convention on Climate Change: The UNFCCC has not yet referred specifically to protected areas and is currently in the middle of intense negotiations about meeting emission reductions. However, its 2007 *Bali Action Plan* set the roadmap for the Copenhagen negotiations and specifically called for more action on mitigation and adaptation strategies – a call that is beginning to be answered by many countries (see table 1). In June 2009, United Nations Environment Programme (UNEP) released a report urging the UNFCCC and others to take greater account of the role of natural ecosystems in carbon sequestration[26].

Fir trees and beech trees in autumn, Finland © Mauri Rautkari / WWF-Canon

Convention on Biological Diversity: The CBD has recognised the role of protected areas in addressing climate change in its Programme of Work on Protected Areas (PoWPA): "1.4.5 Integrate climate change adaptation measures in protected area planning, management strategies and in the design of protected area systems". More explicitly, its Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA), called at SBSTTA 11 (Recommendation XI/14) for *"guidance for promoting synergy among activities addressing biological diversity,*

Table 1: National climate change responses using protected areas

Country	Document	Details
Australia	National Biodiversity and Climate Change Action Plan (2004-2007)[31]	The plan was developed to coordinate activities of different jurisdictions to address the impacts of climate change on biodiversity. It includes strategies and actions related to protected areas including the development of new reserves incorporating assessment of climate change impacts (Strategy 5.2 and related actions) specifically in relation to marine protected areas (Strategy 4.2 and 4.5).
Brazil	National Plan on Climate Change (2008)[32]	The plan defines actions and measures aimed at mitigation and adaptation to climate change. It has 7 specific objectives, 2 related to forests including: *"Seek for sustained reduction in deforestation rates, in all Brazilian biomass, in order to reach zero illegal deforestation"*. Actions include: *"identification of public forests to be protected, preserved and managed",* and creation of an Amazon Fund to *"raise financial resources nationally and internationally for the reduction of deforestation, sustainable use and conservation, especially in the Amazon forest".*
China	National Climate Change Program (2007)[33]	The programme outlines objectives to 2010. Natural resource conservation is mentioned twice; section 2.3.4 states: *"To combat climate change, it is necessary … to strengthen forest and wetland conservation to enhance capacities for climate change adaptation; and … to strengthen forest and wetland restoration and afforestation to enhance capacities for carbon sequestration."* Section 3.3.2: *"Through strengthening the natural forest conservation and nature reserve management and continuously implementing key ecological restoration programmes, establish key ecological protection area and enhancing natural ecological restoration. By 2010, 90% of typical forest ecosystems and national key wildlife are effectively protected and nature reserve area accounts for 16% of the total territory; and 22 million hectares of desertified lands are under control."*
Finland	National Strategy for Adaptation to Climate Change (2005)[34]	The protected area network in the Alpine and eastern zones should be sufficient to adapt to climate change as there is an opportunity to: "*control land use efficiently to reduce the human-induced stress and thus promote the conservation of alpine habitat types and the habitats of species*". However protected areas in southern Finland are less extensive and "*the possibilities for the protected areas to provide species with opportunities for adaptation/transition are restricted*." Responses include: "*a more extensive international evaluation and development of the network of protected areas, for example, within the Barents cooperation…*".
India	National Action Plan on Climate Change (2008)[35]	The plan identifies 8 core "national missions" running through to 2017 and directs ministries to submit detailed implementation plans to the Prime Minister's Council on Climate Change. The National Mission for Sustaining the Himalayan Ecosystem includes: "*aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers that are a major source of India's water supply are projected to recede as a result of global warming*".
Mexico	Special Program on Climate Change (2009 review draft)	The programme's objectives are to develop and solidify guidelines contained in the previously released National Strategy on Climate Change (ENACC). It covers energy generation; energy use; agriculture, forests, and other land uses; waste; and private sector, and contains 41 mitigation objectives and 95 related targets, most by 2012. It includes plans to preserve, widen, and connect protected areas, build ecosystem resilience and design, pilot and implement REDD projects[36].
South Africa	A national climate change response strategy for South Africa (2004)[37]	The strategy concludes with 22 key actions relating a range of issues from CDM projects to health protection and promotion measures to counter climate change; and includes an action to: "*Develop protection plans for plant, animal and marine biodiversity*."

desertification, land degradation and climate change" and called for a range of responses[27]. It is likely that the review of the PoWPA scheduled for late 2010 will increase the emphasis on climate change mitigation and adaptation within protected area policies; these issues featured very strongly at recent meetings to plan the future of the PoWPA[28]. In addition, the CBD and UNFCCC already have a joint working group looking at synergies between the two conventions[29].

Other international conventions: Many other international agreements include discussion of climate change, such as the Millennium Declaration and its Millennium Development Goals (MDG), the World Summit on Sustainable Development and its Johannesburg Plan for Implementation, the World Heritage Convention (which explicitly looks at the role of protected areas in mitigation)[30] and the UN Commission on Sustainable Development.

National responses: An increasing number of governments are drawing on protected areas as tools for combating climate change, although the large majority are still not including them in their National Adaptation Programmes of Action. Table 1 outlines some examples of national initiatives.

Due to its complexity and the array of causes, impacts and responses, climate change requires synergy between many international instruments[38], co-operation between different government departments within countries and the involvement of different stakeholder groups. At present, this is frequently not happening. Governments are focusing on "brown solutions" (emissions reductions etc.) and not always considering the knock-on effects to the "green" or "blue" solutions (carbon stored in terrestrial vegetation or in the seas and oceans). For example, a narrow focus on emission reductions has encouraged biofuel production, which if not properly planned frequently results in additional carbon being lost from terrestrial systems. More integrated approaches are urgently required[39].

The main findings from the study of the economics of ecosystems and biodiversity (TEEB) will be published in 2010; however a summary report on climate change, released in 2009 as an input to the Copenhagen climate negotiations, highlights some urgent issues for policy makers.

The TEEB *Climate Issues Update*[40] highlights three issues of particular importance to be considered by policy-makers in Copenhagen:

1. Urgent consideration of the imminent loss of **coral reefs** due to climate change, which will result in serious ecological, social, and economic consequences.
2. An early and appropriate agreement on **forest carbon** to mitigate climate change.
3. The recognition of the cost-benefit case for public investment in **ecological infrastructure** (especially restoring and conserving forests, mangroves, river basins, wetlands, etc.), particularly because of its significant potential as a means of adaptation to climate change.

The paper also stresses that including forests as a major mitigation option would set an important precedent and a potential platform for the development of other payments for ecosystem services. To this end TEEB recognises that a "*successful global agreement would mark society's entry into a new era which 'mainstreams' the economics of ecosystems and biodiversity: not just demonstrating ecosystem benefits, but capturing them through priced rewards*". Such an agreement would mark the beginnings of the change in the global economic model that TEEB is recommending in all its reports.

However, as the report notes: "*we cannot manage what we do not measure*". The measurement of carbon sequestration (flow) by forests is relatively well established and accurate, whereas the measurement of carbon sequestration by soil, water and other biota (flows) and the stock of carbon are less developed and not standardised; and the assessment of linkages across ecosystems services remain weak. Thus to implement such an agreement will require the reliable global measurement and accounting for carbon storage and sequestration in a variety of ecosystems.

The paper also notes the importance of ensuring that a global forest carbon agreement includes the assessment of conservation success. TEEB suggest indicators of conservation effectiveness may include:

- Efforts to develop non-agricultural income-generating activities in forest dependent communities
- Improving the management of existing protected areas by increasing staffing and equipment as well as agreements with forest communities
- Expanding protected areas through new legislation
- Promoting independent verification of protected area management

Overall, in economic terms the TEEB report notes that: "*Direct conservation, e.g. via protected areas, or sustainable use restrictions, are means of maintaining our ecological infrastructure healthy and productive, delivering ecosystem services. Very high benefit-cost ratios are observed, so long as we include amongst benefits a valuation of the public goods and services of ecosystems, and compute social returns on investment.*"

The potential of the world's protected areas system to address climate change

KEY MESSAGES

Protected areas are essential for maintaining natural ecosystems in perpetuity and already provide critically important ecosystem functions. They use numerous management approaches and governance types, facilitating the development of a resilient, worldwide network.

What are protected areas?
Although there are two global protected area *definitions*, from IUCN and the CBD, it is recognised that they convey essentially the same message.

- **IUCN definition**: *A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*[41].
- **CBD definition**: *A geographically defined area which is designated or regulated and managed to achieve specific conservation objectives.*

Protected areas range from places so strictly preserved that human visitation is banned or strictly controlled, to protected landscapes and seascapes, where biodiversity protection takes place alongside regulated traditional (and in some cases modern) production activities often with resident human communities. Management can rest with the state, local government, not-for-profit trusts, companies, private individuals, communities or indigenous peoples' groups. Over time protected areas have developed from rather top-down, centrally managed designations to far more inclusive, participatory and varied management systems, An internationally recognised typology describes different approaches, recognising six ***categories*** of management objective and four ***governance types***; these can be used in any combination as shown in figure 1.

Modern protected areas focus explicitly on the conservation of biodiversity although most have other roles in terms of providing social and cultural values, which are also reflected in management. An increasing number of governments consciously try to include all national ecosystems and species within the protected area system, on a scale large enough to support populations of resident plant and animal species in the long-term. The IUCN Species Survival Commission reports that 80 per cent of mammal, bird and reptile and amphibian species are already represented in protected areas.

Map of the global protected area network

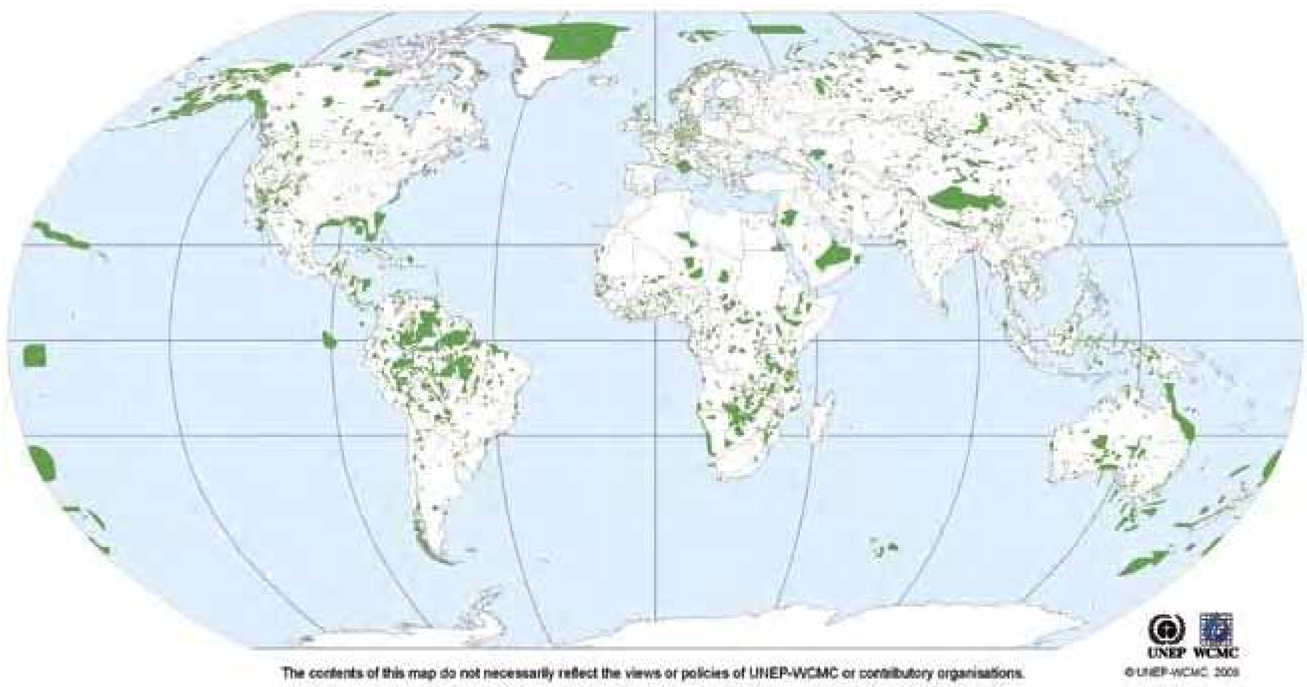


Figure 1: Matrix of IUCN protected area management categories and governance types

IUCN category (management objective)	**IUCN Governance type**										
	A. Governance by governments			B. Shared governance			C. Private governance			D. Governance by indigenous peoples and local communities	
	Federal or national ministry or agency in charge	Local ministry or agency in charge	Management delegated by the government	Transboundary protected area	Collaborative management (various pluralist influences)	Collaborative management (pluralist management board)	Declared and run by private individual	Declared and run by non-profit organisations	Declared and run by for-profit individuals	Declared and run by indigenous peoples	Declared and run by local communities
I – Strict nature or wilderness protection											
II – Ecosystem protection and recreation											
III – Protection of natural monument or feature											
IV – Protection of habitats and species											
V – Protection of landscapes or seascapes											
VI – Protection and sustainable resource use											

Most protected areas do not work in isolation but need to be inter-connected through biological corridors or other suitable habitats. Protected areas thus form the core of most national or regional biodiversity conservation strategies but are not the only conservation tool.

A global system: There are some 120,000 designated protected areas* covering 13.9 per cent of the Earth's land surface; marine protected areas cover 5.9 per cent of territorial seas and 0.5 per cent of the high seas[42]. There are also an unknown number of protected areas outside the state system, including indigenous and community conserved areas, which in some countries may provide comparable coverage to those protected areas set up by the state[43]. These together represent a huge investment by governments, trusts, local communities, indigenous peoples and individuals to protect land and water for conservation purposes. Most protected areas were created during the twentieth century; the establishment of the world's protected areas estate represents the fastest conscious change in land management that has ever occurred. Despite this rapid growth, some ecosystems remain poorly protected, including for example grasslands, inland waters and the marine environment. Opportunities for further protection will inevitably decrease over time as available land and water becomes scarcer.

* As listed by the World Database on Protected Areas (WDPA)

Purpose: Protected areas are the cornerstones of national and international biodiversity conservation strategies. They act as refuges for species and ecological processes that cannot survive in intensely managed landscapes and seascapes and provide space for natural evolution and future ecological restoration. Protected areas are embedded within landscapes and seascapes, often forming the core of remaining natural ecosystems and in this way contribute to the composition, structure and wider functioning of ecosystems well beyond their own borders.

Protected areas also provide a wide variety of more immediate human benefits. People – both those living nearby and at a national or international level – gain from the genetic resources found in wild species, ecosystem services, recreational opportunities provided by wild spaces and the refuge that protected areas can give to traditional and vulnerable human societies. Most people believe that we have an ethical obligation to prevent species loss due to our own actions. Flagship protected areas are as important to a nation's heritage as, say, Notre Dame cathedral or the Taj Mahal, and many have irreplaceable cultural and spiritual values alongside their rich biodiversity.

Although protected areas exhibit huge variety, they are also all bound to certain obligations, as captured in the CBD and IUCN definitions. They are all identifiable,

Table 2: The ecological representativeness of the global protected areas estate in 2009: progress towards the CBD 2010 target[44]

Biome	Area (km²)	% of area protected
Temperate grasslands, savannahs and shrub lands	10,104,060	4.1
Boreal forests / taiga	15,077,946	8.5
Tropical and subtropical coniferous forests	712,617	8.7
Mediterranean forests, woodlands and scrub	3,227,266	10.2
Tropical and subtropical dry broadleaf forests	3,025,997	10.4
Deserts and xeric shrub lands	27,984,645	10.8
Temperate broadleaf and mixed forests	12,835,688	12.1
Temperate conifer forests	4,087,094	15.2
Tropical and subtropical grasslands, savannahs and shrub lands	20,295,424	15.9
Tropical and subtropical moist broadleaf forests	19,894,149	23.2
Montane grasslands and shrub lands	5,203,411	27.9
Mangroves	348,519	29.1
Flooded grasslands and savannahs	1,096,130	42.2

Grasslands, Bosnia and Herzegovina © Michel Gunther / WWF-Canon

geographically-defined areas*, which are **recognised** as being protected. Such recognition usually takes the form of government laws but can also be in the form of self-declared community decisions or the policies of trusts or companies. Protected areas also need to be **managed**; this management could include the decision to leave the area entirely alone but might also include active restoration in cases where the area has previously suffered degradation, or other measures to maintain ecosystem integrity (e.g. by controlling alien invasive species). Critically, protected areas are designed to maintain their values in the **long-term**, i.e. they are not temporary designations that can be set aside or changed but represent a long-term commitment to the sound management of ecosystems and ecological processes and the protection of species. It is precisely because protected areas involve the recognised, long-term protection and management of areas to maintain natural ecosystems that they are so suitable as a means to mitigate and adapt to climate change.

* The boundaries of protected areas can in certain circumstances vary over time, for example if areas are designated "no-go" at certain times of year to protect spawning sites for fish but remain open at other times – but these cases are exceptional.

Why protected areas?

KEY MESSAGES

Although many natural and managed ecosystems can help to mitigate or adapt to climate change, protected areas offer several advantages: recognition (often legal); long-term commitment to protection; agreed management and governance approaches; and management planning and capacity. They are often the most cost effective option. In many situations they contain the only natural or semi-natural habitats remaining in large areas.

Much of this report focuses on the role of natural ecosystems in helping human communities to mitigate and adapt to climate change. In theory, any natural or semi-natural ecosystem can be managed to assist mitigation and adaptation to climate change, whatever its governance system: e.g. unused lands, indigenous lands or those set aside as strategic reserves. So too can many managed ecosystems. Governments and other land owners will need to be creative in finding ways to recognise and maintain ecosystem values within all natural and cultural habitats. Indigenous peoples and local communities often recognise the values of natural systems and may have been managing to sustain these values for millennia[45].

However, many traditional management systems are breaking down due to outside pressure. These include population pressure and demands for access to natural resources, and sometimes due to social changes within communities. As the ecosystems deteriorate, their services are also degraded or lost. The global economic system can exacerbate this process, unless it is implemented within a strong national and international policy framework.

Although it is well established that natural systems have high values, these usually accrue in a dispersed form to many people in a community and even more tenuously to the national or global community in terms of ecosystem services. For an individual or company, it is often more profitable to use the resources in a non-renewable way. For instance a forested watershed may benefit downstream communities by providing clean water with a high market value, but the individual owning the land can often make an immediate profit by selling the timber even if by doing so water quality regulation and provisioning services are compromised. Protected areas offer means to maintain the global and local benefits of ecosystems, and in both the short- and long-term.

Protected areas are in a unique position compared with other governance systems for land and natural resource management in terms of the contributions they can make in the dual areas of climate change mitigation and adaptation. More specifically, protected areas:

Governance and safeguards
- Have defined borders, which can be used to measure carbon sinks and storage and ecosystem services
- Operate under legal or other effective frameworks, which provide a stable, long-term mechanism for managing land and water ecosystems
- Have agreed governance structures to meet a wide range of social and cultural requirements
- Are backed by a range of supportive conventions and agreements (CBD, World Heritage, Ramsar, Man and the Biosphere, CITES etc) and regional agreements such as Natura 2000 to provide policy frameworks, tools and political support
- Recognise cultural and social values of protected areas and have experience in implementing accessible, local approaches involving people in a legitimate and effective way in management

Permanence
- Are based around a commitment to permanence and long-term management of ecosystems and natural resources
- Focus local, national and international attention on a particular protected area, adding to the area's protection

Effectiveness
- Are proven to work as an effective way of retaining natural ecosystems and ecosystem services especially through protected area systems at the landscape/ seascape scale
- Are supported by management plans, which can facilitate rapid responses to new information or conditions related to climate change
- Have staff and equipment which provide management expertise and capacity, including understanding of how to manage ecosystems to generate a range of ecosystem services vital for climate change adaptation
- Provide opportunities to bring the experience developed in planning and managing protected areas to bear on developing broader landscape and seascape scale approaches to climate change mitigation and adaptation
- Can draw on existing funding mechanisms, including government budgetary appropriations, and funding from the GEF and LifeWeb

- Are backed up by networks of experts ready to provide advice and assistance, including particularly the IUCN World Commission on Protected Areas and conservation NGOs

Monitoring, verification and reporting
- Are supported by government commitments under the CBD to establish ecologically-representative protected area systems
- Have organised and populated data sources to set baselines and facilitate monitoring, such as the IUCN management categories, governance types and Red List, and the UNEP World Conservation Monitoring Centre (UNEP-WCMC) World Database on Protected Areas (these systems would need some strengthening to meet UNFCCC needs)

Well managed protected areas can provide a cost effective option for implementing climate change response strategies because start-up costs have already been met and socio-economic costs are offset by other services that protected areas supply. Protected areas are most effective when they have good capacity, efficient management, agreed governance structures and strong support from local and resident communities. Ideally protected areas and conservation needs should be integrated into wider landscape and seascape strategies. The best protected areas are inspirational models for maintenance and management of natural ecosystems. In many places where population or development pressures are particularly strong, protected areas are the only remaining natural ecosystems and thus play a particularly critical role in regulating the supply of ecosystem services.

The CBD's Programme of Work on Protected Areas has shown some major achievements between 2004 and 2009

The PoWPA is widely regarded as the most successful CBD initiative and was the first to set measurable targets so that progress can be monitored. Although implementation remains incomplete and variable, since coming into force in 2004 significant progress has been reported in relation to the actions set out in the PoWPA including:

- 27 countries reporting the establishment of about 5,900 new protected areas covering approximately 60 million ha of terrestrial and marine areas
- A 34 per cent increase in transboundary protected areas between 2005 and 2007
- 30 per cent of protected areas now have management plans; and plans under development for an additional 30 per cent
- Many countries have legislative and policy frameworks for the equitable sharing of costs and benefits arising from the establishment and management of protected areas and relevant laws and policies incorporate a clear requirement for the participation of stakeholders and indigenous and local communities in the planning, establishment and management of protected areas (although implementation of policy and legal frameworks needs further development)
- A study of the results of management effectiveness assessment of 2,322 protected areas found 86 per cent had met criteria for effective management; of which 22 per cent had good management[46]

This report describes the climate change benefits that well designed and managed protected area systems can provide and looks at the steps needed to ensure that such a system is developed and managed effectively on a global scale.

Do protected areas work effectively in protecting ecosystems and the carbon that they contain?
The utility of protected areas in maintaining ecosystem functions and supplying ecosystem services depends on a number of factors including: the integrity of lands outside the boundaries of the protected area, and thus the value added provided by the protected area; the effectiveness of the protected area in buffering land from human-induced threats; and any displacement effect the creation of the protected area may have on land uses, that might undermine ecosystem function elsewhere.

Research on protected area effectiveness has focused on potential benefits in terms of reductions in outright habitat loss, as well as habitat degradation. One large-scale study looked at anthropogenic threats facing 92 protected areas in 22 tropical countries, and concluded that the majority of protected areas are indeed successful in protecting ecosystems. Specifically they do so by stopping land clearance, as well as preventing illegal logging, hunting, fire and domestic animal-grazing compared to un-protected areas[47]. A survey of 330 protected areas around the world using a consistent methodology, carried out by WWF and The World Bank, found biodiversity condition consistently scoring high[48]. A global metastudy, coordinated by the University of Queensland, assessed management effectiveness evaluations from over 2300 protected areas and found that 86 per cent met their own criteria for good management[49]. Another major study from 2008 assessed the effectiveness of protected areas in terms of avoided land-cover clearance, using a metadata analysis that incorporated 22 countries and 49 different locations. The research concluded that protected areas had lower rates of land-clearing compared to their surroundings, and lowered rates within their boundaries following the initiation of protection[50]. Another recent report compared multiple protected area management types (using IUCN's protected area categorisations) across four tropical areas: the Amazon, the Atlantic Coast, West Africa, and the Congo. The methodology included an assessment of natural vegetation changes at varying distances within and around protected areas. This research emphasised that the degree to which protected areas protect natural vegetation depends on the specific geographic context, which varied greatly among these regions; yet overall, this team characterized protected areas as effective; stating that forest cover was found to be high inside reserves and even "strikingly higher" compared to surrounding areas where there were formidable levels of human impact[51].

Fijian men celebrating the creation of a new marine protected area © Brent Stirton/Getty Images

Although there is currently no comprehensive assessment of the effectiveness of the global system of protected areas in securing ecosystems and ecosystem services, they are already more comprehensively assessed than is the case for most comparable land and water management systems. They have been found to perform better than surrounding areas. Without them, the challenges of biodiversity loss and the loss of services upon which human communities depend would be far greater.

Ways in which protected areas assist climate change mitigation and adaptation

KEY MESSAGES

Protected areas can help nature and society to mitigate climate change by sequestering and storing carbon in natural ecosystems, and to adapt to current and predicted changes through the provision of various forms of ecosystem services.

Protected areas can serve to **both mitigate and help adapt to climate change**. Mitigation is achieved by storing and removing carbon that would otherwise be emitted into or retained within the atmosphere and adaptation is achieved through provision of a range of environmental goods and services that address directly some of the likely impacts of climate change on people. These roles have gone largely unnoticed or been under-estimated in the past – at best they have been taken for granted. In later sections we fill in gaps in understanding and outline the steps needed to maximise the potential of protected areas to support climate change response strategies.

The three "pillars" of protected area benefits are summarised in the figure below and discussed in more detail in sections 2 and 3.

Figure 2: The three "pillars" of protected area benefits

Mitigation

Sequestration: carbon **capture** and **storage** in living and dead vegetation in:
- ➜ Forests
- ➜ Grasslands
- ➜ Inland waters
- ➜ Marine systems
- ➜ Soil and humus

Disaster relief: through risk assessment and risk reduction using ecosystem services, against:
- ➜ Avalanche
- ➜ Hurricane
- ➜ Flooding
- ➜ Tidal surges
- ➜ Drought

Supplying human needs: such as:
- ➜ Clean water
- ➜ Fish spawning
- ➜ Wild food
- ➜ Building materials
- ➜ Local medicines
- ➜ Shelter
- ➜ Agrobiodiversity
- ➜ Pharmaceuticals
- ➜ Genetic material

Adaptation

Section 2
Mitigation: The role of protected areas

This section looks at how protected areas contribute to mitigation (capture, storage and avoidance of loss of carbon) in forests, inland and marine waters, grasslands and within agricultural systems. Although the amounts of carbon sequestered vary between biomes, some common features emerge:

- ➜ All biomes store important reservoirs of carbon
- ➜ All biomes can capture carbon dioxide from the atmosphere, although there is sometimes uncertainty about the net flows
- ➜ Current changes in land and water use are causing loss of stored carbon, often at an accelerating rate
- ➜ Some of these changes are also reducing the ability of ecosystems to capture additional carbon dioxide
- ➜ Most ecosystems can therefore switch between being sinks of carbon to becoming net sources depending on factors such as the management employed and the nature and scope of external threats
- ➜ Climate change will likely create a negative feedback: as climate change progresses it may further undermine the sequestration potential of natural ecosystems (for example by increasing the incidence and severity of fires and droughts)
- ➜ Protected areas have a key role to play in securing carbon currently stored in natural ecosystems and in capturing additional carbon: effective management will help to ensure that protected areas continue as net carbon sinks rather than becoming carbon sources

Srebarna Nature Reserve, Bulgaria © Nigel Dudley

Mitigation potential of protected areas

Although studies are still preliminary, ongoing research by UNEP-WCMC already shows that protected areas contain a huge carbon store, conservatively judged to be 15 per cent of the terrestrial carbon stock as illustrated in table 3 below. Carbon is not evenly distributed around the world and 60 per cent of protected area carbon is found in the Americas and Africa. The proportion of regional carbon stocks within protected areas also varies considerably, from over half the total in Greenland to only just over 4 per cent in the Pacific. The implications of this are discussed in detail for a number of critical biomes in the following section.

Table 3: Estimates for carbon stored in protected areas in different biomes[52]

	Region	Carbon stock (Gt)		Percentage
		Total	In protected area	In protected area
1	North America	388	59	15.1
2	Greenland	5	2	51.2
3	Central America and Caribbean	16	4	25.2
4	South America	341	91	26.8
5	Europe	100	14	13.6
6	North Eurasia	404	36	8.8
7	Africa	356	49	13.7
8	Middle East	44	3	7.8
9	South Asia	54	4	7.2
10	East Asia	124	20	16.3
11	Southeast Asia	132	20	15.0
12	Australia and New Zealand	85	10	12.0
13	Pacific	3	0	4.3
14	Antarctic and peripheral islands	1	0	0.3

Note that figures for carbon stock have been rounded up but percentage figures were calculated from the actual numbers

Forests and mitigation

KEY MESSAGES

Forests are the world's largest terrestrial carbon stock and continue to sequester in old-growth phases, but risk losing this characteristic due to deforestation, degradation and the longer-term impacts of climate change. Protected areas offer an important way to maintain and enhance carbon stores in forests, although they need careful management if they are to succeed.

