UNITED NATIONS ENVIRONMENT PROGRAMME
Programme des Nations Unies pour l'environnement Programa de las Naciones Unidas para el Medio Ambiente
Программа Организации Объединенных Наций по окружающей среде برنامج الأمم المتحدة للبيئة
联合国环境规划署
UNEP

Climate change and Ecosystem management: the 'Win-Win-Win' link between mitigation, adaptation and sustainability

The purpose is to:

- Define the problem: the imbalance in the global carbon cycle.
- Emphasise the essential role that ecosystems play in moderating the global carbon cycle and therefore climate;
- Highlight the importance of including ecosystem management in the COP 15 agenda and within a global climate change strategy;
- Indicate the cost-benefit advantages of doing this.
- Highlight the socio-economic and environmental advantages of adopting an ecosystems management approach.

Summary:

Whilst human caused greenhouse gas emissions continue to rise, the global capacity to absorb them is declining due to ecosystem degradation. Continuation of this imbalance will lead to climate instability and reduce essential ecosystem services. Appropriate valuation, protection and management of the world's ecosystems achieves two vital joint objectives:

1. Cost effective mitigation and adaptation for climate stabilisation through use of natural carbon sequestration processes.
2. Secured delivery of essential ecosystem services, e.g. clean air, food and water security.

Climate stabilisation can only be achieved by balancing emissions sources (human and natural) and the global ecosystems' sink capacity. The protection and management of the world's ecosystems offers a highly cost effective multiple 'Win' mechanism for mitigation by enhancing sink capacity and protects the essential life supporting ecosystem services that will enable societal adaptation to climate change.

Important information about this paper – Notes from the authors:

This paper assumes that the reader has some detailed knowledge on climate change. It is beyond the scope here to cover climate change issues in any detail. Instead readers are referred to the IPCC Fourth Assessment Report (http://www.ipcc.ch/) for a comprehensive coverage, and the Synthesis Report of the Climate Change: Global Risks, Challenges and Decisions Conference, 10-12 March 2009, Copenhagen (http://climatecongress.ku.dk/), for an up-date of the current situation. The subjects of ecology, ecosystem management and ecological economics are also large, but we have assumed a lesser understanding of these subjects on the part of the reader. We have aimed at capturing the essential aspects of these subjects at a very generic level.

Where possible we have used reports and journal articles that are available on-line to allow readers easier access to supporting material, but this selection is by no means comprehensive or fully representative of the vast range of material available.

Flexibility in definitions.

All too often concepts and strategies are too rigidly defined and seen to be overly prescriptive to become acceptable by the majority. In this paper we have deliberately used an open interpretation of what ecosystem management means and how it can be implemented. Hence negotiators and others can discuss what the concept means in terms of their own realms and areas of influence. This is to facilitate meaningful dialogue on the notion of tailored 'local solutions to global problems' and 'local scale needs working towards global level objectives'. It needs to be remembered that each individual ecosystem within the world plays a part in the complexity that is the global ecosystem and each contributes to the global good.

Abbreviations used:

CoP 15	UNFCCC Conference of the Parties 15 (Copenhagen, December 2009)
EM	Ecosystem Management
GHG	Greenhouse gases
$GtCO_2$-eq/yr	Giga (thousand million, or 10^9) tons carbon dioxide equivalent per year
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
LULUCF	Land Use, Land-Use Change and Forestry
IWRM	Integrated Water Resource Management
$MtCO_2$-eq/yr	Megatons (million or 10^6) tons carbon dioxide equivalent per year
NAPAs	National Adaptation Plans of Action
Pg CO_2 eq/yr	Peta (thousand million million, or 10^{15}) grams carbon dioxide equivalent per year (1 PgC = 1GtC)
ppm	Parts per million (atmospheric concentration)
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme)
UNFCCC	United Nations Framework Convention on Climate Change
WCMC	World Conservation Monitoring Centre

Contents

Acknowledgements:

We are grateful to Prof. Mary E. Power of the Department of Integrative Biology, University of California, Berkeley, and Dr. Jamison Ervin, of the Supporting Country Action for CBD Programme of Work on Protected Areas UNDP/GEF/UNOPS Global Project, and Dr Richard Birnie at the Macaulay Land Use Research Institute for additions and comments on different versions of this paper.