The Potential
Forests contain huge stocks of carbon. Deforestation and forest degradation are seen as key drivers of climate change. The IPCC estimates that forest loss and degradation are together responsible for 17 per cent of global carbon emissions, making this the third largest source of greenhouse gas emissions, outstripping the entire global transport sector[53]. The Eliasch Review estimates that without a substantial reduction, the global economic cost of climate change caused by forest loss could reach US$1 trillion a year by 2100[54]. Other recent estimates of the role of land conversion to greenhouse gas emissions reach broadly similar conclusions[55]. Virtually all forest loss currently occurs in developing countries.

Halting and reversing forest loss and degradation, particularly in the tropics, is thus one of the most urgent challenges in addressing climate change and is widely recognised as such by intergovernmental bodies such as the IPCC[56], researchers[57], governments[58] and NGOs[59,60]. Each of the world's major forest types has a different potential for carbon storage and presents different opportunities and challenges for policy makers. The most important ones are discussed below.

Tropical forests: are the largest terrestrial carbon stores and are still active sinks, although deforestation and forest degradation continue to erode their role, including from conversion to cropland[61] and pasture[62] with biofuels[63] such as soybean[64] emerging as an important new factor in losses. Estimates for the amount of carbon stored in tropical moist forests range from 170-250 t carbon/hectare (tC/ha)[65,66,67] and the ability of forests to store carbon depends partly on the amount of large woody species[68] (suggesting that a logged-over forest is less useful than a primary forest). Much of the stored carbon resides in above ground biomass, with estimates of around 160 tC/ha in above-ground biomass, 40tC/ha below ground and 90-200tC/ha as soil carbon[69]. Recent research has provided strong evidence that tropical moist forests continue to sequester carbon once they reach old-growth stage, both in the Amazon[70] and in Africa[71], adding to the arguments for retaining natural forests. However, the effects of climate change itself may reduce or even reverse this sequestration; drying out of the Amazon could result in major additional carbon loss for example[72]. Other tropical forests such as miombo forests store less carbon on a per hectare basis but their total reservoir may be large because they cover vast areas. Research in natural

CASE STUDY

Studies of forest sequestration in the mature forests of Gabon illustrate the importance of effective long-term conservation in capturing and storing carbon.

The government of Gabon established its national parks system in 2002; it comprises 13 protected areas and represents more than 10 per cent of the country's total land area. Deforestation is not an issue in Gabon as population pressure on the forests resources is low and the government development policy is partly based on forestry. Due to the vast extent of forests, there is a rich biodiversity and the country is considered a hot spot for wildlife and rainforest vegetation.

Researchers from Wildlife Conservation Society (WCS), in collaboration with other scientists, performed studies on continued sequestration in mature forests in the country, and found that from 1968 to 2007 above-ground carbon storage in live trees increased across study sites. Extrapolation to unmeasured forest components (live roots, small trees, necromass) and scaling to the continent implies a total increase in carbon storage in African tropical forest trees of approximately 260 million t CO_2[97] in that time period.

This study shows that although fast-growing new forests have been thought of as the best carbon sinks, the mature forests of Gabon continue to fix new carbon and act as a carbon sink. This demonstrates the importance of protected areas in regions of old-growth forest like those in Gabon, in ameliorating climate change.

Source: WCS

miombo forests in Southern Africa measured 94-48 Mg C/ha, which declined steeply to 9-28 Mg C/ha once woodland was replaced by maize[73]. Some 50-80 per cent of the total carbon stock in miombo is in the top 1.5 metres of soil[74], but rate of accumulation in soils is very slow after clearance[75].

Boreal forests: are found mainly in Canada, Alaska, Russia and Scandinavia, consisting of mixed conifer and broadleaved forests, often slow growing and with a small range of species. They contain the second largest terrestrial stock of carbon, stored mostly in soil and leaf litter, averaging 60-100 tC/ha[76,77]. There has long been a debate about whether old-growth boreal forests continue to sequester carbon, but the latest research suggests that they do[78]. The future role of boreal forests remains uncertain however because of the ecological effects of predicted climate change, such as increased fire and insect damage. Carbon is lost if fire frequency is high[79]; and climate modelling suggests that fire is likely to increase dramatically in Russia and Canada due to higher temperatures[80], which means that the biome could switch from a sink to a source of carbon in the future unless strategies such as fire management can help reduce the risks.

CASE STUDY

Protected areas in Bolivia, Mexico and Venezuela contain around 25 million hectares of forest, storing over 4 billion t C, estimated to be worth between US$45 and US$77 billion in terms of global damage costs avoided[98].

Bolivia: Tropical forests in Bolivia's protected areas are estimated to store around 745 million t C, worth between US$3.7 billion to 14.9 billion at international carbon market prices (US$5 minimum and US$20 maximum). Deforestation poses a real threat with almost 10 per cent of forest cover already lost through logging, conversion to agriculture and settlement, and fire damage.

Mexico: Over 2.2 billion t C is locked up in Mexico's federal and state protected areas. Even at a very conservative price, this service is worth at least US$34 billion. In addition, low-lying coastal areas of Mexico are vulnerable to sea-level rise; particularly the Rio Bravo Delta, Alvarado Lagoon and lower reaches of the Papaloapan River, the Grijalva-Mezcapala-Usumacinta Delta Complex, Los Petenes and Sian Ka'an Chetumal Bays. Protected areas in these regions have been established in four out of these five sites, to protect coastal settlements, minimise coastal erosion and help to reduce damage from storms and tidal surges.

Venezuela: Carbon storage is currently estimated to be worth US$1 billion in Canaima National Park, US$94 million in Imataca Forest Reserve, and US$4.5 million in Sierra Nevada National Park. Almost 20 million hectares of forest have been identified by the government as being available for mitigation – potentially storing more than 1.4 billion t C worth between US$7 billion and 28 billion. Between 1990 and 2005 Venezuela lost 7.5 per cent of its forest and woodland habitat.

Source: TNC

Temperate forests: although temperate forests have undergone an enormous historical retraction[81], they are currently expanding in many areas[82],[83] and actively building carbon stores. Changes in land use policy and population distribution mean that this trend is likely to continue in many countries. Recent research found the highest known carbon storage (living plus dead matter) was in temperate *Eucalyptus reglans* forests in Australia at an average of 1,867 tC/ha: the authors suggest that important criteria for high carbon includes (i) relatively cool temperatures and high precipitation causing high growth but slow decomposition and (ii) older, multi-layered and multi-aged forests that have experienced little disturbance[84]. There are also increasing options for reforestation in many temperate regions, adding to carbon benefits[85]. In Europe, for example, forests are currently sequestering 7-12 per cent of European carbon emissions[86],[87]. Estimates for carbon storage in temperate forests range from 150-320 tC/ha, 60 per cent in plant biomass and the rest in the soil[88]. Some of this sequestration could be lost in the future, for example through increased forest fires in Mediterranean regions[89] and Australia[90].

The role of protected areas

It is widely recognised that protected areas could and should have a key role in reducing forest loss and degradation[91,92]. For example, the IPCC clearly identifies the role of protection (whilst also noting the need for good management): *"While regrowth of trees due to effective protection will lead to carbon sequestration, adaptive management of protected areas also leads to conservation of biodiversity and reduced vulnerability to climate change"* and "*Legally protecting forests by designating protected areas, indigenous reserves, non-timber forest reserves and community reserves have proven effective in maintaining forest cover in some countries, while in others, a lack of resources and personnel result in the conversion of legally protected forests to other land uses"*[93].

Similarly, the Collaborative Partnership on Forests, a coalition of 14 research organisations, UN bodies and IUCN, notes that, although all forms of sustainable forest management have a role to play in helping to sequester carbon, *"Protected forest areas increase the resilience of ecosystems and landscapes to climate change and can provide a 'safety net' for climate change adaptation through their genetic resources and ecosystem services. Inadequate funding for the management of protected areas, however, poses a significant threat to climate change mitigation and adaptation and needs to be addressed"*[94].

Tropical rainforest in western Congo Basin, Gabon © Martin Harvey / WWF-Canon

Forest protected areas will become increasingly important in a climate context, but only if efficiently managed and with adequate staff and resources.

Research by the UNEP-WCMC[95] suggests that protected areas are far more effective than other management options in maintaining tropical forests. They are not perfect; it was estimated that forests in protected areas accounted for 3 per cent of the tropical forest losses from 2000-2005 that occurred in the countries studied, but this is far better than average. Protected areas have the legal conditions to control deforestation, so that an increase in funds and resources can lead to further improvements.

SOLUTIONS

Increase the area of forest protected areas: both by expanding existing protected areas and creating new protected areas.

Increase the efficiency of management in forest protected areas: by further application of assessment drawing on the IUCN-WCPA management effectiveness assessment framework[96] and building management capacities.

Restore forests in protected areas: for example in logged over areas, abandoned farmland and in places where climate changes make other land uses untenable.

Develop more efficient methodologies and criteria for identifying areas with high carbon storage and sequestration potential: and use this as an additional filter in selecting protected areas.

Undertake management training: to plan for climate change, including likely responses to fire regimes, stream flow and invasive species.

Inland wetlands, peat and mitigation

KEY MESSAGES

Inland wetlands, particularly peatlands, store huge amounts of carbon and their protection are critically important. But they can be either net sources or sinks of carbon, depending on conditions and the management measures that are employed; some current climate changes are putting much of this stored carbon at risk. Knowledge of the net carbon balance in wetlands remains poor, particularly in the tropics, although potential is high both for carbon storage and for increased losses through mismanagement, making careful management choices extremely important.

The potential
Inland wetlands, including particularly peatlands, are very significant carbon stores. Although only covering about 3 per cent of the land surface, peat is believed to contain the planet's largest store of carbon; the same in total as all terrestrial biomes[99]. Intact peatlands have been assessed as containing up to 1,300 t of carbon/hectare[100] and it has been estimated that 550 Gt of carbon are stored globally[101].

There are still major uncertainties about not only the overall carbon balance in wetland systems, but even about the global area of wetland and its existing carbon stock[102]. The Ramsar Secretariat's scientific panel calculated in 2007 that there are 1280 million hectares of wetlands (9 per cent of the planet's land surface) but believed this likely to be an under-estimate[103]. Important locations from a carbon perspective include peat in tropical forests in Southeast Asia, particularly Indonesia, and peat in the tundra areas of the far north in Russia, Canada, Alaska and Scandinavia, which is at present still largely frozen.

Mismanagement of wetlands, and particularly of peatlands, can result in huge carbon losses[104]. A study of peatlands in Southeast Asia calculated that CO_2 emissions from drained peatlands equal from 355-874 Mt per year, with a further 1,400 Mt of CO_2 per year from 1997 to 2006 from peatland fires, predominantly in Indonesia[105]. Peatlands face a variety of threats that are leading to their loss and degradation. The drainage of peatlands, frequently as a step towards plantation establishment, particularly of oil palm, can result in a sharp increase of emissions[106]. The potential of biofuels as an alternative to fossil fuels has also been gaining attention and investment, but from a carbon perspective

Caribou (*Rangifer tarandus*) running on the tundra, Kobuk Valley National Park, Alaska, USA © Staffan Widstrand / WWF draining peat to plant fuel crops makes no sense: it is calculated that it would take 420 years of biofuel production to replace the carbon lost in establishment[107]. Recent estimates by the UNEP-WCMC are that 0.5-0.8 Gt carbon a year is already being lost as a result of peatland conversion[108].

While carbon losses from the tundra regions are currently lower, they have the potential to exceed those from the tropics, as warming thaws ice and further dries and warms peat; some research sites in Alaska have already switched from sinks to sources of carbon[109]. Many of the most serious predictions of climate change running out of control centre on the risk of a sudden pulse of carbon being released from the Arctic tundra[110].

The potential of peat to continue sequestering carbon is variable and still incompletely understood; net carbon balance depends on climate and hydrological variables leading to variation between sites and also within one site over time. Wetlands, including particularly peatlands, tend to be sinks for carbon and nitrogen but sources for methane and sulphur[111]; the balance between these various interactions determines whether the wetland system as a whole is a net source or sink of carbon. Some assessments of overall sequestration from inland wetlands have concluded that carbon sequestration is likely to be balanced out fairly equally by losses, particularly of methane[112]. Caution needs to be exercised in claiming that these ecosystems can contribute to climate change mitigation through continued sequestration, but it is clear that draining or burning peatlands increases emissions to the atmosphere from the enormous stores that have been accumulated over the millennia in those ecosystems.

Sequestration can be extremely long-term when carbon is stored in anaerobic conditions, where emissions of CO_2 are slowed or stopped due to the lack of oxygen; this is particularly true for peat deposits. Slight changes in management (especially that related to hydrology) or climatic conditions can switch a site from being a net sink to a net source of carbon. A recent review found estimates for sequestration ranging from gains of 220g CO_2 per m^2 per year to losses of 310g CO_2 per m^2 per year[113]. There is fairly poor information for anything except temperate peat and all figures and estimates should therefore be treated with caution.

Pressure on wetlands is likely to increase as climate change drives communities that are dependent on wetland resources to increase exploitation levels. For example, increased degradation of land in the lowland ranges in Lesotho has undermined traditional transhumance systems that interspersed cattle grazing in these areas with grazing in upland areas. This system is being replaced by a more sedentary management system that concentrates livestock in wetlands in the mountains, which are also important storehouses of peat. This puts pressure on wetlands, because cattle trample peat (thus increasing carbon loss); moreover, an increase in the resident human population in upland areas has increased the harvest of peat for fuel and cultivation in the wetlands.

CASE STUDY

Under a UNDP project, the restoration of peatlands in Belarus has proven to be a cost-effective way of restoring degraded wetlands and reducing greenhouse gas emissions.

In Belarus 40,000 ha of degraded peatlands have been restored to their natural state, and a further 150,000 ha are awaiting restoration. Half of these areas currently occur in protected areas; the rest will be protected by a new category of protection currently being developed by the Government. This work has led to an annual reduction of greenhouse gas emissions equivalent to 448,000 t CO_2 from peatland fires and mineralization[120]. Rehabilitation of degraded peatlands saves the Government some US$1.5 million annually in terms of the avoided costs of fire-fighting operations. Restoration of peatlands is widely supported by local communities who benefit from recreated wetland hunting and fishing grounds, collection of medicinal plants and wild berries.

The methods employed in Belarus have been adopted by the Government for country-wide replication. Impressed by the economic and ecological benefits of peatland rehabilitation, the Government has mandated that all current peat extraction companies restore peatlands to their natural state at the end of mining operations.

The German Government is supporting efforts to develop greenhouse gas mitigation methodologies for peatland management for the Clean Development Mechanisms of the Kyoto Protocol, based on the experience in Belarus. If successful, peatland rehabilitation projects may be eligible for financing under the Joint Implementation and Clean Development mechanisms of the Kyoto Protocol.

Source: UNDP

However, there is also evidence that conscious changes in management approaches can help to at least slow and possibly eventually reverse carbon losses from degraded peat systems. Research in Canada found that CO_2 losses from cut peat areas could be slowed through restoration and revegetation[114], and similar results are reported from Southeast Asia, Russia, Argentina and the Himalayas[115]. Given that peat loses carbon particularly when it is dry (in extreme cases when it catches fire), re-flooding peatland habitat is one relatively straightforward management response[116], although a number of issues need to be considered, such as the depth of flooding and time of immersion[117]; conversely a research project in Kalimantan found that re-flooding areas of cleared peat made relatively little difference to the carbon balance[118].

CASE STUDY

Flooding is a major problem in the Caribbean islands of Trinidad and Tobago and is likely to increase due to climate change; to help people cope with this additional flooding the natural flood regime of the protected Nariva Swamp in Trinidad is being restored.

Recent major flooding events in Trinidad and Tobago are likely to be further exacerbated by climate change making the need to introduce mitigation measures particularly urgent[121]. The Nariva Protected Area, on the eastern coast of Trinidad, is a nationally and internationally significant wetland with high biodiversity and habitat value. The wetlands have however been threatened by hydrological changes arising from a dam upstream and rice production[122].

The Nariva Reforestation and Carbon Sequestration Project will contribute to efforts to restore and conserve the Nariva wetlands through the recognition of the services it provides as a carbon sink, a biodiverse ecosystem and a natural buffering system against coastal storms. The project is an important opportunity to combine the goals of greenhouse gas mitigation with adaptation needs. Reforesting parts of the degraded wetland with native tree species will be funded by The BioCarbon Fund, which intends to purchase about 193,000 t CO_2 equivalent up to 2017[123]. This funding will contribute to implementing a water management plan, which will remove artificial barriers allowing the restoration of the natural water cycle of the swamp to its original drainage regime[124].

Source: World Bank

The role of protected areas

Management of the carbon already stored in peat is one of the most critical elements in carbon response strategies and well-managed protected areas have the potential to lock up vast amounts of carbon. Protected areas are vital in retaining natural peatlands and other inland water habitats that sequester carbon (see case study from the Caribbean and Canada). Particular priorities include protection of remaining peat, particularly from burning, and re-establishment of natural hydrological systems in degraded peatlands. Further research is needed to improve management (see case study on Belarus).

CASE STUDY

Parks Canada has researched the amount and value of the carbon stored in its network of national parks. Total storage is estimated at 4,432 million t with a value of over Cdn$70 billion.

Research has estimated the amount of carbon stored in Canada's 39 National Parks, which currently occupy about 2.25 per cent of Canada landmass. Using a Carbon Budget Model developed by the Canadian Forestry Service, the parks store in total approximately 4,432 million t, of which about 47 per cent is in the soils, another 8 per cent in the plant biomass and the remaining 45 per cent in the peatlands. Overall boreal areas in Canada store the largest amount of carbon. The study looked at the costs of replacing this carbon, using two scenarios. The cost of replacing carbon through reforestation of protected areas, and the costs of afforesting marginal agricultural lands were worked out to be Cdn$16.25 and Cdn$17.5 per t respectively at 2000 prices. Using these prices as proxy values, the value of national parks for carbon sequestration was estimated at between Cdn$72 and Cdn$78 billion[119].

Source: Parks Canada

SOLUTIONS

Protection of natural peat: urgent steps are needed to protect standing sources of peat in the boreal, temperate and tropical regions, including where appropriate by expansion of protected areas networks. This will often involve some protection for entire watersheds that feed into the peat areas, as much as the areas themselves.

Working out the best management strategies: further work is needed to find out more about carbon balance in peatlands and other inland waters; and particularly the combination of conditions that can tip a system from being a sink to source of carbon, along with the best management methods to maintain wetlands as sinks for carbon.

Marine and coastal ecosystems and mitigation

KEY MESSAGES

Coastal and marine areas store huge amounts of carbon, particularly in coastal zones where capture is equivalent to 0.2 Gt/year. Salt marshes, mangroves and seagrass beds all have important potential to sequester carbon. All these systems are currently under pressure; without better protection they could switch from being sinks to sources of emissions. There is an urgent need both for new protected areas to be established and for better implementation and management of existing protected areas.

Oceans contain fifty times as much inorganic carbon as the atmosphere, existing as dissolved CO_2, carbonic acid and carbonates[125], with cold waters absorbing greater amounts of carbon than warmer areas. Dissolved inorganic carbon is transformed into dissolved particulate organic carbon through photosynthesis by phytoplankton[126]. The world's oceans are believed to have absorbed 30 per cent of CO_2 from human sources since industrialisation[127], leading to a number of ecosystem problems, including ocean acidification[128].

Although small amounts of carbon can be sequestered in the longer term through phytoplankton sinking into deep water and being buried in the sea bed, the coastal zone is the place where most marine mineralization and burial of organic carbon takes place, in total equivalent to 0.2 Gt/year[129]. Slight changes in uptake can therefore be very significant in terms of global carbon balance. However, our confidence in the science of ocean sequestration is still incomplete. There is a strong consensus that net sequestration from the coastal zone could be reversed into a net loss of carbon if current rates of environmental degradation continue[130,131,132]. The carbon sequestration potential of four major coastal zone vegetation types is examined separately below.

Tidal salt marshes
Salt marshes occur on sheltered marine and estuarine coastlines in a range of climatic conditions, from sub arctic to tropical, but are most extensive in temperate climates[133].

The potential: Each molecule of CO_2 sequestered in soils of tidal salt marshes and their tropical equivalents, mangrove swamps, probably has greater value than that stored in any other natural ecosystem due to the lack of production of other greenhouse gases from these ecosystems (i.e. the net carbon balance is better from the perspective of sequestration)[134]. A review of rates of carbon stored in tidal salt marshes around the world revealed that, on average, their soils store 210 g C per m^2 per annum or 770 g CO_2[135], however as with other sequestration, the rate of productivity and hence carbon capture varies considerably between geographic location[136] and species[137,138,139]. Tidal floodwaters contribute inorganic sediments to intertidal soils, but more importantly, they saturate the soil and reduce the potential for aerobic decomposition. Anaerobic decomposition is much less efficient, enabling accumulation of organic matter in the soil, and the effective carbon sink.

However, extensive areas of salt marsh continue to be lost through drainage, with nutrient enrichment and sea-level rise adding further threats to their survival and integrity[140]. Restoration of tidal salt marshes could help to increase the world's natural carbon sinks. Returning the tides to drained agricultural marsh could also make a significant increase in the salt marsh carbon sink. For example, in Canada it has been estimated that if all of Bay of Fundy marshes "reclaimed" for agriculture could be restored, the rate of CO_2 sequestered each year would be equivalent to 4-6 per cent of Canada's targeted reduction of 1990-level emissions under the Kyoto Protocol[141].

The role of protected areas: Sustaining marshes in the face of accelerating sea-level rise requires that they be allowed space to migrate inland. This will require the abandonment of agricultural or other land near to shore in the face of rising sea levels. Also, development immediately inland to marshes should be discouraged and if possible regulated through the establishment of buffer zones. Marine protected areas should encompass a strip of inland coastal areas to allow for future changes. Terrestrial buffer zones also help to reduce nutrient enrichment of salt marshes from agriculture, thus maintaining below-ground production[142] and hence sequestration potential.

Mangroves
Mangroves systems grow mainly in tropical and subtropical inter-tidal zones. Mangroves are rapidly declining worldwide, to less than half their original area[143,144] as a result of[145] clearance, urbanisation, population growth, water diversion, coastal development, tourism, aquaculture (perhaps the most important cause[146]) and salt-pond construction.

The potential: Mangroves can play an important role in carbon sequestration. Using a current estimate of global area of mangroves of 160,000 km^2, the net primary

Mangrove forest at low tide in the Sundarbans National Park, Bangladesh © David Woodfall / WWF-UK

production was recently calculated at 218 plus or minus 72 Tg C per year, with root production responsible for approximately 38 per cent of this productivity, and litter fall and wood production both approximately 31 per cent[147]. Productivity is significantly higher in the equatorial zone[148] and sequestration can be faster than for terrestrial forests[149].

Mangroves contribute to CO_2 sequestration through the burial of mangrove carbon in sediments, locally or in adjacent systems, and the net growth of forest biomass; the former is a long-term sink and the latter much shorter term. An analysis of 154 studies of carbon sequestration within salt marshes and mangroves[150] derived in the latter case either from sedimentation estimates or from mass-balance considerations, converge to a value for mangroves equivalent to approximately 18.4 Tg C per year assuming a global area of 160,000 km^2. The amount of carbon stored within sediments of individual mangrove systems varies widely, with a global median of 2.2 per cent[151]; depending on the individual ecology this can be derived both from local production by mangroves and from organic matter brought in by the tide[152]. These figures are still approximate and the fate of considerable amounts of the carbon in this ecosystem remains unaccounted for[153]. Mangroves affect sediment carbon storage both by direct inputs as a result of production and by increasing sedimentation rates[154]; conversely clearing mangroves can rapidly decrease this storage[155]. Although mangroves generally contain less woody debris than terrestrial forests[156], this may in some cases also be significant for carbon storage, particularly if a major disturbance has created large-scale mortality of trees[157,158,159].

The role of protected areas: An increasing number of mangrove forests are within state or community protected areas, often established to sustain ecosystem services, such as maintenance of fish breeding and protection of coastal communities from storm damage. To date, there has been little work on the potential to enhance carbon sequestration through restoration or rehabilitation of mangroves, although research suggests that productivity will be similar to natural mangrove ecosystems[160] and mangroves are relatively easy to restore. Mangroves should be able to expand their range naturally if the rate of sediment accretion is sufficient to keep up with sea-level rise; however this will depend on existing infrastructure and topography, and thus planning needs to take this into account. IUCN has published guidance with ten strategies that managers could apply to promote the resilience of mangroves against sea-level rise[161]. The rehabilitation/restoration of mangrove forests therefore has the potential of providing an efficient sink of CO_2, both on short and longer time-scales. The magnitude of this sink will be highly variable, depending on factors related to primary production and the degree to which biomass is stored in sediments, which is influenced by the rate of sediment deposition and exchange of carbon with adjacent systems

Seagrass meadows
Seagrasses form extensive, productive meadows throughout marine areas, with estimates for their coverage variously of approximately 177,000[162]; 300,000[163,164]; or 600,000[165]km^2. A recent study estimated that nutrient cycling from seagrass is worth US$1.9 trillion a year[166]. Human interventions have caused extensive losses in seagrass habitats[167], with the major causes of decline being disturbances that lead to eutrophication and siltation. Seagrasses are declining rapidly, with 29 per cent of their known area gone since they were first described in 1879 and their loss is accelerating, currently being estimated at 7 per cent per year[168]. Climate

change is likely to bring further pressures on seagrass from changes in salinity, water depth and temperature, increased eutrophication and possibly changes to UV radiation: the consequences are still hard to predict[169].

The potential: Although standing biomass of seagrasses is relatively low[170], the absolute rate of net production and therefore carbon uptake is comparatively high[171]. Furthermore the leaves degrade slowly[172] and through their root and rhizome system, seagrasses deposit large amounts of underground, partly mineralised carbon; thus they constitute an important CO_2 sink, responsible for about 15 per cent of the total carbon storage in the ocean. The seagrass *Posidonia oceanica*, for example, can bury large amounts of the carbon it produces, resulting in partly mineralised underground *mattes* several metres thick, with an organic carbon content of as much as 40 per cent. These mattes can persist for millennia, thus representing a long-term carbon sink[173,174,175]. There is still much to be learned about the behaviour of other species in terms of long-term storage, particularly with respect to how many species have similar sequestration potential to *P. oceanica*, which in turn makes global estimates of storage very approximate. One compilation of available data suggests that an average of 16 per cent of seagrass biomass is stored[176].

Estimates[177] of short-term carbon storage in sediments average at about 133 g C per m^2 per annum. This value compares well with estimates[178] of longer term carbon burial, averaging 83 g per m^2 per annum. To make more accurate global predictions, reliable estimates are needed of the distribution and density of the dominating seagrass species in different biogeographical regions[179] and the need for more research is recognised.

The role for protected areas: The carbon sink service that seagrass meadows provide can only be sustained by preserving the health and extent of the world's seagrass meadows[180]. Evidence shows that it is difficult to reverse seagrass loss at the meadow scale[181], reducing the potential for restoration and thus making protection and maintenance of existing seagrass meadows a priority.

Coral reefs

Coral reefs support the highest marine biodiversity in the world. Unfortunately, many have been degraded due to human activities. It is possible that there are no pristine coral reefs left; predictions warn that 15 per cent of reefs will be lost by 2030[182]. Indeed, coral reef declines have exceeded 95 per cent in many locations[183].

The potential: Coral reefs do not sequester carbon. Unmanaged reef metabolism is a net CO_2 source, because of side-effects from calcium carbonate precipitation[184,185]. If calcification declines due to climate change[186] (e.g. because of warmer waters or ocean acidification[187]) this could in theory reduce CO_2 emissions from corals, because dead corals do not emit CO_2, but the huge ecological side effects from these losses would more than cancel out any advantages.

The role of coral reefs is more one of reefs being likely beneficiaries of CO_2 management, and also protecting coastal communities and terrestrial ecosystems from incursions from the sea. And as discussed later, coral reefs play a major role in providing ecosystem services that may reduce the vulnerability of coastal communities to sea-level rise and other manifestations of climate change.

Sally Lightfoot Crab (*Grapsus grapsus*), Galapagos © Nigel Dudley

Damselfish laying eggs in coral colonies, Fiji © Cat Holloway / WWF-Canon

SOLUTIONS

Increase protection for coastal mangrove, salt marsh and seagrass communities: through marine protected areas and integrated coastal management as an excellent way to increase the world's natural carbon sink and develop more effective marine management regimes that integrate the ocean in the larger carbon management scheme.

Add carbon sequestration potential to marine gap analyses and other protected area assessments: use and improve simulation models and field studies to develop tools for enhancing management plans for ecosystems protection, rehabilitation and restoration, including optimal scenarios for carbon allocation and CO_2 uptake.

Increase management effectiveness of marine protected areas: retain, maintain and recover ecosystem resilience and hence marine natural carbon sinks by reducing other human induced stressors such as coastal destruction, overfishing or ocean and land-based pollution.