1 Defining the problem

Even if there were no human activities on planet Earth, carbon would flow through the atmosphere because of natural biological and geological activity. Planet Earth is a dynamic geological and biological system. It produces and absorbs carbon and other greenhouse gases through a range of natural cycles and across a wide variety of ecosystems, which has resulted in the past climate patterns.

Human activity has intervened in these natural carbon cycles in two main ways:

- By creating major new sources of carbon emissions from the use of fossil fuels;
- By degrading natural sinks of carbon by polluting or transforming natural ecosystems.

The combined result of these human interventions has been to change the planetary balance between the sources, sinks and storage pools of carbon. Put crudely, Earth is now emitting more carbon to the atmosphere than it can absorb. This changing imbalance is reflected in a progressive increase in CO_2 concentrations in the atmosphere which has lead to climate change.

Putting these things together, it can be seen that there are three main components to the global carbon cycle.

- Those emissions due to human activity.
- Those emissions from ecosystems.
- There is only one sink: the capacity of global ecosystems to absorb carbon.

This is shown in Figure 1.

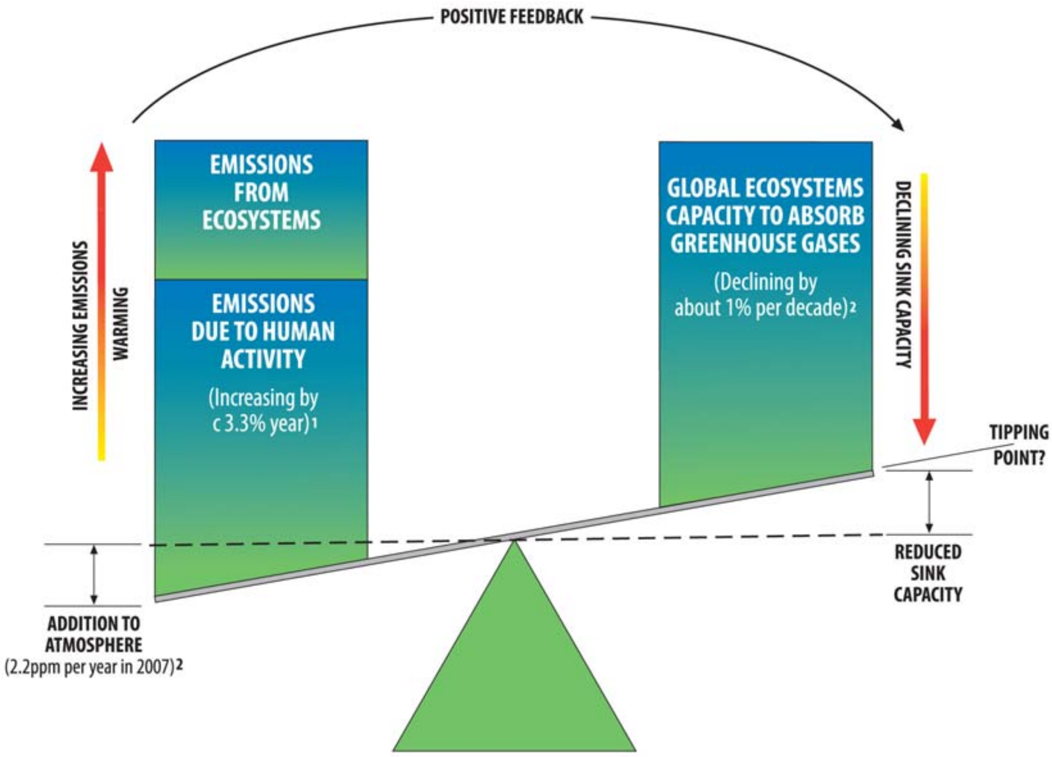

Figure 1. Imbalance of components for climate stabilisation.

[1] Canadell 2007 PNAS, [2] Global Carbon Budget[1]

(Note proportions of size are not to scale and do not reflect actual values of fluxes)

The key observation here is that global and regional ecosystems function as the main climate regulators, both in releasing greenhouse gases (sources) and sequestrating them (sinks) and in other direct and indirect interactions with the climate.

- Ecosystems currently absorb about **half** of anthropogenic CO_2 emissions (Oceans c. 24% and land c. 30%). The remaining amount is the addition to the atmospheric pool.
- But ecosystem absorption capacity is declining by about 1% per decade and is likely to decline more rapidly due to global warming and human impacts.

At the present time emissions due to human activity are increasing:

- Current estimates put the annual global emissions of CO_2 due to human activities at about 10 Giga tons, of which about 1.5 Gt is from land use change (mainly deforestation).

The net effect is that there is an increasing imbalance between emissions and absorption capacity. ***Therefore to achieve climate stabilisation there is need to manage all three components of the global carbon cycle, not just those resulting from fossil fuels and other human activities.***

The key problem is that one component of the three-way balance is concentrated on as part of the post-2012 negotiations. The current policy is to focus on human based emissions. The risk of this situation is that regulating human based emissions will be insufficient to achieve climate stabilisation.

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[1] Global Carbon Budget. See: http://www.globalcarbonproject.org/carbonbudget/07/index.htm

1.1 Increasing emissions and declining sink capacity

Terrestrial and oceanic ecosystems are currently absorbing about half of anthropogenic CO_2 emissions (Oceans c. 24%, land c. 30%[2]). Without CO_2 sinks, the total CO_2 emissions since 1800 would have caused atmospheric CO_2 to increase from 280 ppm in pre-industrial times to about 500 ppm now[3]. Today's concentration is 387 ppm[4]. But climate change feedbacks and other pressures including land-use change, ocean acidification (due to absorption of CO_2 [5]), pollution and over-exploitation reduce this capacity. The efficiency of sinks in removing CO_2 has decreased by 5% over the last 50 years (about 1% per decade), and will continue to do so in the future. Fifty years ago, for every 1000 kg (1 ton) of CO_2 emitted to the atmosphere, natural sinks removed 600 kg. Currently, the sinks are removing only 550 kg for every 1000 kg of CO_2 emitted, and this amount is falling[6].

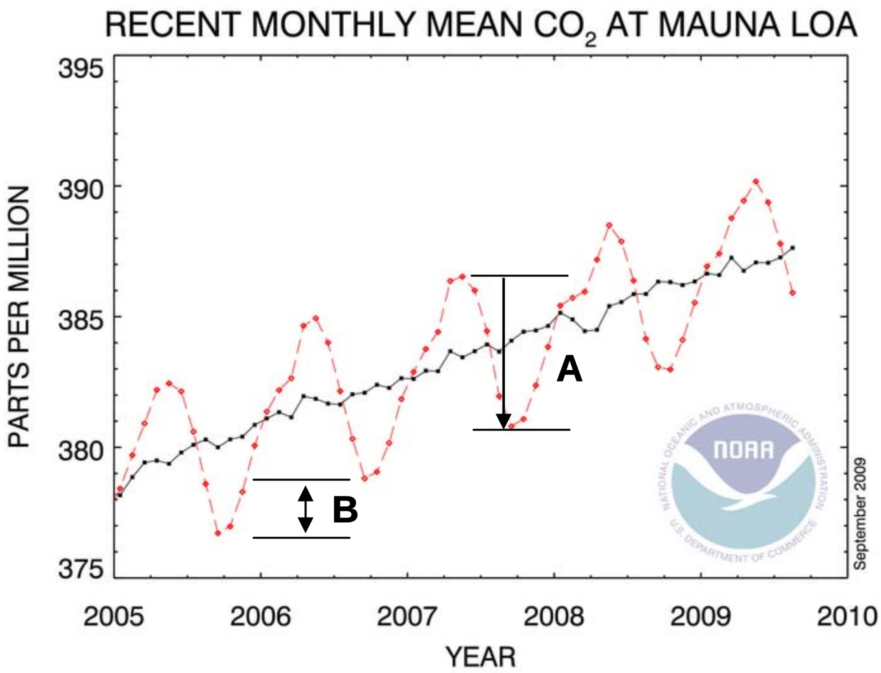

Figure 2. Mean monthly CO_2 concentration cycles showing seasonal patterns (red line) and trend from moving average corrected for the seasonal cycle (black line). Dimension A shows the net decrease in CO_2 concentration in one year (due to absorption particularly during the northern hemisphere summer). Dimension B reflects the imbalance between total emissions (Human and ecosystems) and sink capacity.

Mean monthly data source: NOAA (http://www.esrl.noaa.gov/gmd/ccgg/trends/).