Grasslands and mitigation

KEY MESSAGES

Natural grasslands represent a major carbon store but loss and degradation are currently releasing large amounts of carbon, and grasslands can either be a source or sink for carbon depending on management, precipitation and CO_2 levels. Research shows that some management changes can increase carbon capture and retention in grassland and these should be more widely introduced, along with policies to protect remaining natural grasslands against conversion or mismanagement.

The Potential
Natural grasslands contain large stores of carbon, mainly but not entirely within soils. Historical changes, including particularly conversion to cultivation, have already released large amounts of carbon from this biome. Grasslands still contain major stores of carbon: estimates suggest that grazing lands alone could hold between 10-30 per cent of the world's soil carbon[188] and grasslands hold in excess of 10 per cent of total carbon in the biosphere[189]. Temperate grasslands and steppe generally have lower carbon in biomass than temperate forests (for example in the steppes of China[190]) but can have higher levels of soil carbon[191]. Savannah and tropical grasslands usually have higher rates of carbon storage than temperate grassland, ranging from less than 2 tC/ha for tropical grass and up to 30 tC/ha for wooded savannah[192]. Around 40.5 per cent of the Earth's terrestrial area (excluding Greenland and Antarctica) is grassland: 13.8 per cent woody savannah and savannah; 12.7 per cent open and closed shrub; 8.3 per cent non-woody grassland; and 5.7 per cent tundra[193].

These globally important carbon stores are increasingly under threat. Conversion or degradation of grassland can dramatically increase carbon losses. Research suggests that degraded grasslands can be a major source of carbon, for example a study in China found rapid increases in the rate of loss from grasslands from the 1980s to the 2000s[194]. Rising CO_2 levels are thought to be increasing soil carbon losses, creating a negative feedback; a situation that appears supported by study of long-term data in the UK[195]. It is generally assumed that a switch to wooded savannah from grassland, which is one potential consequence of rising CO_2 levels[196], will increase net carbon sequestration, although this remains uncertain[197].

Grasslands can also capture additional carbon in some situations; measured and modelled rates of carbon sequestration in temperate grasslands range from 0 to greater than 8 Mg C per ha per year[198]. However, a synthesis of numerous experiments suggests that grassland can either be a net source or sink of carbon, being influenced in particular by precipitation and light availability along with clay and silt content, CO_2 levels and temperature. Inter-year variation has been demonstrated for example in Tibet[199] and Canada[200]. A study of eight North American rangelands found that while almost any site could be either a sink or source for carbon depending on yearly weather patterns, five of the eight native rangelands typically were sinks for atmospheric CO_2 during the study period. Droughts tended to limit periods of high carbon uptake and thus cause even the most productive sites to become sources of carbon[201]. The main controlling factors appeared to be either light availability or precipitation[202].

Management practices can help to curb losses and increase the potential for sequestration[203] including those that build surface biomass and soil carbon content. Replacing agriculture with permanent grassland is also likely to result in increased carbon sequestration[204] and may be an option in places where agriculture is unproductive (or will become so under conditions of climate change).

A meta-analysis of 115 studies found that useful management improvements could increase soil carbon content and concentration in 74 per cent of the studies, and mean soil carbon increased with all types of improvement. Conversion from cultivation, the introduction of earthworms, and irrigation resulted in the largest increases[205]. Changes do not necessarily need to be sophisticated: for example introduction of sustainable grazing systems and reducing over-grazing in wetter areas[206] could directly lead to sequestration. Burning coupled with grazing on some rangelands has been found to increase carbon storage[207], in part through creation of charcoal which is resistant to decomposition, but this needs to be balanced against losses from the biomass burning. Clear, site and condition-specific guidance is still lacking in most cases.

The role of protected areas
Temperate grasslands are the least protected terrestrial biome (4.1 per cent[208]) and conversion continues at a rapid pace, as a result of intensive grazing and replacement with agricultural crops, biofuels and pulp plantations. Establishing expanded protected areas in grasslands is an important immediate step towards reducing future carbon losses from grassland that could be taken relatively quickly,

The grasslands of Serengeti National Park, Tanzania © Sue Stolton

and which would have advantages for both carbon storage and biodiversity conservation. Although some important preliminary work has been carried out in Latin America to identify valuable grassland sites[209], this needs to be both refined and also duplicated more widely to create a global gap analysis of important grasslands. Such areas might fit the requirements of IUCN category VI reserves, still lightly grazed but within strictly defined limits.

SOLUTIONS

Expand protected areas in grassland habitats: including both strictly protected areas (IUCN categories I-IV) and protected landscapes (category V and VI) in sites where careful integration of low-level domestic grazing on grasslands can help to stabilise and rebuild carbon stocks.

Improve management: including introduction of sustainable grazing practices within protected landscapes and extractive reserves.

Carry out further research on the status and trends in carbon sequestration in grasslands: focusing particularly on management options that can minimise losses and maximise storage and sequestration.

Soils and mitigation

KEY MESSAGES

Soil provides a huge carbon reservoir. Changes in farming practices that sequester more carbon, including reduced tillage farming, more long-term crops and organic methods, can have important global impacts. Soil management in IUCN category V and VI protected areas can be enhanced to achieve greater carbon storage.

The potential
Soils are thought to be the largest carbon reservoir of the terrestrial carbon cycle, holding more than the atmosphere and vegetation combined[210], although estimates vary widely*. Relatively small changes in soil-carbon flux can be significant on a global scale: yet soil carbon has often been ignored as a mitigation strategy in intergovernmental climate change initiatives[211].

Soil carbon influences all terrestrial biomes; here the role of soils in agricultural systems is examined and the implications for the management of agricultural soils in protected areas (particularly IUCN categories V and VI).

Soil can either be a source or a sink for greenhouse gases, depending on management. Carbon is sequestered into soils by transferring CO_2 from the atmosphere through crop residues and other organic solids, in a form that is not immediately re-emitted. Soil carbon sequestration is increased by management systems that add biomass to the soil, reduce soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity. Conversely, stored soil carbon may be vulnerable to loss through both land management change and climate change, whilst increased frequency of climatic extremes may affect the stability of carbon and soil organic matter pools; for instance, the European heat wave of 2003 led to significant soil carbon losses[212,213].

Present day agriculture: Agriculture is often a source rather than a sink of greenhouse gas emissions and accounts for an estimated 10-12 per cent of total global anthropogenic emissions. It is the greatest agent of change to natural habitat on a global scale. Most of agricultural emissions are not from soil and although agricultural lands generate very large CO_2 fluxes both to and from the atmosphere, the net flux is relatively small[214]. However, past losses are very large, with estimates that most agricultural soils have lost 50-70 per cent of their original soil organic content[215], providing ample room for restoration and hence further carbon capture.

* Many estimates of carbon potential in vegetation include the soil beneath, so that several biomes claim to be the "largest" carbon store, depending on what is included

Potential changes in agricultural practices to increase carbon sequestration: Agriculture has the potential to mitigate carbon through management changes designed to conserve and rebuild carbon stores. There is no universally applicable list of practices which need to be evaluated for individual agricultural systems and settings. However, the IPCC identified mitigation practices currently available to agriculture, of relevance here including[216]:

- Improved crop and grazing land management to increase soil carbon storage
- Restoration of cultivated peaty soils and degraded lands
- Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions
- Improved nitrogen fertilizer application techniques to reduce N_2O emissions

Low-tillage farming practices can build up soil carbon whilst reducing erosion and use of fossil fuels[217]. Building up soil organic matter also boosts crop yield[218]. But results differ with soil type and conditions, and measured rates of carbon sequestration from a variety of the methods outlined above ranges from 50-1000 kg/ha/year[219], making broadscale calculations of net benefits very difficult.

There are large variations in claims of what agriculture has to offer for carbon sequestration. The European Union (EU) has conservatively estimated the potential of EU agricultural soils to sequester CO_2 at 60-70 Mt CO_2 per year, equivalent to 1.5-1.7 per cent of the EU's anthropogenic CO_2 emissions: technical measures would be linked to organic additions; organic farming; conservation tillage; permanent re-vegetation of some areas; and growing woody bioenergy crops instead of a rotational fallow[220]. A 2006 study for the Pew Center on Global Climate Change in the U.S. estimated that if many farmers adopted techniques to store carbon, such as retention of crop residues, zero tillage, and efficient application of manures, fertilizers and water; and undertook cost-effective reductions in nitrous oxide and methane; aggregate U.S. greenhouse gas emissions could be reduced by 5 to 14 per cent[221]. At the other extreme, a 23-year experiment by the Rodale Institute also in the U.S. compared organic and conventional cropping systems and claims that universal adoption of organic methods on agricultural land could sequester nearly 40 per cent of current CO_2 emissions[222]. Actual figures will depend

Agriculture fields in the Evros Delta, Greece © Michel Gunther / WWF-Canon

on the extent to which carbon sequestration techniques are employed and the interplay between sequestration and emissions under various climate change conditions. Sequestration gains from changing agricultural systems have to be balanced against the possibility that more land might need to be cleared for agriculture if farm yields fall as a result; however this should not be assumed as inevitable.

The role of protected areas: Many protected areas include farms as minority holdings or as management systems within protected landscapes and many of these are shifting to more sustainable forms of agriculture to enhance biodiversity benefits[223] and meet conservation targets[224,225]. These will be particularly, although not exclusively, found in category V and VI protected areas.

In Europe, 52 per cent (by area) of category V protected landscapes contain farms[226]. For example, in Italy organic farming receives special encouragement and funding in some category V national parks[227]. Carbon sequestration provides an extra incentive for improving land management on such farms. Restoration of unproductive agricultural land back to natural vegetation is also an effective way of sequestering carbon[228].

New mapping tools, such as the 2008 *Global Carbon Gap Map* produced by the UN Food and Agriculture Organization, can identify areas where soil carbon storage is greatest, as well as areas with the potential for additional carbon to be stored in degraded soils[229], thus providing a valuable additional tool for protected area gap analyses.

SOLUTIONS

Adopt farming methods that capture carbon as well as producing food and fibre: through legislation, incentives, preferential funding and capacity-building in the farming community, particularly focusing on organic production, low tillage and where appropriate permanent set aside.

Promote model approaches: making farming within category V protected areas a model and test-bed for new and traditional carbon-capture techniques.

Reach better understanding of the potential for agricultural sequestration: continuing uncertainty about the size of the potential is hampering implementation of new management approaches; urgent work to complete and synthesise estimates is required.

Section 3
Adaptation: The role of protected areas

Protected areas provide a cost-effective and practical means of addressing many aspects of adaptation through ecosystem-based approaches. Some protected areas are being established primarily for their wider ecosystem services, although there is still much to be learned about integrating these into national and local adaptation strategies and management plans.

Ecosystem-based adaptation uses biodiversity and ecosystem services in an overall adaptation strategy. It includes the sustainable management, protection and restoration of ecosystems to maintain services that help people adapt to the adverse effects of climate change

In this section we look explicitly at how protected areas can contribute to ecosystem-based adaptation across a spectrum of adaptation challenges, and particularly at a local level, using community-based approaches to address climate change impacts.

This includes their role in preventing or reducing the effects of “natural” disasters, providing a secure and potable water supply, addressing climate-related health issues and protecting food supplies including wild foods, fisheries and crop wild relatives.

Finally we look at the role of protected areas in protecting biodiversity under climate change stress. This is important to prevent their extirpation and possible extinction, to maintain ecosystem resilience and to safeguard the economic values they may supply.

Role of protected areas in reducing impacts of natural disasters

KEY MESSAGES

The frequency of natural disasters is rapidly increasing, because extreme weather events are becoming more common and also because people are forced by population pressure or inequalities of land tenure to live in unstable areas like steep slopes and flood plains. Protected, well-managed ecosystems including forests and wetlands can buffer against many flood and tidal events, landslides and storms.

Flooding in East Dongting Lake, Hunan Province, China © Yifei Zhang / WWF-Canon

The Challenge

There is a rapid increase in natural disasters associated with extreme climatic events. Climate change is creating more unsettled weather and human societies, particularly in poor countries (where poor infrastructure and inadequate disaster warning also increases vulnerability), are increasingly at risk. The vulnerability of communities in many developing countries is exacerbated because rising populations and in some cases inequality in land ownership force people to live in marginal, disaster-prone areas. Such communities also lack the financial wherewithal, insurance systems and other resources to recover from extreme weather events[230]. Economic losses from weather and floods have increased ten-fold in 50 years[231] and over half the world's population are now exposed to hazards with the potential to become disasters[232].

Climate change is having a direct impact on many of the hazards that can lead to disasters. Although geological hazards such as earthquakes tend to cause greatest loss of life per event, hydro-meteorological hazards are affecting larger numbers of people.

The latest IPPC report states *"Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas"*[233]. Climate change was also recognised as an underlying threat in relation to disasters by the World Conference on Disaster Reduction in Japan in 2005[234]. For example, flooding risks can be increased by changes in the sea (higher sea-levels and storm surges); glacial lake outburst (a problem in countries such as Nepal); and heavier or more prolonged episodic rainfall events[235]. The intensity and frequency of extreme rainfall are also likely to result in increased magnitude and frequency of landslides[236].

There is also growing evidence that the climate is becoming more variable and more subject to extreme weather. A review of global changes in rainfall found increased variance in precipitation everywhere: in particular increased precipitation in high latitudes (Northern Hemisphere); reductions in precipitation in China, Australia and the Pacific Small Island States; and increased variance in equatorial regions[237]. In subtropical South America, east of the Andes, annual precipitation has increased in some areas by as much as 40 per cent since the 1960s[238]. Already in Malaysia, for example, most natural disasters result from heavy rains[239].

Furthermore, if natural ecosystems are degraded through activities such as deforestation and wetland drainage, and the effectiveness of ecosystem services are correspondingly reduced, the consequences of natural hazards such as heavy rain, hurricanes, earthquakes or drought are likely to be exacerbated. Disaster reduction specialists stress that climate change impacts need to be assessed along with other drivers of natural disasters[240]. In these situations the chances that a natural hazard will develop into a full scale disaster will increase.

CASE STUDY

New Zealand is predicted to incur ever more severe flooding under climate change. Natural solutions can be effective and, for instance, protection of the Whangamarino Wetlands is calculated to save the country millions of dollars in disaster prevention.

A recent study of actual storm events and modelling for different temperature increase scenarios found rainfall in New Zealand increased on average by 3, 5 and 33 per cent for temperature changes of 0.5°C, 1.0°C and 2.7°C, respectively[276]. And generally, more rainfall means more flooding.

Approximately 90 per cent of the wetlands that existed in New Zealand 150 years ago have been drained, filled or otherwise destroyed[277]. The 7,290 ha Whangamarino Wetland, which includes a 4,871 ha Wetland Management Reserve, is the second largest bog and swamp complex in the North Island.

The wetland has a significant role in flood control (the value of which has been estimated at US$601,037 per annum at 2003 values[278]) and sediment trapping. Values rise in years when there is flooding and it is estimated that flood prevention in 1998 was worth US$4 million alone. An assessment of the value of the wetland concluded that: *"If Whangamarino wetland didn't exist, the regional council would be faced with constructing stopbanks along the lower course of the river at a cost of many millions of dollars"*[279].

A trade-off exists however between the increased use of the wetland for flood control and the conservation of other ecosystem values. The site is of considerable biodiversity value and is more botanically diverse than any other large low-lying peatland in the North Island. This diversity gives it an ability to support a wide range of regionally rare communities[280]. The wetland also supports the largest known populations of the endangered Australasian bittern *(Botaurus poiciloptilus)* and is valued for fishing and hunting. Therefore, the input of floodwaters, which increase nutrient and sediment loads, needs to be carefully managed to ensure the indirect impacts of climate change are also mitigated.

Whangamarino is one of three wetland sites in New Zealand which each receive funding of approximately NZ$500,000 a year for wetland restoration[281].

Source: Department of Conservation, New Zealand

When cyclones develop sustained winds of 119 km an hour they become the hurricanes of the Atlantic and northeast Pacific and the typhoons of the western Pacific. In vulnerable coastal areas the consequences of greater storm events will be exacerbated by sea-level rise. The IPCC reports that future tropical cyclones are likely to become more intense, with larger peak wind speeds and heavy precipitation[241]. There is already evidence of more severe storm occurrences. In 2005 Latin America and the Caribbean experienced 26 tropical storms including 14 hurricanes – one of the most destructive hurricane seasons in history[242]. The impacts of such disasters can include loss of life and displacement of whole communities, as well as economic costs which countries are often ill able to afford. In Mexico, for example, Hurricane Wilma was estimated to cost US$17,788 million in 2005 by way of the damage sustained[243], and the Tabasco floods, US$3,100.3 million in 2007[244]. Cyclones are 'fuelled' by warm and humid air above tropical oceans, which must be at least 26.5°C and 50 m deep. The warmer seas become, the more areas will reach this critical temperature and more storms will develop[245]. Until recently, only two tropical cyclones had been recorded in the South Atlantic, and no hurricanes. But on 28 March 2004, the southern coast of Brazil saw its first ever hurricane, Hurricane Catarina[246].

Coastal wetlands are already declining by one per cent per year due to indirect and direct human activities. If sea levels rise by one metre, more than half the world's current coastal wetlands could be lost[247]. According to the IPCC this process is already underway leading to increasing damage from coastal flooding[248]. One estimate suggests that 10 million people are currently affected each year by coastal flooding and this number will increase dramatically under all the climate change scenarios[249].

Ecologists, engineers and disaster relief specialists are increasingly looking for the best balance between development, conservation and disaster preparedness, often drawing on traditional approaches used by indigenous peoples or local communities. However, the International Strategy for Disaster Reduction recognises that "*At present, environmental management tools do not systematically integrate trends in hazards occurrence and vulnerability*"[250]. This is despite the fact that research shows that the cost of disaster reduction is usually much less than the cost of disaster recovery[251]. The World Bank and the US Geological Survey suggests that every dollar invested in effective disaster reduction saves seven dollars in terms of reduced losses from natural disasters[252]. As the IPCC notes "*Climate change will interact at all scales with other trends in global environmental and natural resource concerns, including water, soil and air pollution, health hazards, disaster risk, and deforestation. Their combined impacts may be compounded in future in the absence of integrated mitigation and adaptation measures*"[253].

The role of protected areas

The protection and restoration of ecosystem services is seen as an important step towards enhancing disaster preparedness by many governments and intergovernmental organisations. Some of the earliest protected areas were established to buffer human communities against extremes of climate and associated hazards. In Japan, forest

CASE STUDY

Protected areas can help guard against landslides by reducing forest loss and increasing soil stability; Switzerland has been following a policy of natural hazard management through protecting Alpine forests for more than 150 years, resulting in protection worth billions of dollars.

Climate change has the potential to increase the severity of all types of hydro-meteorological hazards; more intense and frequent rainfall is likely to result in more numerous landslides[282]. This has been identified as a problem in Switzerland[283], with recent increases in landslide activity being attributed to more torrential rainfall and higher livestock density[284]. Forest clearance can also dramatically increase the frequency of shallow landslides on steep slopes[285].

The European Commission, recommends that: "*The reforestation of hill slopes can help to reduce the occurrence of shallow but still dangerous landslides (mainly mud flows and debris flows)*" and that "*excessive deforestation has often resulted in a landslide*"[286]. In Switzerland, study of the pollen record provides strong evidence of anthropogenic forest clearance and agricultural activity correlated with increased landslide activity in the past[287].

Around 150 years ago the Swiss government recognised that over-exploitation of trees was leading to serious avalanches, landslides and flooding and introduced a rigorous system of protection and restoration[288]. Stands are managed to help protect against rock fall, landslides and avalanches[289]. Following a serious flooding event in 1987, further steps were taken to use forests as protection against natural hazards, through the *Federal Ordinances on Flood and Forest Protection*[290]. Four main elements of natural hazard management were identified: hazard assessment, definition of protection requirements, planning of measures and emergency planning[291]. Use of forests was recognised as a major component of disaster prevention and today forests in the Alpine region, making up 17 per cent of the total area of Swiss forests, are managed mainly for their protective function. Apart from the important human benefits, these protection forests provide services estimated at between US$2 and 3.5 billion per year[292].

Table 4: Examples of the role of protected areas in preventing or mitigating against natural disasters

Hazard	Role of protected area	Protected area habitat type	Examples
Flooding	Providing space for overspill of water / flood attenuation	Marshes, coastal wetlands, peat bogs, natural lakes	• The two reserves which form the Muthurajawella Marsh, in Sri Lanka, cover an area of 3,068 ha near Colombo. The economic value of flood attenuation (converted to 2003 values), has been estimated at US$5,033,800 per year[259].
	Absorbing and reducing water flow	Riparian and mountain forests	• Benefits from forest protection in the upper watersheds of Mantadia National Park, in Madagascar, in terms of reduced flood damage to crops were estimated at US$126,700 (in 1991 Madagascar had per capita GNP of US$207)[260].
Landslip, rock fall and avalanche	Stabilising soil, loose rock and snow	Forest on steep slopes	• Floods and landslides are frequent hazards in Nepal, claiming around 200 lives a year[261]. Shivapuri National Park is the main source of water for domestic consumption in Kathmandu. Landslide protection measures have been implemented in 12 localities in the park[262].
	Buffering against earth and snow movement	Forests on and beneath slopes	• 150 years ago the Swiss government recognised that forest loss was linked to serious avalanches, landslides and flooding[263]. 17 per cent of forests are managed to protect against landslides and avalanches[264], providing services worth some US$2–3.5 billion per year[265].
Tidal waves and storm surges	Creating a physical barrier against ocean incursion	Mangroves, barrier islands, coral reefs, sand dunes	• The indigenous communities living in the Rio Plátano Reserve in Honduras are reforesting the shore of the Ibans Lagoon with mangrove and other species to improve fish habitats and counter the erosion of the narrow coastal strip[266]. • Following the 2004 Tsunami, studies in Hikkaduwa, Sri Lanka, where reefs are in a marine park, noted that damage reached only 50 m inland and waves were only 2-3 m high. At nearby Peraliya, where reefs have been extensively affected by coral mining, the waves were 10 m high, and damage and flooding occurred up to 1.5 km inland[267].
	Providing overspill space for tidal surges	Coastal marshes	• The Black River Lower Morass is the largest freshwater wetland ecosystem in Jamaica. The marsh acts as a natural buffer against river flood waters and incursions by the sea[268] and is an important economic resource for 20,000 people.
Drought and desertification	Reducing grazing and trampling	Particularly grasslands but also dry forest	• In Djibouti the Day Forest is a protected area, with regeneration projects initiated to prevent further loss of this important forest area and further desert encroachment[269].
	Maintaining drought-resistant plants	All dryland habitats	• In Mali, the role of national parks in desertification control is recognised, and protected areas are seen as important reservoir of drought-resistant species[270].
Fire	Maintaining management systems that control fire	Savannah, dry and temperate forests, scrub land	• In Mount Kitanglad National Park, Philippines, volunteers from different ethnic communities in the area undertake fire watching duties. Being members of volunteer guard initiatives fits well with traditional ideas of land stewardship and a council of tribe elders endorses their appointment[271].
	Maintaining natural fire resistance	Fire refugia in forests, wetlands	• Studies in and around Kutai National Park, Indonesia, found that the 1982-3 forest fires killed more trees in secondary forest than in protected primary forests, where fire swept through undergrowth, only affecting larger trees when fire crept up lianas[272]. Similarly recent studies in the Amazon found the incidence of fire to be lower in protected areas relative to surrounding areas[273]. Forest fragmentation also leads to desiccation of ground cover, increasing the fire hazard.
Hurricanes and storms	Buffering against immediate storm damage	Forests, coral reefs, mangroves, barrier islands	• The protected mangrove system known as the Sundarbans in Bangladesh and India helps to stabilise wetland and coastlines and contributes to the Sundarbans' role in buffering inland areas from cyclones. Mangroves can break up storm waves that can exceed 4 m in height during cyclones[274], and result in the coastal areas protected by these forests suffering less from wind and wave surges than those areas with little or no mangrove cover[275].

Desert formation in arid grassland, Namibia © Nigel Dudley

protection was introduced in the 15th and 16th centuries[254] to counter landslides. Today Japan has almost nine million hectares of protection forests; with 17 uses including 13 related to reducing impacts of extreme climate[255]. In the Middle East, protected areas called *hima* were established over a thousand years ago to prevent grassland erosion[256]. Many traditionally managed Indigenous and Community Conserved Areas and sacred natural sites use natural vegetation to protect against floods and landslides caused by extreme weather events[257]. The most immediate role of protected areas in disaster risk reduction is to ameliorate the effects of a natural hazard. In this regard, protected areas provide three main benefits:

- Maintaining natural ecosystems that buffer against natural hazards such as tidal surge or floods, including coastal mangroves, coral reefs, floodplains and forest.
- Maintaining traditional cultural ecosystems that have an important role in mitigating extreme weather events, such as agroforestry systems, terraced crop-growing and fruit tree forests in arid lands
- Providing an opportunity for active or passive restoration of such systems where they are degraded or lost

The value of such ecosystem services can be considerable. A recently published analysis of the role of wetlands in reducing flooding associated with hurricanes in the United States calculated an average value of US$8,240 per hectare per year, with coastal wetlands in the US estimated to provide US$23.2 billion a year in storm protection services[258].

SOLUTIONS

Broadscale planning: at a national and regional/transboundary scale opportunity analyses should be undertaken in partnership with disaster response institutions to identify places where natural ecosystems could prevent and mitigate disasters and to develop associated ecosystem protection strategies, including the establishment of new protected areas in vulnerable areas to safeguard vital ecosystem services that buffer communities. This should be undertaken in the context of broader disaster risk management plans and systems.

Some protected area authorities may consider revising management objectives and management plans to better reflect and maintain the contribution of protected areas in mitigating disasters.

Role of protected areas in safeguarding water

KEY MESSAGES

Climate change is expected to have an overall negative impact on water availability; water supply is likely to be more variable and significant areas will have less total rainfall. Some natural ecosystems particularly cloud forests and some old eucalyptus forests can increase net water in catchments, while most wetlands help to regulate water flow, and their protection can help to alleviate climate-induced water stress.

The challenge

Many countries are already facing water shortages[293] and these are likely to increase: it has been calculated that humanity already uses over half the geographically and temporally accessible water run-off[294]. By 2025 around five billion people could be experiencing water stress[295]. The need for new approaches to supplying water is increasingly acknowledged[296]. Three quarters of human water consumption is for agriculture, where it is generally used very inefficiently[297], although irrigation tends to be the first sector to lose out in the event of water scarcity[298].

Climate change is expected to alter water availability. Warmer conditions are likely to accelerate the hydrological cycle, increase freshwater resources and thus in theory reduce water stress, but local changes and fluctuations will offset any advantages[299,300]. For instance, some temperate and semi-tropical regions are likely to have less rainfall while southern and eastern Asia is likely to have more water but mainly through an increase in the duration of the wet season[301]. In many parts of the world there is likely to be an increase in the spatial and temporal variability of rainfall. The hydrological regime is also likely to be affected by other factors. In the Cape Floristic Region of South Africa, for example, climate change is expected to exacerbate the rate of expansion of alien invasive woody plants altering both the fire disturbance regime and groundwater and stream flow.

Cayambe-Coca Nature Reserve Cloud Forest, Ecuador © Kevin Schafer / WWF-Canon

The role of protected areas

Many forests, including young forests and exotic plantations, reduce net water flow, because trees have higher evapotranspiration rates than alternative vegetation such as grassland and crops. However, other natural forests (particularly tropical montane cloud forests and some older forests) increase total water flow, so that in conditions where natural forests are likely to be cleared, the establishment of protected areas can help to maintain water supplies[302].

Cloud forest belts or zones typically occur at elevations of 2000-3500 m on large continental interior mountains or mountain ranges, but on island mountains may occur as low as 400-500 m above sea-level[303]. Cloud forests cover 381,166 km^2 (2004 figures); 60 per cent in Asia, 25 per cent in the Americas and 15 per cent in Africa. The theoretical range is considerably larger, although this is likely to alter under climate change[304].

Cloud forests have the ability to "scavenge" atmospheric moisture by condensing it on leaves and other vegetation, and thus adding to the water supply[305]. Overall water use by cloud forests is typically much lower than that of forests lower on the mountains. These two factors together mean that stream-flow emanating from cloud forests tends to be larger for the same amount of rainfall, and is also more dependable during dry periods.

Water gains from cloud forest can be 100 per cent or more than from ordinary rainfall; although in humid areas, it may be only 15-20 per cent greater – but even this addition can be significant to communities that are experiencing shortages of quality water. This water extraction function is lost if cloud forests are cleared, and therefore the inclusion of cloud forests in systems of protected areas is one way to secure and maintain these water supply benefits. Research in Australia also suggests that some older eucalypt forests can also increase net water flow from catchments (see case study).