From Figure 2 it can be seen that current ecosystem degradation will decrease dimension A (the net effect of the global sink capacity) and enlarge dimension B (the addition of CO_2 to the

[2] Cannedell et al 2007. PNAS. See: http://www.pnas.org/content/104/47/18866.full.pdf+html

[3] Raupach et al 2009, The Global Carbon Cycle. In Richardson et al 2009. Synthesis Report. Climate Change: global risks, challenges and decisions Conference, 10-12 march 2009, Copenhagen. See: http://climatecongress.ku.dk/

[4] NOAA. See: http://www.esrl.noaa.gov/gmd/ccgg/trends/

[5] Turley and Scholes 2009, in Richardson et al 2009 (as above) and IPCC AR4 WG I Ch. 5 p403.

[6] Global Carbon Project (2008) Carbon budget and trends 2007
See: http://www.globalcarbonproject.org/carbonbudget/07/index.htm

atmospheric pool). Conversely, an increase in ecosystem sink capacity (enlarging A) will help negate the imbalance arising in B. Coupled with Human emissions reductions then B can be minimised or even made to be negative.

2 Rationale:

The value of an ecosystem-based mitigation and adaptation approach needs to be an integral part of the 15th Conference of Parties (COP15) negotiations of the UN Framework Convention on Climate Change in Copenhagen in December 2009.

Ecosystems and the services[7] they provide (e.g. climate regulation, food security, freshwater supply, disaster risk reduction) are the fundamental units of life support on Earth. Ecosystems play an unequivocal and increasingly important role in both ecosystem-based mitigation (carbon sequestration and storage) and ecosystem-based adaptation (i.e. societal adaptation to climate change impacts). Healthy, fully functional well managed and adequately protected ecosystems can therefore achieve cost effective objectives for climate change mitigation, adaptation and long-term sustainability whilst continuing to provide the essential services on which we depend. However, inadequate ecosystem protection has lead to degradation and therefore a decline in services whilst reducing the ability of ecosystems to regulate our climate.

Hence international climate negotiations for a post-2012 agreement must incorporate the role of ecosystem management[8] for ecosystem-based mitigation and adaptation, which must be adequately funded. Current efforts to address climate change focus mainly on reducing human emissions of greenhouse gases (GHGs). Negotiating text for the UNFCCC currently refers to ecosystems in terms of their vulnerability, need for protection and capacity for providing some ecosystem services. This paper sets out a compelling argument for extending this role and establishing ecosystem-based management as an essential tool in national, regional and international strategies to mitigate against, and adapt to climate change. Fundamentally it sets out the need to establish ecosystem management as the foundation to enable long-term sustainability.

3 Aims

This paper highlights the vital role that ecosystems and their services play in underpinning mitigation and adaptation to climate change, as well as supporting life on earth.

The aim of this paper is to ensure that ecosystems and the services they provide become the fundamental components underpinning the negotiations at CoP 15 for a post-2012 agreement. Whilst the primary focus of CoP 15 will be to negotiate an agreement to regulate greenhouse gas (GHG) emissions from human activity, it must be remembered that it is the global ecosystem that functions as the main climate regulator – in both sequesting and releasing

[7] **Ecosystem services** are defined as ‘the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly (after de Groot 1992 and de Groot et al 2002, Ecological Economics 41).

[8] **Ecosystem management** is defined in this paper as “an integrated process to conserve and improve ecosystem health that sustains ecosystem services for human well-being”. Here the ‘Ecosystem management’ term is used to encompass ecosystem-based mitigation and adaptation and ecosystem-based management as well. Ecosystems are defined as encompassing all land and marine based natural and semi-natural systems, and associated land uses including conservation, sustainable livelihoods, pastoralism, agriculture and forestry.

GHGs. ***Therefore, any agreement that fails to include measures to appropriately protect and manage ecosystems is unlikely to achieve the goals of climate change risk reduction.***

Furthermore, ecosystems form the foundation for all aspects of sustainability and life support, but they are under increasing threats from climate change and other human driven pressures, hence their protection is crucial to maintain ecosystem services. The value of ecosystems and the services they provide has not been adequately recognised by past economic systems. The CoP 15 negotiations provide an opportunity to redress this by placing ecosystem valuation at the heart of future economic "green" development. ***Appropriate ecosystem management is a cost effective method of achieving a 'Win-Win-Win' link between climate change mitigation, adaptation and long-term sustainability.*** The aim is thus to ensure that the fundamental concept of ecosystem management be included in the CoP 15 negotiations so as to form the basis for a new global scale valuation of the environment.