Many wetlands and hydroscopic soils play a key role in capturing and storing incident rainfall during the wet season, in recharging groundwater supplies, and particularly in mediating the rate of runoff, resulting in year-round water availability for domestic, agricultural and other uses. Protected areas can ensure both the continued function of wetland ecosystems, and management regimes to control fires, the invasion of woody plants, unsustainable pastoralist and other uses can help avoid climate related impacts on these systems, and maintain essential water services for dependent communities because it is an addition to vertical precipitation.

CASE STUDY

A number of governments and municipalities around the world are protecting their forests in order to maintain drinking water supplies. In Australia effective management is particularly important given the challenges of climate change.

Climate change impact predictions for Melbourne tell a story of increased temperatures, reduced rainfall and more extreme climate events. Potential impacts on the water supply include reduced supply due to decreased stream flows and increased risk of bushfires in catchments which could also lead to decreased stream flows and have an impact on water quality[306].

90 per cent of Melbourne's water comes from forested catchments. Almost half are protected and much of the rest is managed for water collection. Protected areas important for water management include Kinglake National Park (IUCN category II, 21,600 ha); Yarra Ranges National Park (category II, 76,000 ha); and Baw Baw National Park (category II, 13,300 ha). Management of Melbourne's water catchment has been guided by a programme of experimental and analytical research on the relationship between catchment disturbance and catchment water yield, which has been particularly important in clarifying links between water yield and forest disturbance. Studies of rainfall and runoff data, collected from large forested catchments in the area that were completely or partially burnt by a wildfire in 1939, concluded that water yield from forested catchments is related to forest age[307]. It was found that forest disturbance can reduce the mean annual runoff by up to 50 per cent compared to that of a mature forest, and can take as long as 150 years to recover fully. This is because evapotranspiration from older forests is lower per unit area than from younger forests. The implication is that forest disturbance, by fire or logging, reduces water yield in the short to medium term (except in the few years immediately after disturbance)[308].

A range of water supply management options have been identified that can help people cope with climate change impacts in Melbourne. In terms of catchment and reservoir management these include managing forested catchments to minimise water yield impacts, from disturbances such as bushfires or logging, and evaporation[309].

Source: WWF

Wetlands, Dyfi Biosphere Reserve, Wales © Sue Stolton

SOLUTIONS

Protected areas can be established to protect forests, wetlands and other ecosystems that provide essential water services and to use adaptive management practices to counter the impacts of climate change on these services. Protected area solutions should be considered and implemented within the context of integrated national adaptation strategies and actions addressing water security under conditions of climate change.

Cloud forests: a global focus on conservation of remaining cloud forests is urgently required, in particular with a view to securing water supplies.

Eucalyptus forests: research is needed on how to balance the water supply benefits of old-growth eucalyptus with added fire danger under conditions of climate change, to work out optimal management strategies.

Freshwaters: the generally under-represented freshwater biome should get special attention in plans to increase protected area coverage.

Role of protected areas in providing clean water

KEY MESSAGES

Lack of access to clean water is a deadly problem for almost a billion city dwellers as well as communities in arid zones, and the problem is likely to get worse under climate change. Forest and wetland protected areas already provide cheap, clean drinking water to countless rural and urban populations, including a third of the world's most populated cities. Protecting sources of clean water in the face of climate change is crucial, necessitating sufficient investment in the expansion and effective management of the protected area system.

Local spring water in Nepal © Simon de Trey-White / WWF-UK

The challenge

In the past century world population tripled, but water demand for human purposes has multiplied six-fold[310]. At the same time many watersheds have been degraded through deforestation and other changes, leading to a variety of hydrological impacts[311]. Climate change combines with other pressures and is exacerbating an existing crisis. Water quality is expected to be negatively impacted by climate change, due to greater variability in rainfall, increased water stress (i.e. periodic shortages) in some regions and breakdown in environmental services, although climate models differ[312]. The 2008 IPCC report *Climate Change and Water* concludes that: *"Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation[313]"*.

Lack of clean water already has a huge effect on public health. Annually, 2.2 million deaths, four per cent of all fatalities, are attributed to lack of clean water and sanitation. Cities are badly affected: it is estimated that 700 million urban dwellers in Asia, 150 million in Africa and 120 million in Latin America and the Caribbean do not have access to adequate potable water[314] and these numbers are expected to increase[315]. Tensions over water access between communities, and between States are creating political problems[316]. All these pressures will increase under conditions of climate change.

The role of protected areas

Well managed natural forests almost always provide higher quality water, with less sediment and fewer pollutants than water from other catchments[317]. Several countries already consciously or unconsciously utilise forests as a cost effective means of supplying potable drinking water. Other natural habitats, including wetlands and grassland habitats, also play a key role in reducing pollution levels and particulate matter in water. Wetlands can also be highly effective in dealing with high levels of nutrients and some water plants can concentrate toxic materials in their tissues, thus purifying the water in which they grow[318]. For example, in Florida's cypress swamps, 98 per cent of nitrogen and 97 per cent of phosphorous in waste water entering the wetlands is removed before water reaches the groundwater reservoirs[319].

Many of the forested watersheds that supply municipal drinking water are already protected. Sometimes this is recognised and watershed protection has been a major reason for establishing a protected area; in these cases water values have sometimes led to the protection of natural areas around cities that would otherwise have disappeared. In other situations, the watershed values of protected areas have remained largely unrecognised and the downstream benefits are accidental, but still socially and economically important. In some cases, full protection may not be feasible due to population pressure or existing land ownership patterns and a range of other forest management options is available, including multiple purpose management with an emphasis on maintaining or enhancing water quality (for example through a forest management certification system) and restoration. Increasingly, national or local governments, private individuals and communities are recognising that this can also help to finance protection[320] for example through payment for ecosystem services (PES) schemes[321].

Research has shown that around a third (33 out of 105) of the world's largest cities obtain a significant proportion of their drinking water directly from protected areas[322]. At least another five of these cities get water from sources originating in distant watersheds that include protected areas. At least eight more obtain water from forests that are managed in a way that gives priority to maintaining their hydrological system functions. Several others of these mega-cities are conversely suffering problems with their water supply because of the degradation of their watersheds, or are currently drawing water from forests that are being considered for protection because of their values to water supply. Effective management of the existing protected areas is crucial to maintaining these water sources and expansion of the protected areas system will ensure that a greater area of these watersheds is buffered against degradation caused by the conjunction of climate change and other human-induced stressors. Some key examples of protected areas that maintain urban water sources are outlined in table 5 overleaf[323].

CASE STUDY

Although rapid glacial melt is threatening the water supply to many Andean countries, an innovative trust fund in Ecuador is ensuring watershed protection measures are adequately managed in the two protected areas vital for the capital city's water supply.

About 80 per cent of Quito's 1.5 million people obtain their drinking water from two protected areas: Antisana and Cayambe-Coca Ecological Reserve. Although formally protected as part of Ecuador's national park system, these reserve lands are also used for cattle, dairy and timber production by the 27,000 people living within or around the reserves[324].

To control threats to the reserves, the government is working with a local NGO to design management plans, which will highlight actions to protect the watersheds, including stricter enforcement of protection to the upper watersheds and measures to improve or protect hydrological functions, protect waterholes, prevent erosion and stabilise banks and slopes[325]. More effective management of the protected areas is being achieved thanks to the establishment in 2000 of a trust fund (called *Fondo del Agua*, or FONAG) with support from The Nature Conservancy and the US Agency for International Development. The fund helps finance watershed protection measures, including acquisition of critical lands and improved agricultural practices[326].

Source: TNC

Table 5: Major cities drawing water from protected areas

City	Protected Area
Mumbai, India	Sanjay Ghandi National Park (IUCN category II, 8,696 ha)
Jakarta, Indonesia	Gunung Gede Pangrango & Gunung Halimun (IUCN category II, 15,000 ha & 40,000 ha)
Karachi, Pakistan	Kirthar National Park (IUCN category II, 308,733 ha) & 5 wildlife sanctuaries (318,391 ha total)
Tokyo, Japan	Nikko National Park (IUCN category V, 140,698 ha) & Chichibu-Tama NP (category V, 121,600ha)
Singapore	Bukit Timah & the Central Catchment Area, (IUCN category IV, 2,796 ha),
New York, USA	Catskill State Park (IUCN category V, 99,788 ha)
Los Angeles, USA	Angeles National Forest (category VI, 265,354 ha)
Bogotá, Colombia	Chingaza National Park (IUCN category II, 50,374 ha)
Cali, Colombia	Farallones de Cali National Park (IUCN category II, 150,000 ha)
Medellín, Colombia	Alto de San Miguel Recreational Park & Wildlife Refuge (721 ha)
Belo Horizonte, Brazil	Mutuca, Fechos, Rola-Moça & 7 other small protected areas (17,000 ha)
Brasília, Brazil	Brasília National Park (IUCN category II, 28,000 ha)
Rio de Janeiro, Brazil	Tijuca National Park (IUCN category II, 3,200 ha) & 3 other parks in the metropolitan area
São Paulo, Brazil	Cantareira State Park (IUCN category II, 7,900 ha) & 4 other state parks
Salvador, Brazil	Lago de Pedra do Cavalo & Joanes/Ipitinga Environmental Protection Areas (IUCN category V)
Santo Domingo, Dominican Republic	The Madre de las Aguas (Mother of the Waters) Conservation Area with five protected areas
Caracas, Venezuela	Guatopo (122,464 ha), Macarao (15,000 ha) & Avila National Parks (85,192 ha, all IUCN category II)
Maracaibo, Venezuela	Perijá National Park (IUCN category II, 295,288 ha)
Barcelona, Spain	Sierra del Cadí-Moixeró (IUCN category V, 41,342 ha) & Pedraforca (IUCN category V 1,671 ha)
Madrid, Spain	Peñalara (15,000 ha) & Cuenca Alta del Manzanares (IUCN category V, 46,323 ha)
Vienna, Austria	Donau-Auen National Park (IUCN category II, 10,000 ha)
Sofia, Bulgaria	2 national parks (Rila & Vitosha) plus Bistrishko Branishte Biosphere Reserve
Ibadan, Nigeria	Olokemeji Forest Reserve (7,100 ha) & Gambari Forest Reserve
Abidjan, Cote d'Ivoire	Banco National Park (IUCN category II, 3,000 ha)
Nairobi, Kenya	Aberdares National Park (IUCN category II, 76,619 ha)
Dar es Salaam, Tanzania	Uluguru Nature Reserve (IUCN category II)
Cape Town, South Africa	Cape Peninsula National Park (29,000 ha) & Hottentots Holland Nature Reserve (IUCN category IV, 24,569 ha)
Durban, South Africa	Ukhlahlamba-Drakensberg Park, (IUCN category I [48 per cent] & II [52 per cent], 242,813 ha)
Johannesburg, South Africa	Maluti/Drakensberg Transfrontier Park & Ukhlahlamba-Drakensberg Park (see above)
Harare, Zimbabwe	Robert McIlwaine (55,000 ha) & Lake Robertson Rec. Parks (8,100 ha, both IUCN Cat. V)
Sydney, Australia	Blue Mountains & Kanangra-Boyd National Parks plus 2 other protected areas
Melbourne, Australia	Kinglake (21,600 ha), Yarra Range (76,000 ha) & Baw Baw National Park (13,300 ha all IUCN category II)
Perth, Australia	Yanchep National Park (IUCN category Ia, 2,842 ha)

Rio de Janeiro by night © Nigel Dickinson / WWF-Canon

SOLUTIONS

Protect forest catchments: particularly those where environmental degradation of forests and other vegetation is undermining water quality; this includes investing in improved protected area management and the expansion of the protected area system to include important watersheds within the framework of comprehensive national adaptation strategies.

Manage wetlands: to maintain their crucial functions including through the removal of invasive alien species that impair wetland functions.

Integrate approaches to forest management and water supply: collaborative approaches are needed between environment ministries, private and state protected area agencies and water companies to ensure that the most effective use possible is made of protected forests in supplying clean water.

Introduce Payment for Environmental Services schemes: lessons from Latin America and elsewhere can provide models for cost-recovery for communities or land-owners in places where land-management choices such as retention of natural vegetation in their catchment areas lead to downstream benefits.

Role of protected areas in supporting marine and freshwater fisheries

KEY MESSAGES

Fisheries are declining globally due to over-fishing and damaging fishing practices. Climate change is likely to accelerate this decline. There is abundant evidence that marine and freshwater protected areas can help to rebuild fish stocks and act as reservoirs for replenishing stocks beyond their borders. More generally, protected areas may be able to increase the resilience of aquatic communities to some climate change impacts by removing other stresses. Careful planning is needed to locate such protected areas in optimal places, including those known to be extremely vulnerable.

The challenge

Marine ecosystems are complex and, even without the added stresses from climate change, are under pressure from factors including: fishing (both through the direct removal of species and because of associated damage such as effects of trawling on the sea bed); pollution including eutrophication; introduced and invasive species and diseases; mining and oil exploitation; coastal development; and tourism. Of these, fishing is probably the most significant in terms of disturbance to overall ecology and immediate impact on human food supply[327]. Many freshwater ecosystems are undergoing similar stresses and, like marine waters, are poorly protected. Climate change is widely accepted to be an exacerbating factor in the decline of fisheries.

Subsistence fishing Mafia Island Marine Park, Tanzania © Meg Gawler / WWF-Canon

Identifying root causes of fish decline is difficult. Marine species tend to have complex life histories with eggs, larvae, juveniles, and adults often found in different places, geographically and in the water column, making it difficult to predict the impact of a particular change factor[328]. Furthermore, recruitment and productivity tend to vary from year to year in a way that makes it difficult to identify longer term trends[329]. Problems are exacerbated by lack of data: the status of most marine fish stocks remains largely unknown, even in developed countries[330].

Nonetheless, we are building a picture of the impact of climate change on fisheries, which is more complex than simply a response to warmer water temperatures[331]. For marine fisheries, changes in ocean chemistry may be more important overall, of which the best known is ocean acidification[332], and ocean circulation will also change, affecting larval transport[333] and thus population dynamics. Impacts on one or two important species may have larger changes at community level. And synergistic effects between climate and other human pressures are likely to be important. Freshwater fish are also likely to be impacted, for example by reduced water availability[334] and shortage of oxygen.

There are already some important regional studies of the effects of climate change on marine fisheries, but it is difficult to predict the aggregate effects on national or regional scales. The International Council for Exploration of the Sea (ICES) examined evidence of the effect of climate change on the distribution and abundance of marine species in the Convention on the Protection of the Marine Environment of the North-East Atlantic (the OSPAR convention) Commission Maritime Area, drawing on 288 individual studies. It found that climate change is a recognisably important factor in around three quarters of cases; particularly for fish species where research found (i) a northward shift or deepening of their distribution; (ii) an increase in abundance in the northern part and a decrease in the southern part of their range. The study concluded that steps to reduce large-scale habitat impacts, such as a reduction in fishing pressure, could be a key adaptation strategy[335]. Preliminary studies suggest that some freshwater fisheries will also decline as a result of climate change, with knock-on effects to human nutrition[336].

Vulnerability of marine capture fisheries to potential climate change was calculated for 132 countries with an indicator-based approach. Highest vulnerability was found in central and west Africa (e.g. Malawi, Guinea, Senegal, and Uganda), Peru and Colombia, and tropical Asia (e.g. Bangladesh, Cambodia, Pakistan, and Yemen)[337].

The role of protected areas

Marine and freshwater protected areas provide an important tool for offsetting the combined impacts of over-fishing and climate change on fish stocks, by providing safe havens for breeding to rebuild populations after catastrophic events, such as coral reef bleaching. A precautionary approach

Table 6: Impact of MPAs on fisheries – some recent research examples from around the world

MPA	Increased fish numbers	Spill-over
Medes Islands MPA, Spain[343]	✔	✔
Columbretes Islands Marine Reserve, Spain[344]	✔	✔
Côte Bleue MPA, France[345]		✔
Cerbere-Banyuls and Carry-le-Rouet MPAs in France, and Medes, Cabrera, Tabarca, and Cabo de Palos MPAs in Spain[346]		✔
Nabq Managed Resource Protected Area, Egypt[347]	✔	✔
Mombasa MPA, Kenya[348]	✔	✔
Malindi and Watamu Marine National Parks, Kenya[349]	✔	✔
Saldanha Bay, Langebaan Lagoon, South Africa[350]	✔	✔
Apo Island, Philippines[351]	✔	✔
Wakatobi Marine National Park, Indonesia[352]	✔	
Monterey Bay National Marine Sanctuary; Hopkins Marine Life Refuge; Point Lobos State & Ecological Reserve; Big Greek Marine Ecological Reserve, USA[353]	✔	
Soufrie`re Marine Management Area, St Lucia[354]	✔	✔
Abrolhos National Marine Park, Brazil[355]	✔	
Rottnest Island, Western Australia[356]	✔	

Note: not all studies referred to above looked at spill-over (which refers to the movement of fish out of the MPA to surrounding areas) to fishery management would seek to reduce existing stressors to marine and freshwater ecosystems and fish stocks: these will not be able to "solve" all the problems for marine ecosystems emerging from climate change but can provide a higher chance of maintaining fish stocks.

In a broad review undertaken for WWF, Roberts and Hawkins (2000), identify a range of benefits of fully protected reserves for marine fish:

- **Enhancing the production of offspring which can restock fishing grounds**: researchers conclude that fish density is generally higher inside marine protected areas (MPAs), particularly when surrounding areas are heavily fished[338]. A recent review of 112 independent studies in 80 different MPAs found that all biological measures were strikingly higher inside the reserve than in surrounding areas (or in the same area before an MPA was established). Relative to reference sites, population densities were 91 per cent higher, biomass was 192 per cent higher, and average organism size and diversity were 20–30 per cent higher in MPAs, usually after as little as 1-3 years; furthermore these increases were found even in small MPAs[339].

- **Allowing spill-over of adults and juveniles into fishing grounds**: as population size and the size of individual fish increases within MPAs, they will start to spill-over into surrounding waters, providing additional catch for fishing operations and helping build up wider populations. Six factors affect spill-over: the success of protection; the length of time that the MPA has been established; intensity of fishing outside the MPA; the mobility of species; the boundary length of the reserve (with greater edge to area ration increased spill-over); and boundary porosity, with out-migration encouraged if there is continuous habitat type[340]. Table 6 on the previous page summarises some recent research.

- **Providing a refuge for vulnerable species**: that react to even minor disturbance or fishing pressure.

- **Preventing habitat damage**: all forms of fishing create some associated damage: trawling and use of dynamite are the most serious but even line fishing results in some disturbance and litter that can damage bottom-living communities.

- **Promoting development of natural biological communities** (which may be different from communities found in fishing grounds): for example in Chile establishment of an MPA led to a replacement of mussel beds with barnacles, due to recovery of a predatory snail *Concholepas concholepas*, which controlled the former but was over-exploited elsewhere[341].

- **Facilitating recovery from catastrophic human disturbance**: healthy ecosystems, with a full complement of species and effective ecosystem functioning, are more likely to recover from sudden major disruptions than ecosystems that are already weakened by over-exploitation[342]. This benefit will become increasingly important under conditions of climate change.

CASE STUDY

A new marine protected area network in Papua New Guinea is being specifically designed to maintain marine resources and biodiversity in the face of climate change

Climate change will add to the existing pressures on both coral reefs and marine resources; with rising sea temperatures leading to coral bleaching and death, and sea-level rise threatening critical coastal habitats such as mangroves and turtle nesting areas.

The Nature Conservancy has been working with the provincial and local governments of West New Britain province in Papua New Guinea and with many of the communities in the biologically richest areas of Kimbe Bay to develop a marine protected area (MPA) network that is designed specifically for resilience to climate change[366]. The network aims to ensure representation of each habitat type, maintain connectivity for larval dispersal and protect areas more likely to survive the effects of climate change, for example areas that have proven more resilient to past coral bleaching events. These efforts seek to ensure that coral reefs can survive the effects of rising sea temperatures and allow coral larvae from healthy reefs to replenish those affected by bleaching. Socioeconomic studies were also carried out during the planning of the network to ensure communities' marine resource needs were also addressed. While these efforts may not address the impacts on coral reefs of ocean acidification, they will have the effect of reducing other stressors on the area's ecosystems, which is expected to play a critical part in enhancing their resilience.

The approach is necessarily participatory, because local communities are ultimately the decision-making powers in the region[367]. The locally-managed marine areas are being established under local government legal frameworks, and plans are being developed for a Bay-wide designation to encompass the whole MPA network. Preliminary research in the area suggests that even quite small MPAs could be effective in replenishing some fish stocks[368], and thus providing for long-term food security. Four large locally-managed marine areas have already been established and a further six are in development[369].

Source: TNC

Table 7: Status of knowledge about the effects of fully protected marine reserves on fisheries in coral reef areas[363]

Reserve impact	Status of science
Increased fish and invertebrate biomass within borders	Confirmed and widely reported
Adult spillover to support adjacent fishery	Confirmed by a few studies but not others
Larval spillover to provide demographic support to nearby fished reefs	Expected but not demonstrated
Increased coral recruitment (Caribbean)	Confirmed by few studies so far
Enhanced biodiversity	Mixed results (positive, negative and no impact reported)

The impacts of freshwater protected areas on fish have been less fully studied, although evidence of beneficial effects exists, for example for Lake Malawi. Fisheries provide nearly 75 per cent of the animal protein consumed by people in Malawi and are significant source of employment[357]. But a few decades ago they were declining seriously[358]. Studies show that both a one year moratorium[359] and protection afforded by the Lake Malawi National Park[360] resulted in increased fish catches, and well-being, for local fishing communities. Research in Lao PDR suggests that co-management approaches in protected areas can often be particularly successful in terms of protecting fisheries, partly because there are often high levels of traditional ecological knowledge amongst fishing communities[361].

Coral reefs around the world have suffered extensive declines, which exceeded 95 per cent in many locations, creating intense interest in their conservation, including the role of protected areas[362]. Corals are also important breeding sites for many fish. MPAs can address some but not all of the problems facing corals. Current understanding about MPA effectiveness with respect to corals is summarised in table 7 above.

Currently most MPAs are inshore. There is increasing support for MPAs for pelagic conservation[364], and for freshwater protected areas, amongst other things to rebuild fish stocks. These need to be planned taking into account changes likely under climate change, e.g. in location of larval stages of fish, otherwise they can be protecting the wrong places[365].

Protected areas may be able to increase the resilience of marine and aquatic ecosystems and of species, through removal of non climate pressures and in particular offtake pressure. New protected areas need to be established in areas that are likely to be extremely vulnerable. Protected areas will not resolve all of the impacts of climate change on fish populations, such as those emanating from changes in ocean chemistry. However, given the huge scientific uncertainties surrounding the impacts of climate change on many fish species, protected areas can provide an insurance mechanism for fisheries as part of a comprehensive adaptive management approach.

SOLUTIONS

Establish marine and freshwater protected areas agreed and managed with local communities as reservoirs for fish stocks threatened by climate change. Such protected areas should be carefully monitored for their impact on surrounding fish populations and size and management regimes adapted if necessary.

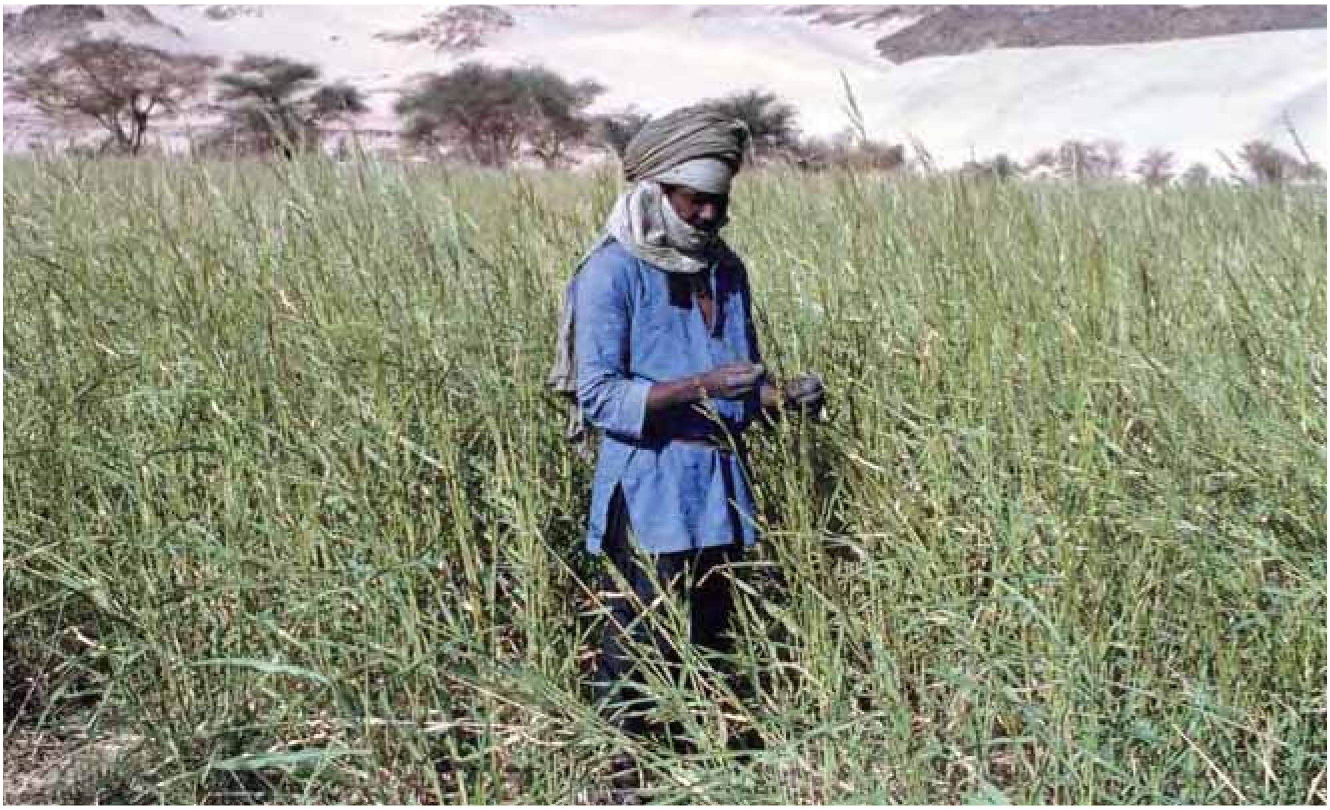
Plan for marine and freshwater protected areas in light of predicted climate change, so that they are located in optimal conditions and of the best possible size and connectivity.

Enhance resilience of marine systems and manage marine protected areas as part of a comprehensive adaptive management strategy for addressing the impacts of climate change on fisheries.

Role of protected areas in safeguarding crop wild relatives and land races

KEY MESSAGES

Crop wild relatives and traditional crop varieties (landraces) contain genetic material that can be used to help modern crops adapt to climate change and many traditional varieties are better adapted to climatic extremes such as drought. Protected areas provide cost effective *in situ* conservation for this vital agrobiodiversity resource.



Relic stand of wild sorghum North Aïr, Niger © John E. Newby / WWF-Canon

The challenge

According to the IPCC, if average temperature increase exceeds 1-3°C, the global potential for food production is likely to decrease[370]. Although there is still much uncertainty about the impacts, they are likely to include a reduction in global food security[371]; increasing differences in food supply between the developed and developing world[372], with particular problems in Africa[373]; and increased risks of malnutrition due to crop failure[374]. Agriculture will need to adapt to rapidly changing conditions and perhaps to increased plant diseases[375]; impacts will be determined in part by crop adaptability[376]. Much of the genetic material used in crop breeding comes from closely related wild species (crop wild relatives or CWR) and from traditional crop varieties (landraces)[377], together known as *agrobiodiversity*. Global estimates of the value of agrobiodiversity vary from hundreds of millions to tens of billions of US dollars a year[378]. However, this resource is being eroded by habitat loss and other factors[379]. Climate change will likely increase the threats facing CWR[380]. Modelling suggests that 97 per cent of some CWR groups could experience a reduction in range size and 16-22 per cent might be threatened by extinction[381]. Strategies to stabilise food supply need to include *in situ* protection strategies for CWR and landraces. But protection in some centres of crop diversity (where CWR are likely to be most plentiful) is considerably less than average and there is a recognised need to address this in national protected area strategies[382].