3.1 Why ecosystem management needs a higher profile in the CoP 15 negotiations.

The challenges faced by humanity require a combination of integrated approaches. The OECD[9] has identified four main environmental challenges:

1. Tackling climate change.
2. Halting biodiversity loss and ecosystem degradation.
3. Ensuring clean water, food security and adequate sanitation.
4. Reducing human health impacts of environmental degradation.

As the ecosystem management approach[10] for mitigation and adaptation deals with the foundations of life support on Earth - ecosystem services: food, water, air and many others, it lies at the heart of solutions to deal with these challenges. The fundamental question must therefore be asked: If an ecosystem management approach is NOT included within the CoP 15 negotiations, then how can environmental protection and steps to address climate change be integrated? The challenges of mitigation, adaptation and sustainability need to be seen as part of the same, whole issue. There are currently no other global policy initiatives or mechanisms that can combine climate change and environmental protection policies. A holistic, integrated approach is required to deal with the multiple issues facing human society. The CoP 15 process presents an ideal opportunity to initiate a framework around which issues of climate change and environmental protection can be addressed and complementary solutions developed.

3.2 Key Messages

The following are key messages that need to be considered:

- Ecosystems form the basis for all forms of life support, including provision of food, clean air and water, disease regulation and many others.
- Ecosystems are the fundamental units of climate regulation, acting as both a source and sink of greenhouse gases. Terrestrial and oceanic ecosystems currently absorb

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[9] Organisation for Economic Co-operation and Development, 2008. OECD Environmental Outlook to 2030. See: http://www.oecd.org/document/20/0,3343,en_2649_34305_39676628_1_1_1_37465,00.html

[10] The ecosystem management approach is explained further in Section 5 and Appendix A.

about half of the current anthropogenic CO_2 emissions but this capacity is being reduced.

- Ecosystems are the 'Win-Win-Win' link between mitigation, adaptation and sustainability.
- Ecosystem based mitigation and adaptation must be seen as complementary to measures to regulate human driven GHG emissions.
- Climate change and human resource use pressures will lead to a shift towards further ecosystem degradation, reducing the quality of ecosystem services and increasing GHG emissions in some cases whilst reducing sequestration capacity in others.
- Social and environmental disruption: observations show that societies and ecosystems are highly vulnerable to even modest levels of climate change, with poor nations and communities, ecosystem services and biodiversity particularly at risk. Healthy, functioning ecosystems can serve as a buffer to such impacts.
- The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land use change, pollution, over-exploitation of resources) (high confidence)[11].
- Resilient, healthy ecosystems can buffer economies and societal infrastructure against climate change and variability threats.
- There is currently no adequate economic mechanism for valuing the services to humanity that ecosystems provide.
- There are potentially large benefits from integrating between a 'green' based economic structure and adjusting human attitudes, aspirations and behaviour.
- Ecosystem management forms the basis for food security, disaster risk reduction and poverty alleviation[12].

4 Climate stabilisation: the need for balance

As a simplified representation, a three way balance describes the global climate stabilisation problem:

Climate stability* = *Global ecosystems' capacity to absorb GHGs – (natural emissions from ecosystems + human induced emissions[13])

The long term evolution of this balance will determine to a large extent the speed and magnitude of human induced climate change and the mitigation requirements to stabilise CO_2 (and other GHG) concentrations at any given level[14].

Hence to achieve stabilisation (or climate resilience), there is need to balance the three components of the global capacity to absorb GHGs, manage the emissions from ecosystems (or

[11] IPCC, 2007. AR4 SPM WGII, p.11

[12] For example see UNEPs' The Environmental food crisis: the environment's role in averting future food crises. http://www.grida.no/_res/site/file/publications/FoodCrisis_lores.pdf

[13] Includes all emissions as a direct result of human activity, including fossil fuel burning, cement production, land use and land use change.

[14] Canadell et al 2007 PNAS. See: http://www.pnas.org/content/104/47/18866.full.pdf+html

at least be able to quantify what they are and understand how the processes work), and reduce emissions due to human activity. The paradox is that if emissions due to human activity increase as they have been doing, then the emissions from ecosystems are likely to increase as well, whilst the capacity of ecosystems to absorb emissions decreases. Such an imbalance poses substantial risks of climate destabilisation. As can be seen from Figure 1, ecosystems function in two of the three components of the stabilisation balance. Again, the danger of not fully recognising and accounting for the role ecosystems play in climate regulation during the CoP 15 negotiations risks addressing only one side of the three way balance.