Table 8: Some examples of crop wild relatives conserved within protected areas

Country	Protected Area	Link to Crop Wild Relatives and landraces
Argentina	Nahuel Huapi National Park (NP), IUCN cat. II, 475,650 ha	Contains potato CWR (*Solanum brevidens* and *S. tuberosum*)[385].
Armenia	Erebuni State Reserve, IUCN cat. Ia, 89 ha	Wild wheat (Triticum spp.)
Australia	Border Ranges NP, IUCN cat. II, 31,683 ha	Contains *Microcitrus australasica* which has helped improve disease resistance in citrus fruit[386].
Bolivia	Madidi NP, IUCN cat. II, 1,895,750 ha	Wild pineapple (*Ananas* sp.) is common in the pampas[387].
Cameroon	Waza NP, IUCN cat. II, 140,707 ha	Perennial grass such as wild rice (*Oryza barthii*) and *Sorghum sp*.[388]
China	Xishuangbanna Nature Reserve, IUCN cat. V, 247, 439 ha	38 species have been identified as having important germplasm[389].
Costa Rica	Volcán Irazú NP, IUCN cat. II, 2,309 ha	Wild avocado and avocado near-relatives *P. schiedeana*[390]
Czech Rep.	Sumava NP, IUCN cat. II, 68,520 ha	Many wild fruit trees[391]
Ecuador	Galápagos Islands, 766,514 ha (terrestrial area)	Endemic tomato (*Lycopersicon cheesmanii*)[392]
Ethiopia	Bale Mountains NP, IUCN cat. II, 247,100 ha	Coffee (*Coffea arabica*) in lower elevation forest[393]
Guatemala	Mario Dary Rivera, IUCN cat. III, 1,022 ha	A rare pepper, *Capsicum lanceolatum394*
Germany	Schorfheide-Chorin Biosphere Reserve, 129,161 ha	Breeding programmes for ancient grain and vegetable species[395]
India	Silent Valley NP, IUCN cat. II, 8,952 ha	CWRs of Cardamom, pepper, yams, beans etc
Indonesia	Bukit Baka - Bukit Raya NP, IUCN cat. II, 181,090 ha	Jackfruit (*Artocarpus* spp.), durians, litchi *(L. chinensis*) and mango[396]
Iran	Touran Protected Area, IUCN cat. V, 1,102,080 ha	CWR of barley (*Hordeum* sp.)[397].
Kyrgyzstan	Besh-Aral State Reserve, IUCN cat. Ia, 63,200 ha	Walnut (*Juglans regia*), pear and wild plum (*P. sogdiana*).[398]
Mauritius	Black River Gorges NP, IUCN cat. II, 6,574 ha	Passion fruit (*Passiflora edulis f. flavicarpa*), pineapple etc[399].
Niger	Aïr and Ténéré NNR, IUCN cat. IV, 6,456,000 ha	CWR of millet, barley, wheat and sorghum[400]
Spain	Montseny NP, 30,117 ha	CWR include *Prunus* sp[401]
Tajikistan	Dashtidzumsky State NR, IUCN cat. Ia, 53,400 ha	Pistachio, almonds, maple, pomegranate and wild figs[402]
Turkey	Kazdagi NP, IUCN cat. II, 21,300 ha	Rich in fruit progenitor, nut, ornamental and forest species[403]
Uganda	Kibale NP, IUCN cat. IV, 76,600 ha	Wild robusta coffee (*C. canephora*)[404]

The potential of protected areas
Two options exist for protecting agrobiodiversity: *ex situ* in gene banks (e.g. the Global Seed Vault in Svalbard, Norway) and *in situ*, by protecting natural CWR habitats and cultural habitats supporting landraces. Both are needed. *Ex situ* collections insure against ecosystem decay, but are expensive, only contain a small proportion of the variety in healthy natural populations and do not continue to evolve. There can also be problems in regenerating stored material, with genetic diversity lost at each regeneration cycle[383]. The importance of bringing CWR range areas into national protected area systems is underscored by the relative success of well managed protected areas in buffering against threats to biodiversity and thus the CWRs, relative to other land governance systems. Protected areas provide an insurance mechanism to protect CWRs that will be critical in allowing society to adapt to climate change. The smaller the gene pool, the more limited the ability of humans to tap genes to breed crops and livestock resistant to diseases or that can adapt to changing environmental conditions under climate change.

Protected areas already protect many CWR species *in situ* and a few are managed specifically to retain landraces, particularly within category V protected landscapes (table 8 gives some examples)[384].

Researching conservation of crop wild relatives in protected areas to provide best practice standards.

Agriculture began with the domestication of wild plants, and the wild relatives of today's crops remain vital for a food-secure future. CWR contribute resistance to pests and other stresses and will play an important role in future crop adaptation to climate change.

Protected areas provide an obvious focus for conservation of wild relatives thereby ensuring availability for future crop improvement. Unfortunately, their conservation, especially in their centres of origin or diversification, remains an immense challenge and is by no means guaranteed, requiring considerable political and institutional effort, as well as time and resources. Despite their importance wild relatives are not considered flagship species and securing such commitment and resources is difficult. Sadly their importance is little understood by those who could make a difference – policy makers and conservation administrations – a situation not helped by the current disconnect between the agriculture and conservation sectors. There are also few examples of successful wild relative conservation to follow or replicate and there is no easy blueprint for success.

Through the UNEP-GEF supported global project, ***'In situ conservation of crop wild relatives through enhanced information management and field application'***, Bioversity International is committed to meeting many of these challenges. Working with international and national partners in Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan the project has invested significant time and resources establishing effective partnerships involving relevant stakeholders. This has resulted in comprehensive assessment of threats to wild relatives and actions for their management, including the drafting of CWR national action plans and management plans for specific species and protected areas as well as guidelines and procedures for conservation of wild relatives outside protected areas. Analysis and strengthening of national legislation to support wild relative conservation has added to this protection. Preliminary evaluation programmes are also underway in all countries which will see wild relatives contribute traits to crop improvement. Information and data from the project has been integrated in national information systems linked to a Global Portal which will provide much needed support to future decision-making and action. The project also hopes to address the lack of practical examples by producing a *Manual of In Situ Conservation of Crop Wild Relatives* based on lessons learned and good practices arising from the project. Combined with innovative public awareness and extensive capacity building the project has contributed substantially to enhanced conservation status of crop wild relatives.

Danny Hunter: Bioversity International

SOLUTIONS

Increase protected areas in Centres of Crop Diversity: using gap analysis to identify those places with high levels of diversity.

Introduce national and local planning: states need National Agrobiodiversity Conservation Strategies[405], including inventories[406] and gap analyses[407] of agrobiodiversity; and protected areas should identify and address conservation of CWR and landraces needs in their management plans. These should be nested within national adaptation strategies and action plans designed to maintain food security under conditions of climate change.

Novel approaches: are needed for agrobiodiversity conservation, including community approaches, such as Indigenous and Community Conserved Areas along with support from the agricultural industry and NGOs.

Climate adaptation: management needs to consider the possibility that ranges will shift out of reserves[408], necessitating creation of new protection in predicted ranges.

New partnerships: increasing collaboration with the agricultural sector, including in particular seed companies, in promoting *in situ* protection.

Role of protected areas in addressing health issues under climate change

KEY MESSAGES

Climate change has the potential to increase several vector-borne and zoonotic diseases. Such increases may be exacerbated by environmental damage. Intact forests including those within large and effectively managed protected areas can be correlated with reduced infection rate from diseases such as malaria, leishmaniasis and yellow fever amongst others. Protected areas are also key sources for herbal medicines and material for new pharmaceuticals that may be an important pharmacopeia to help society to cope with new disease outbreaks.

The challenge
The World Health Organisation (WHO) estimates that 23-25 per cent of global disease burden could be avoided by improved management of environmental conditions[409]. It has stated *"... the greatest health impacts may not be from acute shocks such as natural disasters or epidemics, but from the gradual build-up of pressure on the natural, economic and social systems that sustain health, and which are already under stress in much of the developing world."*[410]. Climate change is seen as one of the most important factors likely to affect our health in the future[411]. WHO has estimated that climate change is already responsible for 150,000 deaths a year[412] and its Director General, Margaret Chan, has identified climate change as a top priority for global public health[413]. Poorer countries will be disproportionately impacted[414].

Production of herbs and medicinal plants, Ismailly Nature Reserve, Azerbaijan © Hartmut Jungius / WWF-Canon

Vector-borne diseases kill over 1.1 million people a year, and diarrhoeal diseases 1.8 million[415]. Many of these diseases are sensitive to changes in temperature and rainfall. The incidence of diarrhoea may increase as a result of scarcity of water needed to maintain hygiene in areas likely to suffer from water shortages under conditions of climate change. Conversely, diarrhoea is also likely to increase in areas where climate change causes flooding if this overwhelms drainage and sewage systems[416]. Research suggests that for example climate change is likely to increase diarrhoeal disease in the Pacific islands[417]. Other impacts could include the northerly spread of tick-borne encephalitis in Sweden and increases in cholera in the Bay of Bengal[418]. Changing temperatures and rainfall are expected to alter the distribution of insect disease vectors, with malaria[419] and dengue[420] being of greatest concern, particularly in Eurasia and Africa[421]. Recent increases may be related in part to climate change[422]. Studies suggest that climate change may put 90 million more people at risk of malaria in Africa by 2030 and 2 billion more people around the world at risk of dengue by the 2080s[423], although others challenge these numbers[424].

CASE STUDY

In Colombia a new protected area is being used to ensure the survival of traditional health care options.

Climate change is expected to increase the spread and prevalence of many diseases. In Colombia, hydrological and climatic change is already leading to increases in malaria[440].

Colombia is one of many countries relying on locally-collected traditional medicines as a major resource for meeting primary health care needs. Sustainable sources of traditional medicines depend to a large extent on ecosystem integrity, for maintaining both the species concerned and the cultural knowledge of their use. However this integrity is under threat[441], in part because indigenous health care is often unable to cope with the consequences of habitat degradation or loss of resources and homelands[442].

The establishment of the Orito Ingi Ande Medicinal Plants Sanctuary was proposed by the indigenous communities who live in Southwestern Colombia, on the eastern slope of Patascoy hill. The sanctuary covers 10,200 ha of tropical rainforests and Andean forests ranging from between 700 and 3,300 metres above sea level. The protected area, designated in 2008, aims to strengthen and restore traditional culture and associated landscapes. Conservation strategies focus on preserving the shamanic tradition of local peoples and on the protection of the associated medicinal plants. The protected area fulfils the aims of local indigenous healers to: *"regain possession of our territories and sacred sites. The forest is for us the fountain of our resources. If the forests disappear so will medicine and life"* [443].

Source: WWF

New infectious diseases have also emerged at an unprecedented rate: between 1976-1996 WHO recorded over 30 *emerging infectious diseases**, including HIV/AIDS, Ebola, Lyme disease, Legionnaires' disease, toxic E. coli and a new hantavirus; along with increasing resistance to antibiotics[425]. There has also been a re-emergence and spread of existing climate-sensitive infections: such as cholera and Rift Valley fever in Africa, and dengue in Latin America and South Asia[426]. Climate change often acts in concert with factors such as the destruction or degradation of natural ecosystems; changes in surface waters; proliferation of livestock and crops; uncontrolled urban sprawl; resistance to pesticides used to control disease vectors; migration and international travel; trade (legal and illegal); and the introduction of pathogens[427]. As the disturbance of ecosystems often results in the proliferation of some reservoir species and arthropod vectors, the predominance of these emerging pests results in higher prevalence and abundance of pathogens with zoonotic potential. The influence of climate change might act synergistically, further favouring reservoir hosts, arthropod vectors and their pathogens.

In 2008, the 193 countries at the 61st World Health Assembly, gave unanimous support for a resolution calling for more engagement on climate change. The Assembly requested WHO to strengthen its programme of support and to ensure that health is fully represented within the international climate change debate[428]. In particular: "work on: ... (c) ***the health impacts of potential adaptation and mitigation measures in other sectors such as marine life, water resources, land use***, and transport, in particular where these could have positive benefits for health protection"; (our emphasis).

The role of protected areas

Protected areas can provide an opportunity to benefit from the conscious management of ecosystems against disease. For example, ecological disturbances have been linked to the emergence and proliferation of diseases such as malaria, leishmaniasis, cryptosporidiosis, giardiasis, trypanosomiasis, schistosomiasis, filariasis, and onchocerciasis, among other diseases, especially those transmitted by arthropod vectors[429,430]. A study in the Peruvian Amazon found that the primary malaria vector, *Anopheles darlingi*, had a biting rate that was more than 278 times higher in deforested areas than in areas that were heavily forested[431]. Avoiding deforestation or restoring natural vegetation can reduce the risk of vector-borne diseases[432]. Many of the areas where malaria poses a serious risk have seen major habitat loss and relatively low levels of conservation[433]. However, where protection does exist, research is beginning to show the benefits.

* An infectious disease whose incidence has increased in the past 20 years and threatens to increase in the near future

In Indonesia, the 32,000-ha Ruteng Park on the island of Flores protects the most intact submontane and montane forests on the island. Researchers studying the impacts of deforestation on rural economies and livelihoods through the spread of infectious diseases such as malaria found statistically significant correlations between forest protection and reductions in the incidence of childhood malaria. The study found that communities living near the protected area had fewer cases of malaria and dysentery, children missed school less because of ill health, and there was less hunger associated with crop failure, than in communities without intact forests nearby[434].

Protected areas also provide vital resources for traditional medicine to help combat increased levels of disease: for example, a survey in Langtang National Park, Nepal found[411] medicinal and aromatic plants being use; with about 90 per cent of the population relying on traditional medicine[435]. Many natural genetic resources also provide material for commercial pharmaceuticals[436.], for example the bark of *Strychnopsis thouarsii*, collected in Andasibe National Park is a traditional malaria treatment in Madagascar and has shown success in treating malaria in experimental conditions[437]. In 2000, over 200 corporations and US government agencies were studying rainforest plants for their medicinal capacities and plant-based pharmaceuticals were estimated to earn over US$30 billion per year[438]. A survey in 2008 found dozens of cases in which protected areas are sources of genetic material for both traditional medicines and pharmaceuticals[439]. More generally, protected areas can also help to protect essential ecosystem services, such as clean water or mitigation against disaster, with attendant benefits for human health.

Kayan Mentarang National Park, Indonesia © Alain Compost / WWF-Canon

SOLUTIONS

Protected areas offer many health benefits, but those with particular relevance to climate change include:

Use of natural ecosystems to control insect disease vectors: further research is urgently needed to establish the links between the retention of forest habitats and the reduction in insect-borne diseases, leading to accompanying management advice for landscape-level planning and for site-level responses including restoration.

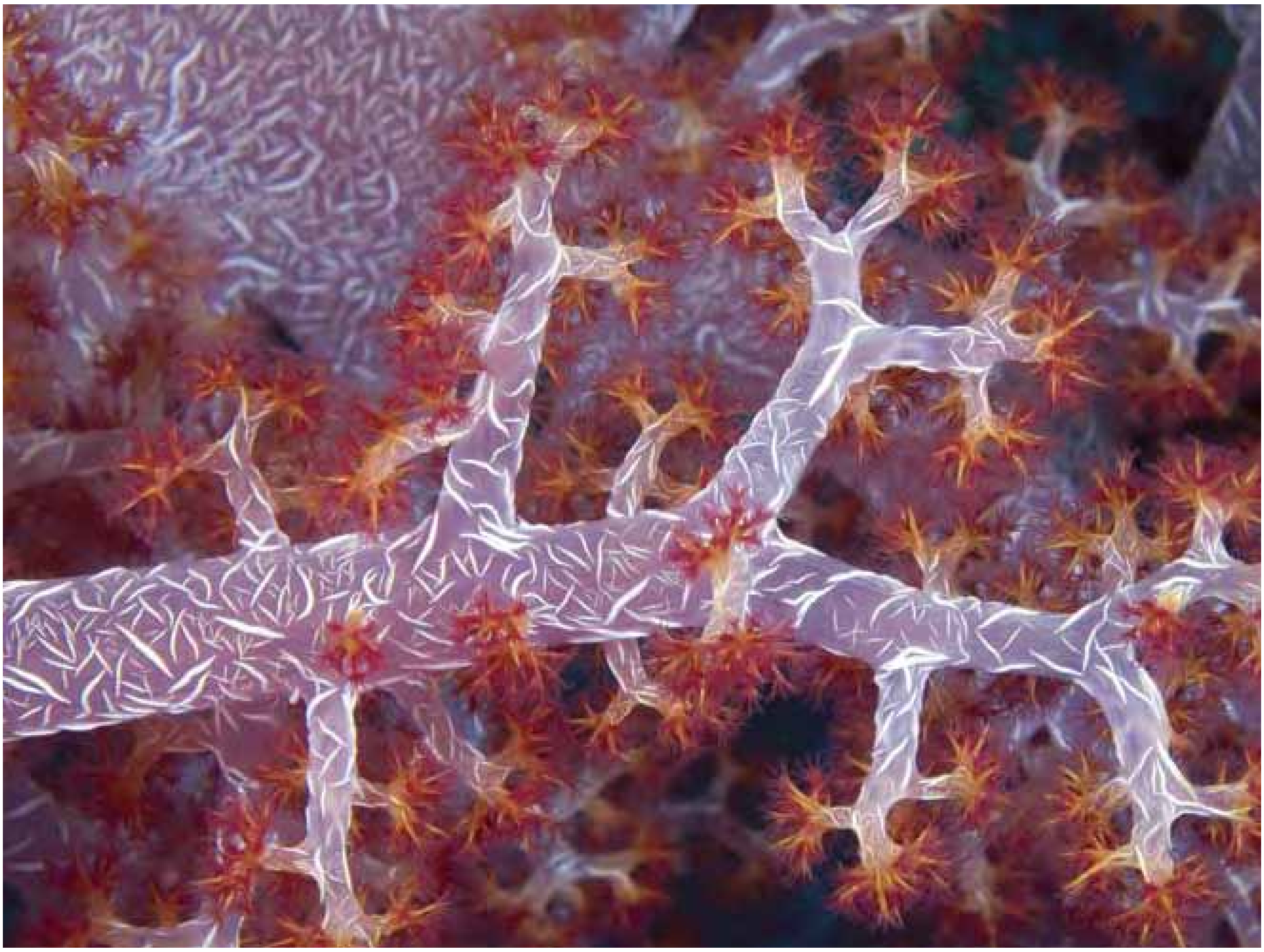
Protect genetic resources to provide materials for new and existing medicines: using protected areas to ensure that the maximum local and global health products are available to fight existing, new and emerging diseases.

Tailor protected areas to ecosystem services for disease control: particularly the provision of potable water supplies, maintenance of fish protein supplies and prevention of flood damage.

Role of protected areas in biodiversity conservation and maintaining ecosystem resilience

KEY MESSAGES

Many strategies outlined in this report (crop breeding, medicines, food, etc) rely on conserving biodiversity as a resource for addressing climate change. Many species are threatened by a mixture of climate change and existing pressures. Protected areas can play a vital role in managing existing threats, thus reducing overall pressures, and also in providing active management measures to reduce climate hazards that threaten biodiversity. More fundamentally, protected areas also provide key instruments for maintaining wider ecosystem resilience at a landscape/seascape level to secure a range of the ecosystem services needed to address climate change. Protected areas do this in several ways by protecting intact or fragmentary ecosystems, in places with and without human presence, and by focusing on particular parts of a species' life-cycle or migratory pattern.



Soft coral, Papua New Guinea © Jürgen Freund / WWF-Canon

Protected areas are usually established primarily for biodiversity conservation. Protected areas offer unique benefits for species and ecological processes that cannot survive in managed landscapes and seascapes. They provide space for evolution and a baseline for future restoration[444], which is especially vital during rapid environmental change. Even "sustainably-managed" ecosystems often eliminate key ecosystem functions or species, such as natural regeneration, the most sensitive species[445] and some microhabitats (e.g. dead wood[446]).

Protected areas are often the only remaining natural or semi-natural areas in whole regions and significant numbers of species are found nowhere else[447]. New tools and approaches have increased the precision with which sites are selected[448,449] and managed[450,451] and their role is acknowledged in national and global policies, including by the CBD[452].

There is a growing conviction amongst conservation biologists that greater biodiversity also confers greater resilience within ecosystems[453] and recognition that ecosystems with high carbon frequently also have high biodiversity[454]. Resilience refers to the ability of an ecosystem to maintain its functions (biological, chemical, and physical) in the face of disturbance. A climate resilient ecosystem would retain its functions and ecosystem services in the face of climate change. Ecosystem-based adaptation will require measures to maintain the resilience of ecosystems under new climatic conditions, so that they can continue to supply essential services.

However the science of resilience is unclear. Scientists still do not fully understand the impact on ecosystem function of different climate change scenarios, due in part to the complex biological and physical feedback loops involved. Furthermore, there is considerable uncertainty about how to manage ecosystems to maintain resilience. Scientists believe that the removal of non climate related stressors on ecosystems (which would otherwise lead to ecosystem degradation) should serve to make most ecosystems more resilient under conditions of climate change: many examples of this have been detailed in previous sections. There are two additional schools of thought on the subject of how to manage ecosystems adaptively to maintain ecosystem resilience. One school hypothesizes that greater species richness within ecosystems increases ecosystem resilience by increasing the interdependencies and robustness of the system (the so called stability-diversity hypothesis). A second school argues that it is not species richness per se but functional diversity that plays the pivotal role: this argues in effect that managers should manage ecosystems for their functions, and species that maintain biological functions (such as seed dispersers) should be the target of management interventions. Irrespective of which hypothesis proves to be correct, there are uncertainties about how to manage ecosystems to maintain their functions. At this stage the precautionary principle would support the reduction of existing (non climate related) stressors to ecosystems that provide critical services, which may help buffer the impacts of climate change.

Moreover, given uncertainties regarding the management strategies that need to be employed to maintain functional diversity, measures to maintain species richness in ecosystems are warranted from the perspective of ecosystem resilience, in addition to the other practical and ethical issues involved.

Climate change puts biodiversity under pressure and thereby throws up new problems for protected areas in their role as the primary vehicle for biodiversity conservation and as a mechanism to enhance ecosystem resilience. For example, the IUCN Species Survival Commission has identified traits that make species particularly susceptible to climate change, including: specialized habitat requirements; narrow environmental tolerances; dependence on specific environmental triggers that are likely to be disrupted; dependence on inter-specific interactions that are likely to be interrupted; and poor ability or limited opportunity to disperse[455].

The role of protected areas

The key roles of protected areas in conserving biodiversity and maintaining ecosystem resilience are outlined below:

- **Manage protected areas within the context of sustainable management of ecosystems and maintaining functional diversity**: protected areas cannot usually conserve biodiversity on their own, but must be embedded in a wider landscape or seascape, parts of which have sympathetic management. They remain, however, the essential core of such strategies and a fundamental tool in addressing the uncertainties of climate change.

- **Conservation of large, intact ecosystems**: at a scale that maintains ecosystem structure and diversity, with populations of species large enough to survive over time[456]. Such areas protect both known species and species not yet been described by science[457]. Ecological processes may be as important as species or habitats. Transboundary protected areas may have a key role to play here. The conservation of large intact ecosystems may be an important measure for sustaining the populations of species in areas where climate change will reduce habitat condition. For example, water dependent antelope and other large fauna in areas of Africa likely to witness water stress, may need access to large dry season forage areas. Failure to provide for this may lead to the collapse of wildlife populations, including those of economic importance (for example, species that are important to the tourism industry).

- **Conservation of endangered fragments of ecosystems**: is useful where degradation and ecosystem loss is already widespread and where key features are at risk within otherwise managed landscapes or seascapes. Here protected areas provide key elements in wider efforts to maintain resilient ecosystems, as one element in a suite of responses[458]. Resilience is likely to be enhanced through the protection of functions and structural diversity.

- **Conservation of natural ecosystems without human interference**: despite the long history of human influence, some species, habitats and ecosystems remain highly fragile: e.g. plant species damaged by trampling[459,460], animals with easily disturbed social structures [461]; species susceptible to introduced diseases[462]; or subject to over-collection[463]. Strictly protected areas provide a buffer from interference. This may be critical in allowing vulnerable species to cope with the impacts of climate change by reducing the other threats they face.

- **Conservation of species or habitats through management tailored to their specialised needs**: in places where ecosystem change has been profound (including from invasive species), protected areas may need management actions tailored explicitly to maintain or if necessary restore a particular species or type of ecosystem functioning. Management decisions are driven primarily by conservation needs. Such intervention may be particularly important in managing habitats threatened by fire, drought, spread of new invasive alien species and other risks and manifestations of climate change.

- **Protecting range-limited and endemic species**: some species are so rare or restricted that protected areas conserve all or much of the population, as insurance. While climate change on the levels projected threatens mass species extinction in the wild, by removing other human induced stressors on vulnerable species, protected areas will diminish the conjunction effect of pressures and so reduce extinction risk.

- **Conservation of particular aspects of species' life-cycles**: protected areas can be established to conserve particular periods of the life-cycle of a species or group, at particular times or with some kind of flexible zoning. This may be an important measure to reduce existing pressures on species that are vulnerable to climate change. The most common cases are temporary zoning to protect the breeding grounds of marine or freshwater fish, which often builds on traditional practices as in the Pacific[464].

- **Conservation of habitat fragments for migratory species**: migratory species face particular challenges in needing suitable habitat along routes of hundreds or thousands of miles. Protected areas can maintain flyways, "swim-ways" or mammal routes. They may include provision of food for migratory birds, as for the white-necked crane[465]; fishing restrictions on rivers with spawning salmon[466]; or protection of "stepping stones" for migratory birds, like the Western Hemisphere Shorebird Reserve Network in the Americas[467]. Many migratory species provide important economic benefits, including to fisheries, nutrient cycling and tourism, and these ecosystem benefits are likely to be further undermined by climate change.

CASE STUDY

Fishery health through protection of coral reefs can provide dual benefits by protecting both corals and livelihoods in East Africa.

Marine protected areas have a dual benefit: by rebuilding depleted fish stocks, they support coral reef health and can also increase income for fishers operating nearby. Reefs are better able to withstand the impacts of climate change if herbivorous fish species that graze on algae and help keep the ecosystem in balance are present. Studies on herbivore and coral interactions suggest that in the absence of herbivores, corals are more susceptible to bleaching events induced by warming temperatures[468]. When herbivores disappear from the waters, the reefs become significantly more prone to the detrimental effects of climate change and less able to support their vital ecosystem functions as nursery ground for fish.

A study of coral reef fish and other herbivores in four national marine parks off the coast of Kenya, using nearly continuous data spanning 37 years, has provided scientists with valuable information on coral reef management[469]. Working with local communities, WCS scientists have been able to use these finding to recommend changes in management practices.

Closing some key areas to fishing and restricting certain types of particularly detrimental fishing gear, helps build increased resilience in marine systems against the impacts of rising sea temperatures. In a recent study by a team of scientists, Kenya was found to be one of the fishing nations worldwide which showed marked improvements in fish stock health, on par with industrialized countries such as New Zealand and Iceland[470].

Additionally, WCS's researchers recently obtained new data on economic improvements in fishing communities: this economic benefit can be explained by the fact that not only did fish stocks overall improve in fisheries next to the protected areas, but more valuable fish groups recovered sooner and were more common, enabling better catches. The gross effect was such that per capita incomes in the restricted gear and closure sites were, respectively, 41 per cent and 135 per cent higher than landing sites with no restrictions[471].

Source: WCS

Section 4
Opportunities to use protected areas to address climate change

Reviewing the evidence collected above, the next section looks at the opportunities for protected area systems to maintain and increase their role in climate change mitigation and adaptation, through:

- ➜ Increasing the total area within protected area systems
- ➜ Extending existing protected areas through landscape management approaches that integrate protected areas within a matrix of land uses and as part of local adaptation strategies through community-based approaches
- ➜ Increasing the level of protection within existing protected area systems to ensure that they are effectively addressing threats and storing carbon
- ➜ Improving and adapting management of protected areas
- ➜ Encouraging different protected area governance models including indigenous and community conserved areas and private reserves
- ➜ Focusing protected areas management explicitly on climate change mitigation and adaptation, in addition to addressing biodiversity conservation and other objectives

These strategies however will only be effective if protected areas are incorporated into national and local climate change adaptation and mitigation strategies and action plans and these efforts integrated with other community and sector-based adaptation and mitigation actions. These plans will require capacity-building and adequate finance; this section therefore also briefly reviews the current situation regarding protected area finance and specifically looks at the potential use of fund and market based mechanisms to finance adaptation and mitigation.

Opportunities to expand the protected areas system, integrate it into broader conservation strategies and national and local climate change mitigation and adaptation plans

KEY MESSAGES

The role of protected areas in climate response strategies can be increased in six ways: (1) increasing protected area *size* and *coverage*; (2) extending the functions of protected areas through *landscape/seascape approaches*; (3) encouraging different protected area *governance models*; (4) increasing protected area *management effectiveness*; (5) increasing the *level of protection* within protected areas; and (6) focusing some management activities specifically on *climate responses*. In addition, special planning requirements will be needed to maximise the contributions of protected area systems to ecosystem-based adaptation.

Protected area systems are effective means of retaining and maximising the mitigation and adaptation functions of natural ecosystems. Consolidating, expanding and improving the protected area system is a logical response to climate change that meets many aims of proposed mitigation strategies, particularly those to reduce deforestation and the loss of other ecosystems with large carbon reservoirs. There are existing legal and policy initiatives and tools to accelerate this process, so that many of the initial steps needed to implement these responses have already been taken.

There are six options available for increasing the role of protected area systems in contributing to climate change response strategies (each of which is discussed in greater detail in the following pages):

More and larger protected areas and buffers: to improve ecosystem resilience particularly where much carbon is stored and/or captured and is likely to be lost without protection, or where important ecosystem services are under threat – such as in tropical forests, peatlands, mangroves, freshwater and coastal marshes and seagrass beds, as well as marine ecosystems.

Connecting protected areas within landscapes/ seascapes: using management of ecosystems outside protected areas or intervening waters. This can include buffer zones, biological corridors and ecological stepping stones[472], which are important to build connectivity to increase ecosystem resilience to climate change at the landscape/seascape scale and to increase the total amount of habitat under some form of protection. Such measures will need to be taken within the framework of a landscape level land use plan and management system.

Recognition and implementation of the full range of protected area governance types: to encourage more stakeholders to become involved in declaring and managing protected areas as part of community climate response strategies, particularly indigenous and community conserved areas and private protected areas.

Improving management within protected areas: to ensure that ecosystems and the services that they provide within protected areas are not degraded or lost through illegal use or unwise management decisions such as illegal logging and conversion, other forms of poaching, impacts from invasive species and poor fire management.

Increasing the level of protection within protected areas: by recognising protection and management aimed at specific features that have high carbon storage values, for example: to maintain old-growth forest; avoid ground disturbance or drying out of peat; and also to restore degraded ecosystems.

Focusing some management specifically on mitigation and adaptation needs: including modification of management plans, site selection tools and management approaches as necessary.

1. More and larger protected areas

Increasing the number of protected areas, and particularly of large protected areas, will become important for maintaining ecosystem integrity and for maximising ecosystem resilience under conditions of climate change[473]. Overall size of protected areas can be addressed by expanding borders of individual protected areas and by linking different protected areas including across national

Gap analysis as a way of identifying suitable sites for expansion of protected areas

The CBD *Programme of Work on Protected Areas* (PoWPA) contains multiple objectives with time-bound targets. The overall goal is to complete ecologically representative networks of protected areas, and Parties were guided to begin by completing a gap analysis of their protected area systems with the full and effective participation of indigenous and local communities and relevant stakeholders (activities 1.1.4 and 1.1.5 of the PoWPA[477]). Details of the methodology for national protected area gap analysis process are available, including information on tools and case-studies[478]. Accordingly, several Parties have completed gap analyses of their protected area systems. Currently, the UNDP GEF is supporting ongoing gap analysis in 20 more countries (see table 9). Portions of these biomes, many high in carbon stocks and currently without protection, hold the potential to be protected in order to safeguard natural carbon reservoirs under REDD or as part of countries' individual efforts to address climate change.

The CBD gap analysis can already provide mapping data and tools for identification of carbon-rich natural ecosystems in need of protection. Many pilot countries are within the Forest Carbon Partnership Facility and/or the UN REDD Programme. Through their national gap analyses, countries have identified high priority sites (HiPs) to expand or improve protected area systems. Technology and capacity are available in countries that have completed or are undergoing gap analyses of their protected areas. HiPs are proposed for protection based on a rigorous analysis of multiple GIS data layers including ecosystem characteristics. Relevant stakeholders have been involved in the analysis. The identified areas are of high value for biodiversity and important for the livelihoods of surrounding populations through the provision of ecosystem services[479].

Source: CBD

or regional borders. Appropriate social safeguards are needed to address the needs of, and generate livelihoods and other benefits for, local communities living within these areas or adjacent to them.

Many governments are currently still expanding and consolidating their protected area systems, in line with the commitments made in the CBD's PoWPA[474]; the main objective of which is to complete ecologically representative well managed protected area networks. The PoWPA has agreed actions, a timetable and political support; in many countries it has resulted in concrete actions to identify and gazette new protected areas[475]. Data on area and location of protected areas is improving all the time[476]. This could provide a policy framework for additional protection aimed at addressing climate change adaptation. The CBD provides a range of tools to help identify areas that should be considered for inclusion within national protected area systems, including a gap analysis methodology that can help to locate the most suitable areas of land and water (see box). Many protected area agencies are adapting gap analysis methodologies so as to integrate climate modelling and improve the robustness of systematic conservation plans to climate change impacts.

Gap analysis is not the only source of information on these issues: other prioritisation exercises including those run on a global scale (such as ecoregions[480] and key biodiversity areas[481]) and national initiatives, also provide value data on site selection.

2. Connecting protected areas within landscapes/seascapes and increasing connectivity among protected areas

Protected areas do not exist in isolation and function as part of a larger landscape or seascape. Given the complexity of issues involved in their establishment and management, the proportion of territory under protection has to remain flexible to local conditions. A mixture of protection, management and usually also restoration is therefore required in what has become known as a *landscape approach*, appropriate to particular locations and circumstances. Interventions are needed at both national and local scales, considering livelihood issues and existing policies, institutions and interests. The overall principle of a landscape approach is to create a balanced mosaic of protection, management and restoration providing biodiversity, ecological, economic and social benefits and resisting detrimental change.[482] Implicit within this are the twin concepts of increasing ecological connectivity with a view to increasing resilience[483] and thinking constructively about other management systems that can contribute to broader-scale conservation aims[484]. The approach does not imply that there is one "ideal" mosaic which, once achieved, will remain static indefinitely, but rather that there are a range of possible mosaics, which if implemented can help to make a landscape or seascape resilient to environmental change. Any "conservation vision" will exist alongside other, actually or potentially, competing visions (economic development, sustainable development, cultural values) and planned or unplanned social and political upheavals. Adaptive management will therefore be essential over the timescale needed to implement a landscape approach. Successful broad-scale conservation programmes have therefore built partnerships with governments, private sector and local communities. As part of the landscape approach, opportunities to create corridors between and among natural protected areas will substantially contribute to the persistence of ecosystem services provided – for example in providing migratory pathways for wildlife.

Any such approach will need to be nested into a landscape level land use planning and management system, that seeks to reform the production practices employed by economic sectors such as agriculture, forestry, fisheries and mining, and reduce threats to ecosystem integrity that stem from them.

Table 9: Countries currently assessing gap analyses and carbon rich biomes with potential to implement land-use and forest based mitigation measures, including REDD

Biome	Countries currently implementing gap analysis
Flooded grasslands & savannahs	Dominican Republic
Temperate coniferous forests	Mongolia
Montane grasslands & shrub lands	Afghanistan, Mongolia, Papua New Guinea
Mangroves	Dominican Republic, Panama, Papua New Guinea, Samoa, Nicaragua
Tropical & subtropical moist broadleaf forests	Afghanistan, Antigua & Barbuda, Maldives, Micronesia, Dominican Republic, Panama, Papua New Guinea, Samoa, Solomon Islands, Fiji, Comoros
Tropical & subtropical grasslands, savannahs & shrub lands	Papua New Guinea, Mauritania
Deserts & xeric shrub lands	Afghanistan, Antigua & Barbuda, Armenia, Djibouti, Mongolia, Mauritania
Temperate broadleaf & mixed forests	Albania, Armenia, Bosnia and Herzegovina
Boreal forest/taiga	Mongolia
Tropical &subtropical dry broadleaf forests	Antigua & Barbuda, Dominican Republic, Panama, East Timor
Mediterranean forests, woodlands & shrub	Albania, Bosnia & Herzegovina
Tropical & subtropical coniferous forests	Dominican Republic, Nicaragua
Temperate grasslands, savannahs & shrublands	Afghanistan, Armenia, Mongolia
Marine biomes (coastal shelf)	Albania, Antigua & Barbuda, Djibouti, Dominican Republic, Maldives, Micronesia, Panama, Papua New Guinea, Samoa, Solomon Islands, Nicaragua

3. Recognition and implementation of the full range of protected area governance types
A major expansion of protected areas driven entirely by the state is a limited and probably unachievable target. New protected area initiatives are more effective if a far broader range of stakeholders is involved, including in particular the local communities and indigenous peoples living in natural and semi-natural ecosystems, but also involving private individuals, trusts and companies that are willing and able to manage land and water for its conservation and climate response values. Governments are recognising this need; for example the new Australian report *Australia's Biodiversity and Climate Change*[485] stresses the need for new governance approaches. In particular, there is a need for governments to recognise the long-term existence of indigenous and community conserved areas, incorporating traditional approaches to adaptation that have been developed over centuries, while respecting the rights and cultures of these communities.

This also means accepting and welcoming new concepts of protection, some of which may fall outside the precise definition of a protected area but nonetheless contribute to viable climate response strategies[486]. It will often mean negotiating precise forms of protection with many other stakeholders, accepting different management models, taking risks and including other peoples' priorities within planning processes. Increasingly, as climate change becomes a reality, local communities are themselves taking the initiative and recognising the importance of natural ecosystems, sometimes moving faster than the government. Some "bottom up" responses compiled by the World Resources Institute, for example, include: participatory reforestation of Rio de Janeiro's hillside *favelas* to combat flood-induced landslides; reinstating pastoral networks in Mongolia; and reviving traditional enclosures to encourage regeneration in Tanzania[487].

4. Improving management within protected areas
Protected areas also usually exist in the presence of a range of cross cutting pressures and threats (or "drivers of change"), so that attention must also be paid to these issues in landscape-scale approaches. Once pressures have been identified and assessed, it is important to build strategies that address both the key threats: such as poaching, encroachment, forest fires, illegal logging, climate change and conversion, and also the underlying causes such as poor governance, poverty, perverse subsidies, trade barriers and investment flows. As with other elements of a landscape approach, strategic interventions to address threats will range from site-based actions to those at landscape, national, ecoregional and international level. Wherever possible, attempts to counter specific pressures should make the most of opportunities for work with partners, such as increasing community involvement in forest management.

From a mitigation and adaptation perspective, increasing the effectiveness with which ecosystems are protected within protected areas can be as effective as creating new protected areas. Approaches to understanding protected area management effectiveness are well developed[488] and assessment tools are widely applied[489]. Some of these may require adaptation to meet the needs of protected areas used in climate adaptation strategies, for example in calculating benefits of ecosystems services to adaptation. Assessing and improving protected area management effectiveness are both the subject of a range of quantifiable targets in the CBD PoWPA, giving important impetus to this development, although there is still a lack of advice for managers about how climate change will affect protection, both in terms of maintaining particular ecosystems and in maximising the value of the services that they provide.

In order to manage effectively for the range of valuable ecosystem services especially in light of climate change, park managers will need to implement periodic assessment of these benefits in a fully participatory manner.

5. Increasing the level of protection for carbon stores within protected areas

In some cases, extra steps may be justified to maximise protection for carbon stored in protected areas. This might involve modifying management aims, to provide stricter protection for natural habitats: for instance zoning areas of stricter protection within protected areas that have previously allowed some utilisation within their borders (in other words moving from an IUCN category V or VI protected area to one closer to category Ia, Ib or II). In other instances, the effort might be focused on vegetation restoration or changes in patterns of fire management or water flow. Improving management of current protected area sites is also of importance to sequestration potential.

CASE STUDY

UNDP/GEF protection of 1.63 million ha of virgin taiga forests and peat soils in the Komi Republic, Russian Federation, will ensure a reduction of greenhouse gas emissions equivalent to 1.75 million t CO_2 between 2010 and 2020.

A quarter of the Earth's remaining virgin forests are in Russia. The highly biodiverse boreal forests of the Komi Republic are home to threatened species and habitats of international importance. They are listed on the WWF Global 200 ecoregions and UNESCO list of World Heritage Sites. The Komi Government is committed to achieve a target of 14.6 per cent protected areas coverage. In line with that commitment, UNDP with funding from GEF is helping to establish better protection of 1.63 million ha of virgin taiga forests and peatlands in the Republic. These store over 71.5 million t C but are at risk from fires and climate change; about 41,760 ha of forest are destroyed annually by fires, and climate change is impacting forest structure through increased deciduous trees and loss of endemism. Under the project capacity is being developed in Komi's protected areas to better manage fire and increase resilience of the coniferous stands to the impact of rising temperatures. A sophisticated carbon monitoring system is being installed, which will improve the global scientific understanding of the taiga forests' and peat-soils' carbon cycles.

Source: UNDP

In general carbon storage and sequestration needs to be measured and planned for at a landscape scale rather than simply within individual sites and will be subject to some trade-offs, particularly in fire-prone ecosystems. Prescribed burning to reduce fuel load will, for example, release some carbon but may prevent future, more catastrophic losses. Natural disturbance patterns need to be factored into efforts to increase sequestration, as do the likely impacts of climate change itself on ecosystem functioning.

6. Focusing some management specifically on mitigation and adaptation needs

To implement the management effectiveness and management planning issues identified above, those responsible for protected areas may need special planning and assessment tools. Further scientific research may be needed to define the exact protected area management prescriptions needed in some ecosystems, such as in peatlands, and to maintain ecosystem resilience.

More generally, managing protected areas under conditions of climate change will require significant changes in the way in which protected area agencies do business, including with respect to issues that relate to planning, organisation, leadership and evaluation. Within protected area agencies, implementing such wide-ranging changes will require that a major change strategy plan be developed at the protected area systems level and management plans for individual protected areas. Capacity building will also be needed, to establish the know how at the institutional level and within staff cadres, to deal with the emerging management challenges and opportunities. Many of these skills will also be needed by local communities and others managing land for protection outside government agencies and indeed protected area agencies may in some cases be a useful conduit for such information. Details of such changes are beyond the scope of the current report. However, some related issues are discussed in section 5 following.

Other management solutions to address adaptation

Maintaining ecosystem function generally requires management of large areas, often larger than the boundaries of an individual protected area. In such cases, protected areas will be one management tool along with a range of other land management systems within an overall matrix of land uses at landscape level, each under different governance systems (depending on the uses to which they are put). The methodological details of using protected

CASE STUDY

A partnership between Aboriginal owners and a liquefied natural gas producer in Australia is improving wild fire management to offset greenhouse gas emissions.

Appropriate fire management is a major issue for social, economic and cultural reasons; it can also reduce carbon emissions. Wildfires are responsible for roughly 40 per cent of fossil fuel carbon emissions[490]. Although some fires are ecologically necessary, wildfire is increasing as a result of carelessness, arson and the impacts of climate change.

In Australia, indigenous ranger groups are implementing strategic fire management across 28,000 km^2 of Western Arnhem Land in the Northern Territory. Wildfires have increased dramatically since Aboriginal people left the area several decades ago. This has had severe consequences for cultural sites and wildlife; savannah fires are now also the greatest source of greenhouse gases in the Northern Territory. The new management strategy creates a mosaic of patch burns across the landscape early in the dry season, limiting both spread of wildfires and greenhouse gas emissions.

The first four years have been successful, abating the equivalent of around 122,000 t CO_2 a year. There has been a significant reduction in destructive wildfires; however it will take time to discover if this has produced a recovery in the status of threatened species.

The project, a partnership between Aboriginal traditional owners and indigenous ranger groups, Darwin Liquefied Natural Gas (DLNG), the Northern Territory Government and the Northern Land Council, offsets the emissions from a liquefied natural gas plant in Darwin. As part of the arrangement, DLNG is providing around Aus$1 million a year for the next 17 years for fire management.

The lessons learned have potential application across fire-prone tropical Australia and other tropical savannahs, including in protected areas. Major companies are investigating the feasibility of entering into similar offset agreements using this approach[491].

Source: Cooperative Research Centre for Tropical Savannas Management, Australia

areas as a tool for climate change responses are beyond the scope of this publication, but some of the key elements are worth outlining. The following questions need to be answered in developing an ecosystem-based adaptation strategy:

- What are the ecosystem-based options available, and what evidence (scientific or Traditional Ecological Knowledge) exists to show that the options are feasible?

- What are the thresholds for failure in buffering risks (this question also applies to engineered solutions: a typical question would be: *what is the maximum rainfall that wetlands can absorb, without leading to catastrophic flooding?*).

- What measures are needed to maintain resilience?

- What other adaptation options exist? This would require that the feasibility, costs and benefits of engineered solutions or behaviour-based solutions be addressed.

- What ecosystem management options exist?

- Which option is most suitable given the local socio-economic and ecological context? Options could include protected area establishment, in which case the question arises as to what protected areas design and management system is appropriate; ecosystem restoration; and changing production practices employed by economic sectors, to reduce threats to ecosystems.

- What are the comparative costs and benefits of ecosystem-based adaptation in a long-term versus other adaptation options? The opportunity costs of conservation need to be factored into this equation. Moreover the costs of ecosystem-based adaptation will depend on the management system employed.

- What incentives are needed to sustain ecosystem-based adaptation? These may include for instance tax credits, payments for ecosystem services, and insurance schemes.

- What can existing protected areas do to contribute to ecosystem-based adaptation and what new protected areas might need to be established to supply the necessary services?

- What other benefits (economic and non-economic) might such protected areas supply to be included within cost comparisons?

- How do local communities and other stakeholders view the various options?

Ecosystem-based adaptation solutions should not be pursued in an ad hoc way – but assessed and developed as part of comprehensive national adaptation strategies. Eventually they will need to be assessed and compared with other options and decisions made on economic, political and cultural grounds.

Fisherman hanging nets up to dry, Papua New Guinea © Brent Stirton / Getty Images / WWF

SOLUTIONS

Methodologies for identifying and managing sites: need to be further developed and refined particular in terms of integrating climate change responses into protected area gap analysis.

Policy links: the UNFCCC and CBD should jointly recognise and support national actions that simultaneously implement protected area and climate change objectives.

Multi-sector approaches: at a landscape/seascape scale, it is important that different sectors plan and work together rather than operating independently; for example conservation, disaster mitigation, agriculture, forestry, fisheries and others.

Financing effective protected area networks

KEY MESSAGES

Despite some welcome initiatives, current funding for protected areas remains inadequate. Taking into account the benefits of climate mitigation and adaptation amongst the outputs from protected area system increases recognition of the true value of protected areas and should be taken into consideration by various financial mechanisms.

CASE STUDY

In Madagascar, forest conservation projects aim both to address the causes of climate change through sequestration and to help communities in adapting to existing climate change pressures.

Around six million hectares of new protected areas are being created in Madagascar – responsible for 4 million t of avoided CO_2 a year. Protected areas are expected to provide triple benefits in the form of carbon storage and capture, provision of a range of ecosystem services and biodiversity conservation[501]. The idea of linking multiple benefits into Payment for Environmental Services schemes is gaining widespread attention[502].

For example, the Mantadia forest corridor restoration project is restoring 3,020 ha of forest linking the Antasibe and Mantidia protected areas[503]. Habitat restoration and reforestation are together expected to sequester 113,000 t CO_2 equivalent by 2012 and 1.2 million t CO_2 equivalent over 30 years. The project also aims to reduce slash and burn agriculture, provide alternative income through carbon credits and in addition offers five specific sustainable livelihood activities for local communities: forest gardens, saroka gardens, fruit gardens, mixed endemic species plantations and fuelwood plantations. Amongst other benefits, the current protected areas are important in ameliorating floods[504].

The Ankeniheny-Zahama corridor, at 425,000 ha one of the largest tracts of remaining forest in the country, will be conserved by local communities under contractual agreements, which provide them with secure legal access to forests and use rights under a quota system. Carbon credits will be channelled back into communities and further incentives range from additional health care to support in establishing sustainable agriculture. The project is expected to secure 10 million t CO_2 equivalent over 30 years[505].

Source: Conservation International

Background

Since the CBD came into force in 1993, the world's protected areas have grown by almost 100 per cent in number and 60 per cent in area. Yet in the same period, international financing for biodiversity conservation has grown only 38 per cent[492]. Current financing for protected areas is generally judged to be inadequate; estimates of global shortfalls range from US$1.0-1.7 billion a year[493], US$23 billion a year[494] up to US$45 billion per year[495]. A separate estimate suggested that funding a comprehensive marine protected areas system covering 20-30 per cent of the seas and oceans would cost US$5-19 billion a year[496]. These shortfalls seem to represent massive amounts of money, particularly in times of economic downturn, until they are compared with the annual value of total goods and services provided by protected areas, which are estimated to be between US$4,400 and US$5,200 billion, depending on the level of resource use permitted within protected areas[497].

This gap in funding is currently not being addressed. An analysis of government funding of protected areas in over fifty countries carried out in 2008 suggested that financial support is generally declining, despite commitments made to the CBD PoWPA[498]. For the role of protected areas in mitigating and adapting to climate change laid out in this report to be realised, this shortfall will have to be confronted. The alternative is to forego the huge contribution that systems of protected areas could make to address climate impacts, and that may result in even more costly measures having to be taken at a later stage.

New opportunities

Climate change incentive mechanisms open up a number of new opportunities that should be factored into national planning and financing. Protected areas should be included as a key component of national REDD and other land use strategies, and ecological gap analyses should be used to help identify priority investments from a climate perspective. Countries should explore opportunities to include "other" sequestration mechanisms, such as the management of peat, freshwater, grasslands, marine and soil carbon stores as part of mitigation action, and specifically to address the opportunities to invest in the maintenance of essential ecosystem services that will be vital to effective climate change adaptation.

Valley of baobab trees, Madagascar © Nigel Dudley

CASE STUDY

Sequestering Carbon by Enhancing PA Management Effectiveness: A Case Study from Tanzania

Work commissioned by the Government of Tanzania with funding from UNDP-GEF has shown that the Eastern Arc Mountains constitute an important carbon reservoir. The study calculated that 151.7 million t C is stored in the Mountains, 60 per cent of this amount in existing forest reserves. Deforestation has resulted in the loss of around 34 million t C in the past 20 years – primarily in unprotected forests and woodlands. The study further calculated that disturbed forest stores around 85 t C per hectare, whereas undisturbed forest stores between 100 and 400 t per ha (mean 306 t per ha).

These findings have been used to leverage funding from the International Climate Initiative to strengthen management in three new nature reserves that have been established. The baseline carbon estimate for these reserves is in the region of 18.25 million t, but is declining as forests continue to be degraded. With implementation of a stronger management system, the forests will sequester an additional 5.5 million t C through the regrowth of degraded forest areas, resulting in an overall storage of around 23.8 million t C.

Source: Neil Burgess, UNDP

Various climate-related initiatives both market and non-market, should be considered to support financially the creation and management of protected areas, including:

- Regulated international market for bio-carbon offsets
- Voluntary international market for bio-carbon offsets
- Voluntary payment for ecosystem services (PES) for watershed protection
- Voluntary households environmental offsets
- GEF payments for global biodiversity conservation
- Voluntary international business biodiversity offsets
- Regulated international business biodiversity offsets[499]

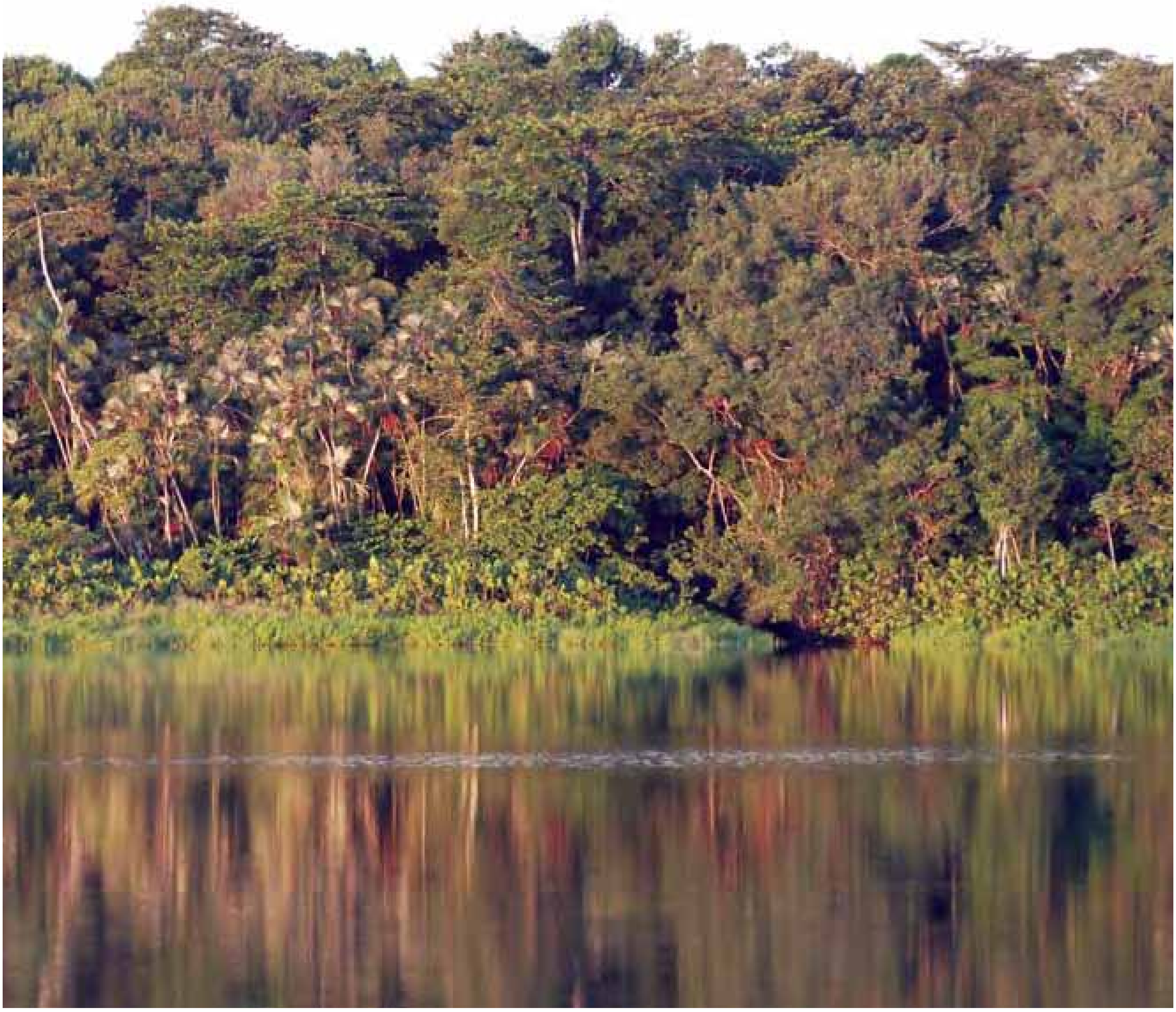
In addition to the development of funding relating to ecosystem services, economic measures should be put in place to:

1. Remove environmentally perverse subsidies to sectors such as agriculture, fisheries, and energy that promote development without factoring in environmental externalities
2. Implement appropriate pricing policies for natural resources
3. Establish mechanisms to reduce nutrient releases and promote carbon uptake
4. Apply fees, taxes, levees, and tariffs to discourage activities that degrade ecosystem services[500]

The use of protected areas as tools to strengthen REDD schemes

KEY MESSAGES

Protected areas have the potential to be an important building block of national REDD strategies. Protected areas have proven to be powerful vehicles for reducing deforestation and forest degradation where effectively managed. New protected areas may directly reduce emissions from land use change and therefore be eligible under some proposed REDD crediting mechanisms within the context of national programmes that address potential emissions leakages. Beyond reducing forest loss and degradation, such areas would secure ecosystem services vital to climate change adaptation and safeguard threatened species (REDD Plus).



Yasuni National Park, Ecuador © Nigel Dudley

Background

Forests, and possibly other habitats, contained within protected areas offer important potential for "*reducing emissions from deforestation and forest degradation*" (REDD). Methods to measure and verify reductions resulting from changes in land-use and management are currently being developed under the UNFCCC*. Many institutions already assume that protected areas will be a part of REDD[506] and the need for a global network of forest protected areas has been identified under the CBD[507], which is also now explicitly investigating the potential synergies between protected areas and carbon sequestration and storage. Most discussions about REDD focus on avoiding forest loss in multiple-use landscapes, but forests in protected areas also offer important options in conjunction with commercial or community forest management outside those areas. It is also possible that maintenance of carbon stored in other ecosystems, such as grasslands, peatlands, and wetlands, could be eligible for funding under REDD-type mechanisms[508].

The major policy negotiations currently underway envision the establishment of reference emissions levels and monitoring, reporting and verification systems on a nationwide basis. National governments would therefore have to negotiate a scientifically-defensible reference emission level from deforestation and forest degradation, and reduce emissions below that level in order to receive compensation through REDD mechanisms. Existing forest conservation efforts, including protected areas and indigenous and community conserved areas, that have reduced reference deforestation levels, need to be taken into account when establishing national REDD programmes so as not to penalise these efforts. Compensation may occur within a system of nationally appropriate mitigation actions (NAMAs) with relatively flexible accounting standards and supported through fund-based mechanisms; or under a market-based approach that would be financed by private sector investors seeking more precisely-measured emissions reductions.

As of this writing, initial plans to make REDD incentive only available to high emitting countries that have undertaken deep cuts seems to be giving way to inclusion of the full Bali Action Plan's definition of REDD (i.e. inclusion of conservation of standing forests and enhancement of carbon stocks or "REDD Plus"). There is also discussion about the need for REDD to recognise the efforts and cater to the needs of countries that have already invested in conservation, either through the establishment and effective management of protected areas or other means, and historically have had low emissions levels from deforestation and forest degradation as a result. This is important so as to avoid creating perverse incentives for conservation.