Terrestrial and oceanic ecosystems play a significant role in the global carbon cycle. They are currently absorbing about half of anthropogenic CO_2 emissions as demonstrated in Figure 2 (Oceans c. 24%, land c. 30%[15]). Without CO_2 sinks, the total CO_2 emissions since 1800 would have caused atmospheric CO_2 to increase from 280 ppm in pre-industrial times to about 500 ppm now[16].

Today's concentration is 387 ppm[17]. But climate change feedbacks and other pressures including land-use change, ocean acidification (due to absorption of CO_2 [18]), pollution and over-exploitation adversely affect this capacity. The efficiency of sinks in removing CO_2 has decreased by 5% over the last 50 years (about 1% per decade), and will continue to do so in the future. Fifty years ago, for every 1000 kg (1 ton) of CO_2 emitted to the atmosphere, natural sinks removed 600 kg. Currently, the sinks are removing only 550 kg for every 1000 kg of CO_2 emitted, and this amount is falling[19].

It is therefore essential to fully understand how much capacity is being lost, where, why and what further reductions may occur in the future. Current estimates put the annual global emissions of CO_2 due to human activities at about 10Gt, of which about 1.5 Gt is from land use change (mostly deforestation, at about 13 million hectares per year). Since c. 1700, the global forest area has decreased by about 40%. There is therefore large potential to reduce emission by reducing land use change, particularly deforestation[20] [21] and reverse GHG absorption capacity decline through active ecosystem restoration. At the same time this conserves biodiversity. Deforestation will release an estimated 87 to 130 billion tonnes of carbon by 2100, which is greater than the amount of carbon that would be released by 13 years of global fossil fuel combustion[22].

'Bio-sequestration'[23] refers to this ability of photosynthesising organisms to capture carbon from the atmosphere. Terrestrial ecosystems have remained constant in the sequestration efficiency, and have the potential to grow as sinks (if given adequate protection and management), whilst the capacity of the oceans may have been reached and is now declining

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[15] Cannedell et al 2007. PNAS. See: http://www.pnas.org/content/104/47/18866.full.pdf+html

[16] Raupach et al 2009, The Global Carbon Cycle. In Richards et al 2009. Synthesis Report. Climate Change: global risks, challenges and decisions Conference, 10-12 March 2009, Copenhagen. See: http://climatecongress.ku.dk/

[17] NOAA. See: http://www.esrl.noaa.gov/gmd/ccgg/trends/

[18] Turley and Scholes 2009, in Richardson et al 2009 (as above)

[19] Global Carbon Project (2008) Carbon budget and trends 2007 See: http://www.globalcarbonproject.org/carbonbudget/07/index.htm

[20] See UN-REDD http://www.undp.org/mdtf/un-redd/overview.shtml

[21] The Eliasch Report. See: http://www.occ.gov.uk/activities/eliasch.htm

[22] See: http://www.csiro.au/news/GlobalCarbonProject-Deforestation.html

[23] Trumper et al 2009. The Natural Fix? The role of ecosystems in climate mitigation. A UNEP rapid response assessment. UNEP-WCMC.

(primarily due to acidification).

Given this shifting efficiency of sinks, to achieve sustainable resource use and to ensure the provision of ecosystem services, there is need to balance many opposing demands. Human population is expanding and the expectation of an increasing number of people is for material gain, placing additional demands on resource use. So to achieve a balance there needs to be a shift in human expectations, aspirations and behaviour (cultural) and immediate resource use.

At the same time it needs to be recognised that for many people the aspiration is to raise there standards of living (poverty alleviation). It is the poor of the world who are the most immediate beneficiaries of ecosystem services, but also those that will suffer most from ecosystem degradation. The aspirations of the poor need to be respected and support given to realise them (of which ecosystem management plays central role), whilst on the other hand excessive resource consumption by wealthy people needs to be reduced in order achieve suitable levels of equity and long-term sustainability.

4.1 Ecosystem process feedbacks and tipping points

Strong positive and negative feedbacks exist that interact to give us the climate conditions we currently have. Negative feedback loops are generally good – they help maintain equilibrium. However, positive feedback loops are generally very bad and lead to destabilisation. As a worse case example of a positive feedback, in its 4th Assessment Report, the IPCC states that a 2 to 2.5°C global average temperature increase above pre-industrial levels may cause many ecosystems to turn from carbon sinks into carbon sources. The current state of the Arctic climate feedbacks is a prime example[24]. This must be seen as a serious risk to our actions for mitigation, as it would jeopardize our efforts to reduce emissions. In order to keep global warming below 2°C, global emissions must peak by 2020 and then be at least halved from 1990 levels by 2050, whilst at the same time we need to increase the global ecosystem's capacity to regulate the climate. This requires a new global climate agreement and concerted efforts to reduce GHG emissions and enhance ecosystem resilience.