Governments will ultimately choose how to reduce emissions, and will design the internal incentive and policy mechanisms to reduce emissions from land use change and forestry. Strong international support exists for the development of social safeguard policies and other guidelines to ensure broad stakeholder consultations and programme designs that avoid adverse effects, particularly on local and indigenous people. Depending on national REDD implementation strategies adopted, project-based approaches may continue as a good way of addressing local drivers of forest loss and insuring accountability and equity of REDD strategies. National baselines will help insure against leakage that may occur in any individual project; wide participation in REDD initiatives from among forested developing countries will guard against international displacement of deforestation (international leakage).

Pros and cons of REDD

The resources needed to effectively implement REDD throughout the developing countries are substantial: figures of up to US$55 billion a year have been suggested[509] although there are major differences in predictions about both the potential for reducing deforestation through financial incentives and the likely money available. The Stern report[510] suggests that US$10 billion/year would be needed to implement REDD mechanisms. REDD has the potential to address several critical issues within a single mechanism: mitigation of climate change, reduced land degradation, improved biodiversity conservation, increased human well-being and poverty alleviation. Institutions such as the World Bank and the United Nations are investing in REDD projects, which will require capacity building and continuous, predictable and long-term funding.

However there will be challenges for protected areas in implementing REDD in overall forest policy. Most REDD funding is expected to go to both countries and to regions within countries that are currently experiencing the highest rates of deforestation. While interventions in high deforestation areas might stem forest loss locally, such REDD activities may have the perverse effect of placing renewed pressure on the protected areas estate, which may not in fact be well protected. REDD policies must take into account the need to fortify protected areas against potential incursions due to the implementation of REDD elsewhere. Similarly, REDD incentives focused on the most carbon-rich forest ecosystems may devalue other habitats, such as wetlands and grasslands, which are also crucial for biodiversity and which may provide other significant ecosystem services. REDD schemes should incorporate biodiversity safeguards and be part of a broader national land-use planning process that takes into account the needs of people and wildlife as it optimizes land-based carbon sequestration.

* Under the UNFCCC Kyoto Process Clean Development Mechanism (CDM), only afforestation and reforestation projects are eligible to be used as offsets, meaning that protection of existing forests fall outside the mechanism. However, this could change. Agreement was reached at the 13th UNFCC Conference of Parties (COP), in Bali Indonesia in 2007, to develop a mechanism to compensate reduced emissions from avoided deforestation and degradation in the replacement to Kyoto. The details of what REDD will mean in practise are still to be worked out. To date other natural carbon stores, such as peat, some freshwaters and marine ecosystems such as seagrass beds will not fall under REDD, although in theory they might do so in the future.

Amazon rainforest, Loreto region, Peru © Brent Stirton/Getty Images

Protected areas offer substantial additional advantages over most other land management systems in terms of permanence, in that by their nature they have been set aside for the long-term maintenance of natural habitats. Most good protected areas should have agreed management policies and governance arrangements and will usually also often have baseline data and monitoring systems in place, at least at some level, which could aid the development of national carbon inventories. Protected area monitoring could also feed into national baseline and monitoring efforts.

At the same time, illegal logging and other threats are leading to forest degradation in many established protected areas under weak management. The improvement of management effectiveness in these protected areas could reduce forest degradation and enhance forest sequestration of carbon. Much destructive forest loss and degradation is illegal, including within protected areas, and there is reason to think that many of the countries undergoing rapid deforestation do not have the governance systems to address this problem[511]. REDD investments in areas that are later deforested are simply wasted and are also likely to undermine confidence and thus hamper future opportunities to use such a mechanism. However, this is true for any ecosystem management and there is an assumption that one important use of REDD funding in protected areas would be to address illegal logging issues.

At the sub national level mechanisms are needed to account for accidental forest loss, for instance through extreme wind, fire or disease (that may in itself be caused indirectly by climate change); this might be achieved by "pooling" several areas. In general, these stochastic events would not be large enough to effect national targets for emissions reductions, but in some cases (such as El Niño caused changes in fire regimes) they may be significant enough to warrant pooling among several countries.

More generally, some analysts fear that badly managed REDD projects will increase pressure on poor communities in terms of security of land tenure and access to resources[512,513]: a substantial proportion of forest loss is due to the actions of poor farmers and subsistence gatherers who will be left with few other options if these resources are locked up. These problems could encourage investors to put their REDD money into the safest options, which are usually not those forests facing the most acute problems, although mechanisms are being discussed to address this loophole.

Some activist groups and indigenous peoples' organisations have already stated opposition to REDD on the basis that it will rely on sacrifices made by the poorest people rather than cutting energy and fossil fuel consumption by the world's rich. These questions require strong social safeguards[514,515] such as those already

Table 10: Comparison of elements in the WWF Meta-standard framework for carbon projects with likely conditions in protected areas

Issue	Details	Protected area implications
Carbon accounting	Additionality	REDD funding should only usually be applicable to new protected areas in areas where forests are at risk or to protected areas where independent assessment shows clearly that vegetation is being lost or degraded and where additional resources could reduce this.
	Leakage	Analysis will be needed to ensure that establishment of a protected area does not simply move forest loss elsewhere, i.e. that any loss of resources to local communities is adequately compensated e.g. by establishment of timber plantations or other renewable energy sources.
	Permanence	Protected areas aim to protect native vegetation in perpetuity. This could be complicated if vegetation removal is part of management: e.g. if fire control uses prescribed burns to reduce fuel. This will only apply to some places in some countries (and would be applicable in forest outside protected areas). Approaches exist for accounting for such losses.
Social and environmental impacts	Stakeholder consultation	Protected areas are increasingly required to have strong stakeholder processes – for example this is a requirement for new protected areas established under the CBD Programme of Work on Protected Areas. It is reflected in a growing number of self-declared protected areas by indigenous peoples' communities.
	Sustainable development	Protected areas increasingly adhere to rigorous social and environmental safeguards to ensure that they do not undermine livelihoods. Application of a range of management approaches and governance types can help; for example IUCN category VI extractive reserves facilitate sustainable collection of valuable products (such as non-timber forest products) whilst maintaining living trees: an ideal scenario for a REDD project if the forest would otherwise have been under threat.
	Identification of High Conservation Values	Protected areas are selected specifically for their value to conservation and an increasingly sophisticated set of tools are available to identify suitable sites.
	Assessment of environmental impacts	Similarly, there is now a range of methodologies for assessing the environmental benefits of protected areas in terms of e.g., water supply, soil stabilisation or protection of communities from climatic extremes.
	Long-term viability	The IUCN definition of a protected area stresses the long-term nature of protection as a key feature that distinguishes protected areas from other forms of sustainable and nature-friendly land use.
Validation and certification	Validation	Methodologies for monitoring and assessing management effectiveness of protected areas have developed rapidly over the past decade. Some of these already address issues relating to carbon (for example monitoring of forest cover through remote sensing) and it would be possible to integrate carbon accounting into existing assessments, although some development work would be needed.
	Certification	Some protected area certification schemes exist, e.g. the Pan Parks scheme in Europe and green ecotourism schemes; others are being developed. Some protected areas also use existing schemes, such as the Forest Stewardship Council, to certify forests in protected areas. Either approach could be applied to carbon accounting under REDD. There are also a growing number of certification schemes developing especially for REDD projects.

Note that some purely technical issues common to all carbon offset projects – such as avoidance of double counting, proper registration procedures and issuance and tracking are not discussed in this table.

The potential for carbon sequestration from protected areas and indigenous peoples' lands in the Amazon: results of a workshop at Stanford University

Combining maps of carbon stocks, models of future land use change, and information on location and management of protected areas and indigenous lands allows estimates of their impact on REDD. One study found that together they are likely to prevent an estimated 670,000 km² of deforestation by 2050 in the Brazilian Amazon alone, representing 8 billion t of avoided carbon emissions[527]. Location is important: those protected areas and indigenous lands in areas of high deforestation risk have more potential to reduce emissions by lowering that risk.

Protected areas and indigenous lands could be credited under likely emerging REDD frameworks but probably only for the "additional" emissions they avoid (i.e. not for the carbon stocks themselves). Credits are therefore most likely for newly established sites in areas of current deforestation, or for existing sites that improve their management and reduce deforestation and degradation. Brazil favours non-offset rules (Amazon Fund), though markets could be allowed to operate. Peru allows project-based offsets that directly benefit the areas being protected. Four REDD projects were described at the workshop, in Peru, Bolivia and Brazil (three in protected areas and one on indigenous lands) demonstrating the potential of and challenges to REDD projects using these mechanisms.

The conference concluded that:

- Indigenous lands and protected areas can be attractive options for REDD frameworks and can reduce deforestation in measurable, reportable, verifiable (MRV) ways
- How much depends on location, funding, laws, etc. and whether this carbon is currently vulnerable
- Funding gaps for protected areas and indigenous lands, and the paper park syndrome, together results in continued emissions from these sites
- Immediate emerging REDD frameworks will most likely reward reduced emissions against national baselines
- Indigenous lands and protected areas will have to make the case that they reduce emissions
- Their advocates must focus on placement of new reserves and better management of existing ones if REDD funding is to be accessed

Source: WWF

in existence for voluntary schemes (e.g. the Climate Community and Biodiversity Alliance), coupled with a strong policy framework; the fact that many indigenous peoples organisations and local communities are already investigating REDD schemes suggests that many do not see these problems as intractable.

We argue for a balance in approaches. There are potential benefits from a REDD mechanism, both for biodiversity conservation and for people living in natural forests, but only if there are sufficient social and environmental safeguards in place to ensure that REDD delivers real benefits within a framework that maximises social benefits to those most in need. Stopping forest loss is the most urgent priority for use of potential REDD funds at present. However, there is also significant potential to develop enhanced REDD initiatives that compensate for other ecosystem services vital to climate change adaptation, such as reforestation and afforestation in protected area buffer zones, and investing in measures to protect threatened species. This could include measures to avoid deforestation and forest degradation in biodiversity hotspots, and other areas with high human population growth where intervention might not otherwise be as cost effective. Protected areas are ideally suited and tested conduits for such initiatives.

Advantages of including protected areas in REDD programmes: One way of reducing forest loss and degradation is to set forests permanently aside from development – the philosophy of both REDD and of many protected area management models – so incorporating REDD mechanisms into protected area networks is a potentially powerful way of achieving both ends simultaneously. Protected areas offer several advantages in terms of carbon sequestration, which have been mentioned above but are worth summarising in this context:

- Effectively managed protected areas usually offer complete protection for forests, particularly in protected areas that include more stringent controls on use (IUCN categories I-IV), thus maximising the climate benefits and making measurement and accounting relatively easy.

- Most countries have laws and policies governing protected areas, so that funding protected areas under REDD can fit into an existing framework, without long political and legal delays.

- Most countries also already have an institutional framework for protected areas, such as: an agency linked to the relevant ministry; agreed standards for protected areas; and a staffing structure; so that the application of REDD would have a readymade infrastructure.

- Most countries have a cadre of trained protected area staff, plus associated capacity such as equipment, data management systems and consultation procedures (although improving all of these is a potential use for REDD funds where capacity is low or lacking). Many countries also have associated NGOs to help implementation.

- Protected areas usually have systems for establishing and codifying land tenure agreements, which has already been identified as a key requirement of REDD.

- Carbon storage is likely to be particularly high in biodiversity-rich, tropical forests, which are also a focus for many conservation strategies[516].

Zebra on migration, Tanzania © Sue Stolton

- Techniques for monitoring management effectiveness of protected areas are already well advanced[517] and in many cases could be modified to include carbon accounting without the need to develop a whole new skill set. Systems of certification are also under development[518].

- Protected areas include a wide range of management approaches and governance types, summarised in the six IUCN management categories, and are thus a flexible tool adaptable to many different social and environmental conditions.

- Existing work, including ecoregional conservation plans, national and local level protected area gap analyses[519] and other broad scale planning initiatives, provide information on likely sites for new protected areas.

- Protected areas are well equipped to generate multiple environmental benefits. These can include benefits in the arena of climate change adaptation, as well as from threatened species protection.

- Making protected areas eligible for REDD funding would help to increase synergy between Rio conventions and other international instruments[520], by forming a direct link with e.g., the CBD's Programme of Work on Protected Areas; this will help nations faced with challenges of meeting multiple commitments regarding environmental protection and climate change.

- Many protected areas have additional social and economic values (which are discussed in Section 2 of this report).

Some potential limitations with using protected areas in REDD: Protected areas share many of the challenges inherent to REDD. Badly planned or implemented protected areas can increase poverty and reduce well-being as a result of forced relocations and denial of access to traditional resources[521]. Illegal logging or use of fire happens in protected areas as well as in the wider landscape. Many protected areas still suffer from ineffective management at the systems and site levels and their values continue to decline[522]. Tools, techniques and processes exist to address all these issues, but a well-managed REDD scheme will need to ensure that they are applied.

There may also be a specific REDD-related question regarding additionality – i.e. the level of greenhouse gas emission reductions generated by a carbon offset project over and above what would have occurred in the absence of the project. If protected areas are already in place, there may be little additional benefit in putting money into their protection. It is likely that REDD funding in protected areas may be applicable only in those situations where:

- The protected area is being newly created, in areas at risk of forest loss and degradation

- The protected area is under-resourced and losing forest cover or quality (determined by an independent assessment)

- There are no alternative, long-term funding sources and without REDD funding deforestation is likely to increase

- Without support for protected areas, REDD risks creating perverse incentives (e.g. converting natural forests to plantations or more generally rewarding forests under pressure, thus penalising countries that have good conservation policies and a record of strong environmental governance)

- REDD payments can be used to support development and livelihoods in surrounding communities, in a way that will encourage long-term forest conservation.

There are a number of issues relating to protected areas that are still to be worked out. Would “upgrading” of an area currently protecting a forest under a less rigorous scheme into a full protected area “count” under REDD? Examples might be changing the status of forest reserves into protected areas. How would the offsets be calculated in the case of capacity building? Would REDD projects be confined to forests? Protection or restoration of other vegetation types, such as peat, might store as much or more carbon than a forest.

Ensuring social equity and environmental success
WWF has identified critical steps needed to ensure that potential REDD projects are effective and socially equitable[523]. Proper application will be a pre-requisite of success and for public acceptance of REDD offset schemes[524]. In table 10, these steps are taken as a framework and the implications for protected areas discussed.

Potential gains in terms of climate change will vary depending on the type of forest, its age and associated soils and vegetation. Forests that would be particularly valuable include those with the highest levels of biomass, such as the peat forests of south-east Asia where carbon in living trees is dwarfed by carbon stored below-ground[525] and other forests of the tropics.

SOLUTIONS

Forest protected areas provide viable and practical tools for implementing REDD within national adaptation strategies, with the potential to address successfully some of the criticisms of REDD schemes that have arisen to date. In order to maximise this potential, a number of developments or refinements are required:

Additionality and leakage: spelling out clearly how additionality can be assured in protected area projects and what would count as additionality in terms of protected area creation and management; and describing mechanisms to avoid emissions leakage including broadscale assessment methods[526].

Permanence: developing mechanisms for improving guarantees of permanence in non-state protected areas, including in company reserves and indigenous and community conserved areas.

Stakeholder consultation and active involvement: agreeing minimum standards for stakeholder consultation and involvement in REDD schemes associated with protected areas, particularly with indigenous and local communities.

Assessment of environmental and social impacts: outline of methods used in assessing additional benefits from REDD projects in terms of environmental services, poverty reduction and other social issues relevant to human well-being.

Validation and certification: identification of how carbon accounting could be integrated into existing management effectiveness assessments; and an outline of how certification processes could either be adapted for protected areas or, in the case of those already used in protected areas, how they could be modified to include carbon accounting.

Section 5

Implications of climate change for protected area design, management and governance

Protected areas themselves face many problems related to climate change. We summarise some of the key threats identified, and conclude that protected area systems will be able to cope with a large proportion of these pressures and maintain their values and services, provided that the predicted course of climate change and resilience building principles are explicitly included in design and management.

At present, most protected area systems remain incomplete and many are inadequately managed; these problems must be overcome before the incremental impacts of climate change can be addressed, or protected areas can achieve their full potential.

This brief section offers some suggestions for adaptation actions to maintain the effectiveness of protected areas in conserving biodiversity, maintaining ecosystem services and contributing to climate change mitigation and adaptation.

Likely climate change impacts on protected areas

KEY MESSAGES

Studies suggest that under moderate change scenarios protected area systems will be reasonably robust in terms of sustaining biodiversity, if they are designed to take future climate change into account, include resilience building principles, and are fully ecologically representative and well managed. This is not always the case at present. Impacts will come from habitat loss, loss of suitable conditions for individual species, poor connectivity, pressures from invasive species, alteration of fire and other disturbance regimes and extreme weather events, and associated human pressures, especially those resulting from the impacts of climate change on human settlements and resource use.

The challenge

Modelling exercises, backed by field observations, provide the basis for assessment of climate change impact on ecosystems. Changes are expected everywhere, but the areas projected to be most vulnerable include the Amazon region, threatened by drought, forest dieback and wildfire; parts of the boreal forest; and the Arctic tundra, at risk from forest invasion[528]. In some areas, climate change is likely to have a transformational impact on ecosystems, leading to extreme risk of species extinction, and major changes in ecosystem functions and ecological processes. Researchers at The Nature Conservancy studied potential climate-related vegetation shifts at an ecoregional level and found potential vegetation changes on 34 per cent of global non-ice areas from 1990-2100, varying from an average of 24 per cent in Africa to 46 per cent in Europe[529]. Climate models undertaken in South Africa have indicated that large areas in the south and western parts of the country, within the Succulent and Nama Karoo, and parts of the fynbos biome will be transformed to more arid, desert like conditions – an ecosystem not presently found within the boundaries of the country. A loss of the fynbos biome of between 51 and 65 per cent is expected by 2050, based on the bioclimatic model and scenario used 10 per cent of endemic Proteaceae have restricted ranges within areas of the biome that are likely to be lost.

It might be expected that protected areas, which have fixed locations and are often isolated, will be particularly vulnerable. In fact modelling and field observations show mixed responses. Many individual protected areas are likely to lose habitats and species, but there is evidence that well designed protected area systems may be able to withstand climate change reasonably well. One study modelled shifts in distribution of all sub-Saharan African breeding birds. It predicted that *species turnover* (local extinction and replacement by other species) across Africa's Important Bird Area (IBA) network will involve over half the priority species at 42 per cent of IBAs by 2085; but in the whole network 88–92 per cent of priority species would find suitable habitat in one or more of the IBA(s) where they are currently found. Only seven or eight species were predicted to lose all suitable habitats[530]. Similarly, research on 1,200 plant European species, using an "ideal" rather than the actual reserve network, found theoretical losses of 6-11 per cent of the bioclimatic range of species within Europe by 2050[531].

These studies look at climate impacts alone and assume that species are otherwise secure, in well managed, ecologically representative protected area networks. Another study applied distribution modelling in three regions: Mexico, the Cape Floristic Region of South Africa and Western Europe. Assuming a completed protected area network, the study found that in the Cape 78 per cent of species met the representation target for future range, in Mexico 89 per cent retained full representation, and in Europe 94 per cent. However, if the *current* protected area system was assessed, survival of many more species was jeopardised[532].

In fact, few protected area systems are 'complete' – a global analysis estimated that 6-11 per cent of mammals and 16-17 per cent of amphibians were "gap species" with inadequate protection, with the percentage larger for threatened species[533]. So as things stand, climate change may have even greater impacts for protected areas than elsewhere as systems are not fully representative and there is a northerly bias in protection where more extreme climate change is predicted[534]. For example one study estimated that between 37-48 per cent of Canada's protected areas could experience a change in terrestrial biome type due to climate change[535].

These findings are important indicators of future trends under changing climate. What is less well understood is the relationship between ecosystem resilience and the maintenance of ecosystem services upon which so much of climate mitigation and adaptation action depends. For now, we are making the assumption that an important component of maintaining ecosystem resilience is the maintenance of the underlying composition, structure and function of natural ecosystems.

Birch covered slopes, Nalychevo Nature Park, Kamchatka Oblast, Russian Federation © Darren Jew/WWF-Canon

Impacts on protected areas
Some of the specific impacts currently being studied in individual sites or systems of protected areas are examined in more detail below.

Loss of habitat: This is likely to be particularly noticeable in coastal areas and in mountains, where loss of snow cover and glaciers also causes loss of associated species[536]. For example, a third of the Blackwater National Wildlife Refuge marshland on Chesapeake Bay, USA, has disappeared since 1938 and the rest of the marsh, which provides winter habitat for many bird species, is expected to undergo massive change. While half the loss is thought to be due to extraction from aquifers, the rest is believed to be due to sea-level rise[537]. Modelling based on the assumption that long-term rate of sea-level rise continues to be about 3 mm/year, shows the area of habitat managed for migratory waterfowl (the high marsh) staying relatively constant until 2050, but then being totally converted to intertidal marsh. The Sundarbans mangrove forest of Bangladesh and India provides an invaluable buffer against storms. This role is increasingly under threat, initially from deforestation[538], but it is now thought that sea-level rise and resultant changes in salinity will hamper natural regeneration and impact even protected mangroves[539]. All of these changes have significant implications for adaptation measures in these ecosystems and their impact on dependent communities and livelihoods.

Loss of climatic conditions for particular species: there is already evidence that species are being influenced by climate change through changes in their population and life-history, shifts in range and altered species composition[540]. Three responses are commonly observed: (i) species move particularly when they are able to maintain equal range areas by migrating upward and poleward; (ii) they increase because of favourable climates or (iii) they decrease due to limited migration potential, limited dispersal, and/or shrinking areas of suitable conditions[541]. If the "new" range of the species falls outside a protected area, it becomes more vulnerable. For example, studies in the Tehuacán-Cuicatlán Biosphere Reserve in Mexico suggest that shifting climate will take suitable habitat for rare cacti outside the current reserve boundary[542].

Field observations confirm the theories and species are already shifting their territories due to climate change[543]. A meta-analysis of 143 different studies showed a

CASE STUDY

Low-lying Bangladesh is more vulnerable to flooding than most countries, and climate predictions suggest that flooding will increase. The natural protective functions of mangroves have proved to be effective in mitigating storm damage; however more of Bangladesh's natural mangrove forests, the Sundarbans, need to be effectively protected to ensure these vital ecosystem services can mitigate climate change impacts.

Bangladesh tops the list of countries facing the highest mortality rate from multiple hazards[573]; it is also one of the most vulnerable countries in the world to the effects of climate change[574]. Normal flooding (barsha) affects about 30 per cent of Bangladesh each year; settlements are well adapted to flood, which provide major benefits in terms of soil fertilisation and the provision of breeding grounds for fish. Abnormal flooding (bonya) can submerge more than 50 per cent of the total land area, and be very destructive[575]. Analysis of global climate models suggest a five-fold increase in rainfall during the Asian monsoon over the next 100 years, with major implications for flooding in Bangladesh[576].

As the ecosystem services provided by natural habitats have failed through environmental degradation, infrastructure has been developed in their place. During the later half of the twentieth century a series of coastal embankments were constructed in Bangladesh to protect low lying lands from tidal inundation and salinity penetration. The land created behind the embankments has been converted to highly valuable agricultural land. The embankments, however, block the drainage of freshwater from the land on the other side of the barriers after excess rainfall and /or riverine flooding. If sea-levels rise, as predicted, higher storm surges could also result in over-topping of saline water behind the embankments. As the OECD concludes, "*climate change could be a double whammy for coastal flooding, particularly in areas that are currently protected by embankments*" [577].

Natural habitats able to mitigate the impacts of hazards do still exist in Bangladesh. The Sundarbans are the largest mangrove forest in the world[578], recognised as a natural World Heritage site, and represent about 43 per cent of the total natural forest in Bangladesh[579]. They provide a subsistence living to 3.5 million people and offer protection from cyclones in southwest Bangladesh[580]. The mangroves' extensive root systems help stabilise wet land and coastlines, break up storm waves that exceed four metres in height[581] and result in the areas with good mangrove coverage suffering less from wind and wave surges than those areas with less or no mangroves[582].

Due to deforestation, however, the width of the mangrove belt is rapidly being diminished[583] and some 50 per cent of the forest has been lost over the last fifty years[584]. Only 15 per cent of the Sundarbans ecoregion is strictly protected, despite World Heritage status, and only one area, Sajnakhali Wildlife Sanctuary, is considered large enough adequately to protect ecosystem functions. Protected areas also lack trained and dedicated personnel and infrastructure for adequate management[585].

The most disastrous floods, in terms of lives and livelihoods lost, occur in the coastal areas when high tides coincide with the major cyclones[586]. The human toll of these events is dreadful – with those affected by floods always in the many millions. The effectiveness of the mangrove buffer was reinforced after Cyclone Sidr in 2007. The Sundarbans bore the brunt of cyclone, thus saving residents near this area from more disastrous consequences; the thick growth of mangrove trees successfully reduced the intensity of both the wind and the storm surge[587].

consistent temperature-related shift in species ranging from molluscs to mammals and from grasses to trees[544]. A similar study of 1700 species also confirmed climate change predictions, with average range shifts of 6.1 km/decade towards the poles[545].

As average temperature increases, optimum habitat for many species will move to higher elevations or higher latitudes. Where there is no higher ground or where changes are taking place too quickly for ecosystems and species to adjust, local losses or global extinctions will occur unless there are direct interventions (such as artificial translocation of species). Species at the extremes of their ranges are likely to be impacted first. For example, seven arctic-alpine vascular plants at or near the southern limits of their ranges were studied in Glacier National Park, USA, from 1989 to 2002. Mean summer temperature during this period averaged 0.6 °C higher than the previous four decades. Four species declined in abundance from 31-65 per cent, while none increased; consistent with predictions of climate-induced extirpation of high-elevation species[546].

Observations suggest that tropical montane cloud forests are at high risk due to fewer clouds and warmer temperatures, with serious impacts underway[547], particularly in relation to amphibians[548]. (Amphibian species are declining throughout the world[549].) Climate change associated with an El Niño/Southern Oscillation-related drought in 1986/7 is thought to have caused amphibian losses in Monteverde Cloud Forest, a well-managed protected area in Costa Rica[550]. The golden toad (*Bufo periglenes*) and harlequin frog (*Atelopus varius*) disappeared[551], and four other frog and two lizard species suffered population crashes; a detailed survey in a 30 km^2

Small patch reef in Kepulauan Auri chain of islands Teluk Cenderawasih Marine Reserve, West Papua, Indonesia © Ronald Petocz/WWF-Canon

study site found that 20 out of 50 frog and toad species disappeared at that time[552]. There is also evidence that the distribution and abundance of hummingbird species are shifting in the reserve[553].

A study of US National Parks indicates that if atmospheric CO_2 levels double, on average 8.3 per cent of current mammalian species would be lost; with predicted losses being greatest from the Big Bend and Great Smoky Mountains National Parks (20.8 per cent and 16.7 per cent, respectively). Impacts will come from forecasted changes in vegetation types. Most mammals would be affected, with the exception of hoofed mammals. Generally, most species are expected to remain stable at or near their current geographic locations and to expand their range geographically northward [554]. Some of these predictions are backed by observations comparing data over a hundred years for small mammals in Yosemite National Park, California. Half of the 28 species studied have moved (500 meters on average) up in elevation. Although some high-elevation species are threatened, the protection of elevation gradients is currently allowing other species to respond via migration[555]. These changes are in line with estimates for a wide range of species in Mexico, which predicted relatively few extinctions, but drastic range reductions and high species turnover (over 40 per cent of species)[556].

Changes in mammal populations are often linked to availability of suitable food. For instance, in Ranomafana National Park, Madagascar, winters from 1986-2005 were drier than from 1960-1985 and fruit production and thus lemur survival decreased[557].

Mountain ecosystems are often identified as being particularly sensitive to climate change. Research in three national nature reserves in the Scottish Highlands studied distribution models for 31 species, representing a range of community types. A relationship between distribution and temperature was found for all species; and models indicate that Arctic-alpine communities could undergo substantial species turnover, even under the lower climate change scenario. For example, *Racomitrium-Carex* moss-heath, a distinctive community type of the British uplands, could lose suitable climate space as other communities spread uphill[558]. At the International Mountain Biodiversity Conference held by ICIMOD in November 2008, it was noted that because of the vertical (altitudinal) elevations, even marginal changes in temperature, moisture and solar radiation would have marked impacts on the distribution of the highly endemic fauna and flora, with concomitant impacts on the highly specific and localised resource uses patterns of local communities[559].

New pressures: these changes will bring new, associated pressures to protected areas. In wetlands, for example, an influx of new species may alter existing competitive interactions and trophic dynamics[560]. An equally serious threat comes from relatively quick changes in disease and pest species, some of which may spread due to climate change. Temperature directly affects insect species for example: in temperate regions warmer conditions will increase winter survival and extend the summer season, increasing insect growth and reproduction[561]. In the United States, the pinon pines (*Pinus edulis*) of Bandelier National Monument are dying as higher temperatures and drought have led to infestations of bark beetles, which have expanded to higher elevations and new ranges. Bark beetle is also leading to increasing mortality of the nutrient-rich whitebark pine (*Pinus albicaulis*) seeds in Yellowstone, which are a critical food source for grizzly bears[562]. There are predictions that an increase in invasive species due to climate change could fuel hot, cactus-killing fires in the Sonoran Desert in the USA[563].

Loss of key species: impacts of climate change are already being studied for several migratory species. Results show substantial evidence that species have responded over the last few decades. Studies in the Northern Hemisphere[564] and Australia[565] show similar patterns of birds arriving at their breeding grounds earlier and delaying departure. In Lake Constance, a Ramsar site at the border of Germany, Austria and Switzerland, the proportion of long-distance migrant birds decreased and short-distance migrants and residents increased between 1980 and 1992, during a period when winter temperature increased, suggesting that warmer winters may pose a particularly severe threat to long-distance migrants[566].

Flora is also being affected. Climatic warming observed in the European Alps has been associated with upward movement of some plant species of 1-4 metres per decade and loss of some high altitude species, posing direct threats to protected areas such as the Swiss National Park[567]. *Juniperus procera* woodlands of the Asir Highlands of Saudi Arabia are exhibiting widespread decline, linked to climate change[568]. In the USA, Joshua Tree National Park may lose the tree for which it is named. Researchers predict that because of climate warming the Joshua trees (*Yucca brevifolia*) will be unable to persist much longer within the park[569].

Extreme events: in addition to gradual shifts in species, climate change can also affect ecosystem functioning and increase drought and fire risk. Increases in mean annual temperature of around 3°C in the Peak District National Park in the UK may result in a reduction of 25 per cent in the extent of blanket bog, as reduced soil moisture and aeration, and increased oxidation of peat soils change vegetation type from blanket bog to dry heath and acid grassland, leading to increased fire risk[570]. Warmer conditions are blamed for increased fires in many protected area systems, particularly in Australia[571].

Extra human pressure: impacts from climate change cannot usually be assessed in isolation from human pressures. Climate change is an additional pressure, which can accelerate the impacts already being caused by resource exploitation, pollution and degradation. In coral reefs, for example, recent research suggests that climate change is exacerbating existing local stresses from declining water quality and overexploitation of key species, driving reefs increasingly toward functional collapse; the study concluded that climate change is now the biggest threat to coral reefs[572].

SOLUTIONS

Complete fully representative protected area networks: studies suggest that protected area systems can continue to be reasonably effective, but only if they are completed, ecologically representative and designed with increasing options for resilience.

Promote connectivity: ensuring that protected area systems are ecologically linked through use of buffer zones, biological corridors and stepping stones to facilitate genetic interchange.

Step up measures to increase effectiveness: climate change will operate in tandem with existing pressures from human use. Understanding how resource uses will change under a range of climate change scenarios can help managers foresee impacts on protected areas; it will also facilitate working with stakeholders to modify approaches to resource use that could undermine ecosystem integrity.

Recognise that there will be tradeoffs: climate change will have a transformational effect on natural ecosystems, though there will be a huge asymmetry between regions in terms of the scale of impacts. The costs and benefits of adaptation measures required to maintain ecosystem integrity within protected areas will need to be considered in the context of the likelihood of success, given that it will not be possible to maintain the status quo. This will have a bearing on decisions regarding where to focus investments geared to adapting protected area management.

Planning and managing protected areas under climate change

KEY MESSAGES

Protected area systems will need to be adjusted and often expanded to fulfil their potential climate response roles of mitigation and adaptation, with implications for planning, assessment, policy and training. Individual protected areas will need adaptive management to meet changing conditions. In addition, protected area agencies have the potential to be major facilitators of natural resource management in the wider landscape, thereby contributing to sectoral and community-based adaptation.

As outlined in section 4, protected area planning and management must evolve if the opportunities identified here are to be maximised, so that: (i) **protected area systems** are expanded and integrated as part of large scale natural areas, with protected areas identified and designated using full knowledge of and accommodation for likely climate changes; (ii) **existing protected areas** are managed for their present and future conservation values, in a dynamic environment, under climate change; (iii) **connectivity** ensures that protected areas are embedded into the wider landscape and seascape and (iv) **additional benefits** in terms of mitigation and adaptation to climate change are maximised. Protected areas thus become a core part – often the core part – of broader strategies to build resilience into natural and semi-natural ecosystems, and to use this for the purposes of conserving biodiversity and supporting climate change adaptation and mitigation functions.

This section therefore looks briefly at some of the steps needed to maintain resilience in protected area systems and individual protected areas. These need to address resilience both at a general ecosystem level and also at the finer scale of species and genetic diversity.

Some general management considerations
Those managing protected area systems under climate change need to consider a range of issues that are new or newly emphasised, which have implications for planning, capacity, and day to day management and include:

Forecasting: to decide on the number and location of protected areas, and on their relationship with the wider landscape or seascape, reflecting forecasts of future ambient weather conditions; changes to biomes; important refugia areas; and areas of importance to facilitate the movement of species where feasible[589].

Improving and maintaining a comprehensive and representative reserve system: in particular to expand the number of core, strictly protected areas, which are effectively buffered and linked ecologically to other, similar protected areas[590], but also to align protected area systems to changing environmental conditions such as marine incursions as necessary.

Facilitating connectivity: to ensure that protected areas are linked both with other protected areas and with land and water that is managed in ways that help to maintain genetic links and ecosystem functioning in the wider landscape and seascape, encouraged through, for example, incentive schemes and policy instruments.

Implementing management effectively: to minimise existing stresses on protected areas and thus strengthen their resilience to climate change[591].

Retaining and restoring key habitats: applying restoration techniques as necessary to regain or to increase the degree of ecological integrity and to strengthen resilience[592], although restoration will need careful planning to account for natural disturbance and for social and cultural values, and from a climate change mitigation perspective to ensure additionality[593].

Using flexible approaches: exploring new management models[594] and governance options[595] to maximise the flexibility of the system and its effectiveness. This can act to help ensure support from stakeholders and to unleash the potential value of many traditional approaches to conservation by collecting, conserving and disseminating traditional and local knowledge, innovations and practices related to biodiversity conservation and sustainable use, with prior and informed consent from traditional knowledge holders[596].

Capacity building: changing management to build the skills and knowledge needed to manage protected areas under conditions of climate change and to integrate protected areas into wider efforts to mitigate and adapt to climate change.

Investing in quality information: management of research to ensure that the information to help manage rapidly changing environments is readily available to protected area managers and, through them, to the wider community.

Protected areas as models for adaptation

In addition to immediate management issues, protected areas should also be exemplars of the principles of sustainable management, leading by example and playing a key role in education and awareness-raising. They should demonstrate a full range of adaptation and mitigation responses to climate change, by for example minimising greenhouse gas emissions caused by consuming fossil fuel energy through aircraft use, heating and cooling, waste management; use of effective design, technology and insulation; maximising utilisation of renewable energy sources[588]; recycling; life cycle assessment of materials used; and by facilitating the use of public transport to reach protected areas. In many situations, there is also a wider role open to protected areas in providing information and resources to the wider community, for example on weather patterns, resource management responses and the skills and knowledge needed to adapt to climate change, along with educational material and facilities for adults and children. Protected areas will often be the only source of local information on weather, ecological baselines, changing conditions and new threats. If adaptation strategies are implemented proactively, they can also be major sources of practical experience about management responses. Individual protected area management teams could thus provide the conduit for wider access to knowledge and skills in natural resource management under rapidly changing climatic conditions. This new additional emphasis for protected areas implies more resources and a paradigm shift in approaches to management and expectations amongst staff.

Providing a greater role in the surrounding landscape and community: such as education and advice on management in changing conditions, emergency responses; and community services.

Challenge 1
Building representative and resilient protected area networks

In addition to the general points above, some other important issues in relation to developing protected area networks include:

Planning – designing representative systems and identifying potential new protected areas

- Designing at least some protected areas to be as large as possible, with more than one area designated for each important habitat and community type[597].

- Seeking to maintain viable ecosystems and populations of species to facilitate rapid, natural adaptation and evolution, and conserving species throughout their range and variability, to reduce the probability of all viable habitats being lost[598].

- Focusing particularly on maintenance of: (i) vulnerable ecosystems and species; (ii) climate refugia at all scales[599] including for marine species[600]; and (iii) areas where climate is predicted to be stable.

- Recognising the need to accommodate the predicted changes in rivers flows and coastal topography[601].

- Maximising potential conservation gains from predicted climate changes: such as new areas of coastal wetland, new vegetation assemblages, etc.[602].

- Reducing fragmentation and maximising large-scale connectivity between protected areas[603] and the introduction of active management to these large scale natural areas (with the caveat that some areas may need to remain isolated in a trade-off between genetic interchange and risk of invasive species).

- Facilitating large-scale conservation corridors to include an latitudinal, longitudinal and altitudinal gradients that allow species to shift ranges quickly, particularly if the gradient change is abrupt[604].

Planning – individual protected areas

- Allowing as much altitudinal, latitudinal and longitudinal variation as possible within individual protected areas, to facilitate dispersal as temperature and precipitation change.

- Seeking to include topographic heterogeneity within a protected area to provide room for utilisation of new sites by species (e.g. north and south facing slopes, elevation differences and presence of valleys).

- Factoring predicted stress factors into management plans: such as drought, fires, glacial lake burst, stream drying, invasive species etc[605].

Planning – buffer zones

- Encouraging establishment of buffer zones around protected areas through use of sympathetic management such as sustainable forest management; designation of agricultural land suitable for extensification[606]; returning to traditional management practices; or changing fishing permits[607].

- Linking the management of protected areas and buffer zones into land use planning and management systems at landscape level, which manage economic activities to ensure the overall ecological integrity of the landscape, so as to sustain ecosystem functions and resilience.

Policy and legislation relating to planning resilient protected area systems

- Ensuring strong political support for the maintenance and expansion of protected areas, with multiple designations and management approaches, implemented with prior informed consent by local communities.

- Assuring the involvement of stakeholders; local and indigenous communities as well as national interest groups and supportive private sector enterprises, such as low impact tourism.

- Drafting legislation to accommodate potential change, such as allowing flexible zoning of protected area boundaries if species response to climate change necessitates this need.

- Providing insurance through appropriate *ex-situ* conservation of rare or endangered species[608], including in the country of origin[609], to help ensure that species are conserved and may one day be returned to nature; this implies some selection process for which species are conserved outside their natural habitats.

Training and capacity building to develop a new approach to protected area systems

- Providing detailed training for managers and rangers covering technical (e.g. forecasting, modelling, threshold of potential concern, adaptive management); managerial (e.g. budget implications, new investments, new management challenges) and social (e.g. negotiation, information provision, ramification of changes) issues.

Challenge 2
Adaptive management of existing protected areas

A considerable amount of the world's land surface is already in protected areas, yet much of this is still inadequately managed and under threat, and some is deteriorating in quality and unlikely to maintain its values[610], adding to a biodiversity crisis[611] and reducing environmental services including carbon sequestration; these problems will be exacerbated by climate change. Adaptive management often starts by strengthening existing management[612], but there are a wide variety of additional actions that managers can take to reduce the impact of climate change:

- Introducing effective forecasting, including climate trends and population ecological modelling, to maximise the ability of protected area staff to meet changing conditions[613].

- Implementing, as appropriate, stabilising measures to address likely changes in fire frequency[614]; snowfall[615]; ice-melt[616]; degree and incidence of drought[617]; catastrophic weather events such as typhoons, hurricanes, torrential rain, flooding or ocean incursions[618]; changing flux of water in ephemeral wetlands, etc.

- Recognising and planning for changes in species' migration patterns, both for long-term migrants and changes in movement patterns of large mammals within a landscape.

- Planning for, and if necessary implementing, control measures against harmful invasive species[619] and new diseases caused by or exacerbated by changing climate.

- Planning, and if necessary implementing, procedures for translocation of species that cannot move quickly enough themselves in the event of altitudinal changes in weather conditions, sea-level rise or other major changes[620].

- Introducing new approaches to managing visitors in light of expected changes to the ecology and the biome: such as additional fire hazards, extra avalanche risk or severe heat, along with actions to reduce carbon emissions such as better public transport access to protected areas.

- Developing new approaches to collaborating with local communities and indigenous peoples in and around protected areas, particular on issues relating to management approaches and wider connectivity.

Modifications to the structure of individual protected areas

- Assessing boundaries and considering whether these need to be changed in light of changing environmental conditions, for example to include different altitudinal gradients or areas inland of coastal reserves.

- Building up buffer zones around protected areas wherever possible[621], encouraging more sustainable forms of management where natural resources can help to support human communities and also where wild species are able to colonise if the climate changes.

- Increasing permeability for species within landscapes and seascapes dominated by human activity[622], to reconnect protected areas via biological corridors and other management strategies.

Monitoring and research

- Establishing baselines for key conditions and species against which to measure future changes[623].

- Identifying key indicators (species, ecological processes etc) that can be used to monitor any future changes in climate and ecosystem responses[624].

- Carrying out long-term monitoring and assessment and applying the results to design adaptive management strategies[625].

Implications for managers

The changes listed above imply a major new role and new challenges for protected area managers and also the development of skills and tools. Some of these are introduced in more detail below:

Assessment

Currently protected area managers seek to understand their site's biological values and, increasingly, also to measure social and economic values for local communities and other stakeholders. Extending the role of protected areas into climate stabilisation implies that a number of additional values will need to be taken into account, requiring:

- An understanding of the amount of carbon stored within the protected area; the potential for further carbon

CASE STUDY

The Finnish government has identified the need for policies to help adaptation to climate change[627] and a *National Strategy for Adaptation to Climate Change*[628] has been completed, including a discussion of the role of protected areas.

In terms of designation and management of protected areas, several issues are identified in relation to the size and location of protected areas. It is noted that areas of suitable habitat are more likely to remain available in larger protected areas; and that protected areas should be interconnected where possible by ecological corridors or 'stepping stones', to form networks that allow species to spread and migrate. Attention should also be paid to climate change when decisions are made about the locations of protected areas. It is particularly important to protect areas where threatened species occur today, but can also be expected to continue to occur in the future.

In terms of the current protected area network it is noted that many parts of northern Finland lie within arctic regions that may be greatly affected by climate change, but these regions already have extensive protected areas that can help to reduce the impacts on arctic plants and animals. In southern Finland, contrastingly, there are fewer large protected areas. The prospects for threatened species can be improved by restoring habitats in protected areas, but it may also be necessary to expand the network of protected areas as conditions change.

Current management of protected areas also highlights that the prospects for some native species may be improved by preventing the spread of invasive species that would otherwise compete with them. But the capability of ecosystems and species to adapt will ultimately depend on the extent of climate change. If spruce trees are gradually replaced by broad-leaved tree species across much of southern Finland, for instance, there will inevitably be considerable changes in other forest species. In the most extreme scenarios, the southern limit of spruce forest would shift northwards as far as Oulu and eastwards to the Finnish-Russian border.

Source: Ministry of Agriculture and Forestry

sequestration; and the management implications of increasing stocks of carbon (e.g. potential for restoration of vegetation on degraded lands, risks of fire, ecological implications).

- The potential for carbon release through human activities (e.g. timber poaching) and periodic disturbance factors, particularly fire, along with proposals for ways to mitigate such losses. Where prescribed fire is used as a necessary management tool, understanding the carbon release and sequestration implications of varying burning regimes will be important.

- Goods and services offered by the protected area that could help to mitigate impacts and adapt to climate change, such as amelioration of natural disasters, supply of valuable genetic material, provision of food and water etc.

- An understanding of the tradeoffs associated with protected area management adaptation measures. Adaptation will impose new costs on protected area agencies; the cost benefit calculus of planned adaptation measures will need to be taken into account, taking into consideration the likelihood of success.

In order to be able to undertake such assessments and to implement an adaptive approach to management under the uncertainties created by climate change, a greater emphasis will need to be placed on resource assessment and monitoring. Managers will need to have a well developed understanding of the key biotic and abiotic characteristics and interactions that maintain the major values of the area and how these might be affected by climate change.

Tools

To achieve this, a number of new tools need to be identified or refined:

- Rapid methods for calculating current and potential carbon sequestration from different vegetation types and ages within a protected area, carbon sequestration opportunities through restoration of degraded lands within protected areas may be particularly significant.

- Quick assessment methods to identify and measure the value (social and economic) of wider protected area benefits[626].

- Cost benefit assessment, to take into account tradeoffs and the cost effectiveness of different adaptation options, given prevailing budget constraints.

- Additional methodologies to be integrated into national protected area gap analysis to factor in potential for climate change mitigation and adaptation within protected area networks (such refinements may also be needed with some reserve selection software such as MARXAN).

- Modifications to protected area management effectiveness assessment systems to include additionality (the net increase in carbon stored in response, in this case, to either forming a protected area or increasing management effectiveness of an existing protected area) as well as effectiveness of climate adaptation measures – this may involve taking into account responses at a national or even a global level.

Mangrove monitoring. Mafia Island, Tanzania © Jason Rubens / WWF-Canon

- Methods for calculating carbon trade-offs between different management strategies, for example carbon impacts from use of prescribed burning as compared to occasional larger, hotter fires, taking the whole landscape and seascape mosaic into account and including issue of disturbance regimes and changes over time.

- Guidelines for adapting protected area management practices to ensure continuation of their ecological, economic and social functions in light of climate change.

- Guidelines and best practices for accessing funding options for protected areas including climate-related market and fund mechanisms.

- Possible modifications to existing certification schemes, such as the Forest Stewardship Council, to address issues of climate change within certification.

Protected area managers will already be wrestling with a range of different management challenges inherent in maintaining protected area values under climate change; bringing in additional protected area benefits will add to these tasks. Effective management therefore implies a period of intense research to develop techniques and rapid and widespread capacity building to ensure that managers are able to use them on the ground.

Governance implications of using protected areas for climate change mitigation and adaptation

KEY MESSAGES

All sections of society must work together in designing solutions to reduce vulnerability to climate change. The protected area concept can provide a framework for recognising and where necessary safeguarding traditional forms of management such as indigenous and community conserved areas. More generally, all protected area managers will need to work to engage stakeholders fully in management decisions, and in adaptation.

Masai people in Kenya © Mauri Rautkari / WWF-Canon

Many years of experience has shown that protected areas are most effective when governance issues are both understood and agreed by all or at least most of the people involved; and where stakeholders are supportive of protected area objectives and ideally are also actively involved in management decision taking. Climate change will put pressure on societies around the world as systems for managing water, food, climatic events and disease break down under the pressure of rapid environmental change. Although this report argues the case for greater use of protected areas in addressing the impacts of climate change on biodiversity, managing land use change responsible for emissions and facilitating ecosystem-based adaptation; these changes need to be addressed within an equitable social and environmental context. Poorly planned protection policies can do more harm than good. If more land and water resources are protected for long-term climate mitigation and adaptation purposes; short-term demands for essential resources may result in conflict over the land which has been protected.

Some of the social problems of badly-planned protected areas have become well known: dispossession from land, social exclusion, increased poverty and resources being appropriated without adequate benefit sharing[629]. But the "new paradigm" of protected areas agreed at the Fifth World Parks Congress in Durban in 2003, and further codified within the CBD's 2004 PoWPA, presents a very different approach, which seeks to involve rather than exclude people; understand and manage the costs and benefits of protection; and address social and environmental issues side by side. It is clear that the increased levels of protection that we are promoting here will only be possible if they are implemented through socially and culturally acceptable processes, including such elements as prior informed consent, equitable compensation and a fair distribution of costs and benefits. These approaches will not solve all the problems, nor will they automatically sweep away the tensions that surround protected areas in many situations, but they can certainly help.

As noted earlier in this report, IUCN recognises a range of different governance types for protected areas – from governance by governments to local community responsibility. The CBD PoWPA also provides clear guidance on how protected areas should be governed and in particular in ensuring that issues of protected areas' costs and benefits are equitably managed. This balancing of cost and benefit will become even more critical when decisions about protecting essential ecosystem functions are made in areas with depleted resources and high levels of poverty and/or where resources from protected areas, such as compounds for pharmaceuticals or plant breeding for agriculture, are used to help adaption to climate change impacts. If protected areas are going to succeed in helping us cope with the climate crisis, issues related to the governance of a site, such as accountability and sharing of responsibilities, will need to be agreed amongst all those who are affected by protection strategies.

Gaining acceptance for the rationale of particular governance and the management objectives often depends on an understanding of socio-economic questions. If local people know the value of a site they are more likely to support or be involved in management, than if the site's values are not recognised or are seen as irrelevant to their needs.

CASE STUDY

Community protection of forests in Tanzania is proving a very effective at reducing deforestation and thus carbon sequestration

A large portion (45 per cent) of Tanzania's forests are found in forest reserves of different types; including those under participatory forest management through joint forest management arrangements (communities and government working together) and within village land forest reserves (managed only by the local communities).

Land conversion is occurring at a greater rate outside these protected areas than within them – meaning that reserves have proven to be an effective vehicle for reducing deforestation and thus ensuring effective carbon sequestration. Case studies published in 2008[635] compared forest condition in forest reserves managed using participatory forest management approaches, compared to areas where participatory forest management approaches were not employed. This indicates that the former is 'correlated with improving forest condition'. The first case study showed '*increasing basal area and volume of trees per ha over time in miombo woodland and coastal forest habitats under participatory forest management compared with similar forests under state or open access management*'. The second case study looked at three coastal forest and sub-montane Eastern Arc forests under participatory forest management. This demonstrated a '*greater number of trees per ha, and mean height and diameter of trees compared to three otherwise similar forests under state management*'. The third case study showed that '*cutting in coastal forest and Eastern Arc forests declined over time since initiation in participatory forest management sites.*'

Key drivers of success and failure in this context include the degree of social cohesion at the village level, degree of leadership, tenure security and distribution of the resources, the design of the institutional arrangement and the degree of support rendered by the local government authority.

Source: UNDP/Neil Burgess

(It is equally important that managers of a site, if it is not managed by the local community, understand its often intangible values and that these are also seen as part of a site's management). In particular, in the face of climate change, managers and local people must work together in designing solutions to reduce the vulnerability to climate change impacts. In many cases protected area staff will have valuable expertise that can be shared by the whole community.

When communities work together, when they engage with each other in planning and implementing programmes, multiple benefits in community resilience can be achieved. For instance, in India, the ecosystem services provided by mangroves are often ignored in the process of mangrove conversion. But when asked about the services provided by, for example, the Bhitarkanika mangrove ecosystem in relation to cyclone damage (taking the cyclone of 1999 as a reference point) householders were clearly positive about mangrove protection. Surveys were carried out in households in 35 villages located in the Bhitarkanika Conservation Area. In the villages protected by the mangroves, adverse factors were lower (e.g. damage to houses) and positive factors (e.g. crop yield) higher than in the villages not sheltered by mangroves. Economically the villages protected by mangroves suffered damage worth the equivalent of about US$44 per household when cyclones stuck, compared with damage costing US$153 per household in villages that were not sheltered by mangroves, but instead had an embankment. Overall, the local people were aware of and appreciated the functions performed by the mangrove forests in protecting their lives and property from cyclones; and importantly in terms of governance and management issues were willing to cooperate with the forest department in mangrove restoration[630].

Taking the lessons from this and many other similar examples, and applying them more generally in approaches to development of protected areas of all management and governance types, is a critical factor in the wider use of ecosystems within climate responses.

CASE STUDY

Resource use such as logging provides economic benefit but little environmental benefit. It is acknowledged that reducing forest deforestation and degradation is an important strategy against climate change – but how can this be achieved without economic and social disadvantage? A project in Guyana has a possible answer.

'Conservation concessions' aim directly to reconcile resource protection with development by protecting natural ecosystems in exchange for structured compensation. The simplest model mirrors a timber concession, where a logging company pays the government for the right to extract timber from an area of public forestlands[631]. In 2002, Conservation International (CI) and the Government of Guyana entered into an agreement that protects 80,937 ha of relatively pristine forest. Based on the timber concession model, CI obtained a 30-year logging license for a portion of the upper Essequibo River watershed, with the objective of managing the area for conservation rather than timber exploitation. Over this period CI will pay the Government annual fees comparable to those that would have been paid by a logging company, and is also providing a Voluntary Community Investment Fund to ensure benefits to local communities[632].

Although the conservation concession is currently not recognised as an official protected area in Guyana, it functions like a protected area by safeguarding the forests and its resources from the pressures of extractive economic development – for at least the 30 year period[633]. Through the project it is hoped that Guyana can also become a beneficiary of carbon credits and/or other payment schemes for the provision of ecological goods and services such as clean air, quality freshwater and climate regulation. However, at present countries like Guyana with negligible rates of deforestation and intact high biodiversity-value rainforests wait upon the proposed modifications to the Kyoto Protocol[634].

Source: Conservation International

Section 6
Policy recommendations

We conclude this report with some specific policy recommendations.

Firstly, we call on the two key multilateral environmental agreements – the UN Framework Convention on Climate Change and the Convention on Biological Diversity – to recognise and support the role of protected areas in climate change mitigation and in providing adaptation benefits.

Secondly, we call on national and local governments to incorporate protected area systems into national climate change adaptation strategies and action plans.

Policy recommendations

KEY MESSAGES

Currently national and international policy instruments aimed at the twin environmental crises of biodiversity loss and climate change are often not sufficiently coordinated, wasting resources and missing valuable and complementary policy opportunities. Several key recommendations are made below to maximise the effectiveness of protected areas as conservation tools for climate change mitigation and adaptation.

Opportunities to use protected areas in climate response strategies need to be prioritised at the international level and by national and local governments. Several steps are needed to improve the effectiveness of protected areas as a significant tool for climate change mitigation and adaptation within the implementation programmes of both conventions, thus enhancing their potential to achieve targeted outcomes at country level, and collectively for the global community. These include:

UNFCCC
- Recognise the role of protected areas as tools for permanent carbon storage and sequestration and call for the implementation of robust protected areas systems as a core component of national strategies to achieve land-based emissions reductions
- Emphasise the role of ecosystems in climate change adaptation and incorporate protection of natural ecosystems within national adaptation strategies and action plans (including National Adaptation Programmes of Action – NAPA) for protection of natural ecosystems as a cost-effective alternative to technology- and infrastructure-based adaptation measures and to avoid mal-adaptation
- Permit nationally appropriate mitigation and adaptation actions that involve the enhancement of protected areas or national protected area networks to receive financial and technical assistance through climate-related financial mechanisms

CBD
- Renew the Programme of Work on Protected Areas at COP 10 to address more explicitly climate change impacts and response strategies, in liaison with other CBD programmes
- Encourage development of tools and methods to support countries to evaluate climate impacts and increase resilience of their protected areas systems, and ensure that their role in mitigation and adaptation is fully explored
- Emphasise the importance of increasing connectivity among national protected areas and transboundary protected areas to further enhance the benefits of protected area networks as a climate change response strategy
- Cultivate political urgency for the development of marine protected areas and protected areas in under-represented biomes

National and local governments
- Incorporate the role of protected area systems into national climate change strategies and action plans
- Address mitigation by reducing the loss and degradation of natural habitats
- Strengthen adaptation by reducing the vulnerability and increasing the resilience of natural ecosystems
- Ensure effective management of protected areas to provide benefits to biodiversity and climate change mitigation and adaptation

A school of blue maomao fish (*Scorpis violaceus*), Poor Knights Islands, New Zealand © Brian J. Skerry / National Geographic Stock / WWF

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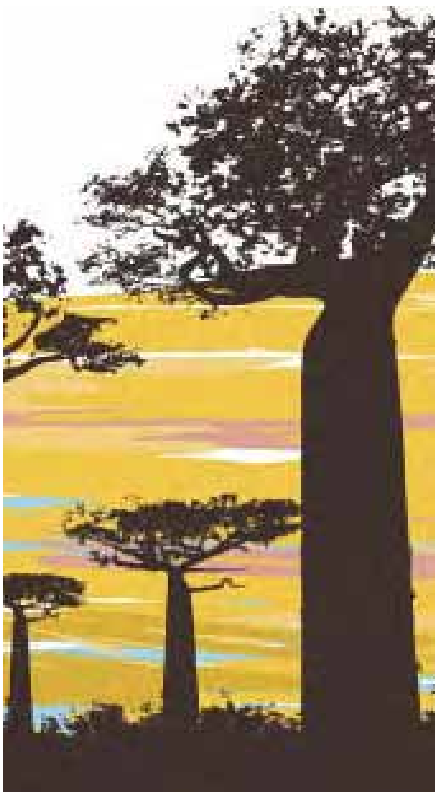
“This book clearly articulates for the first time how protected areas contribute significantly to reducing impacts of climate change and what is needed for them to achieve even more. As we enter an unprecedented scale of negotiations about climate and biodiversity it is important that these messages reach policy makers loud and clear and are translated into effective policies and funding mechanisms.”

Lord Nicholas Stern



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