Changes in ecosystem composition, and especially in ecosystem structure, have important implications for the interactions between the biosphere and the climate system, as well as for ecosystem services on which society depends. We cannot solve climate change without addressing ecosystem management and protection.

Figure 3 shows that ecosystems are the key factors in budgeting the global CO_2 balance. Historically human society has on the one hand been increasing GHG emissions, whilst on the other decreasing the capacity to absorb those emissions, leading to the current high levels of atmospheric GHGs. Though the capacity to absorb CO_2 in the oceans has increased over time, the cost has been an increase in ocean acidification which will ultimately reduce absorption capacity.

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[24] Sommerkorn and Hassol 2009. Arctic Climate Feedbacks: Global Implications. See: http://assets.panda.org/downloads/wwf_arctic_feedbacks_report.pdf

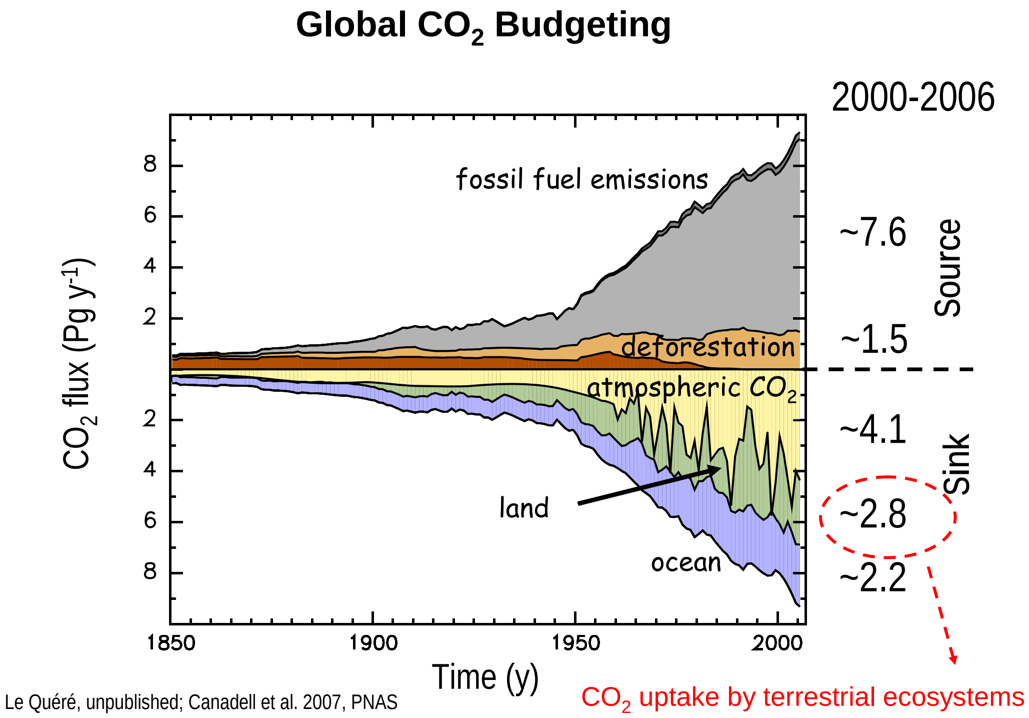

Figure 3: Global CO_2 Budgeting

It is important to note that the IPCC projections for future warming do not include carbon-climate feedback responses from ecosystems, as these are difficult to quantify in terms of their amplification effect. Estimates for an additional increase above future projections of 4°C (medium-high emissions scenario) range from 0.1°C to 1.5°C as a result of considering the vulnerability of land and sea sinks[25].

The combined effects of climate change and associated disturbance and other drivers including pollution, land-use change and over-exploitation may exceed the resilience of many marine and terrestrial ecosystems during this century. These changes may either amplify or dampen the response of the climate systems. Although our detailed knowledge is limited, there is certainty about the existence of multiple positive and negative feedbacks between ecosystems and climate. Most feedbacks that we are learning about tend to be reinforcing, making climate warming worse. These positive feedbacks are generally non-linear and have the potential to produce large undesirable results particularly at the regional level.

It is generally agreed that one of the main feedbacks to the climate system will be through the increase of soil respiration under increased temperature, particularly in the arctic with the potential to add up to 200 ppm CO_2 to the atmosphere by 2100[26]. Another feedback is the Amazon forest drying and dieback. Although there is considerable uncertainty, most models indicate reduced precipitation leading to increased drying of the Amazon rainforest (coupled with on-going deforestation). It has been suggested that CO_2 emissions will be accelerated by up to 66% arising from global soil carbon loss and forest dieback in Amazonia as a consequence

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[25] Raupach et al 2009. The Global Carbon Cycle. In Richards et al 2009. Synthesis Report. Climate Change: global risks, challenges and decisions Conference, 10-12 march 2009, Copenhagen. See: http://climatecongress.ku.dk/.

[26] Canadell et al, 2007a

of climate change[27]. The current models for temperature increase projections do not take into account climate-carbon cycles feedbacks. This means current temperature projections may be under-estimates.

Hence we are in a situation of uncertainty, declining absorption capacity but increasing human emissions, which is likely to lead us into a process of positive feedbacks and the probability of exceeding critical thresholds of climate stability. ***It is widely debated as to whether we have already reached such a 'tipping point' for many ecosystems responding to positive feedback. If is the case, or becomes the case in the near future, then ecosystem absorption of GHGs will be the ONLY brake effect on catastrophic climate destabilisation.***

4.2 Ecosystems: the 'Win-Win-Win' link between mitigation, adaptation and sustainability.

An ecosystems approach can fulfil objectives for both mitigation of, and adaptation to climate change as well as being the foundation for long term sustainability. Protecting ecosystems can provide social, economic and environmental benefits, both directly through sustainable management of biological resources and, indirectly through protection of ecosystem services[28]. Parallel to this, ecosystems can function as tools for mitigation, through appropriate management to reduce natural sources of emissions or increase absorption potential. These together provide countless streams of benefits to, and opportunities for human societies (economic, cultural, health and many more):

- **Social**; Secure livelihoods, particularly the poor; Health; Cultural and aesthetic values; Community support.
- **Economic** – Resilient ecosystems secure service provision to support all forms of economic activity.
- **Climate regulation** - ecosystems function as tools for mitigation, through appropriate management to reduce natural sources of emissions or increase absorption capacity.
- **Environmental** – Resilient healthy ecosystems have the capacity to support long-term sustainability.

Indeed, a fourth 'Win' can be added in that profitable outcomes can be generated by utilising the benefits of healthy ecosystems.

4.3 Ecosystems as a 'safety net'

The adoption of an ecosystems management approach at a global scale will serve as a 'safety net' against possible failures in the efforts to reduce emissions from human activity. However, it must not be seen as an alternative, but rather as a complementary approach. Whilst it is vital to achieve agreement on emissions reduction, there is no absolute guarantee that the targets set will be met. Also, there is uncertainty as to the effect of positive feedback responses from the environment and what level of atmospheric GHG concentrations and associated radiative forcing, will lead to climate destabilisation. Similarly there is uncertainty in the projections

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[27] Betts et al, 2006

[28] World Bank 2009: Convenient solutions to an inconvenient truth: ecosystem-based approaches to climate change. See: http://climate-l.org/2009/07/06/world-bank-publishes-report-on-ecosystem-based-approaches-to-climate-change/

made by climate models. It therefore follows that, using the precautionary principle, that a secondary mechanism for climate regulation is also employed as a back-up. Appropriately managed ecosystems have the capacity to function as a buffer against such uncertainties.

4.4 Priority areas

Ecosystem degradation and biodiversity loss are the most serious threats to the local, national and international scales of ecosystem services provision. The battle against this can be fought on several fronts:

Firstly, strengthening Ecosystems governance and institutions at local and national levels is a pre-condition for any effective policy response.

Secondly, it should be explicitly recognised that one of the main drivers for ecosystem degradation is economic, e.g. forests are destroyed because it is more profitable in the short run to use land for other purposes than to keep them standing. Substantial reductions in GHG emissions can be achieved by reducing deforestation[29]. Therefore an effective policy has to reward the value of the services provided by ecosystems above that of the short term gain. There is need therefore for an economic mechanism that values ecosystems and the services they provide.

Thirdly, because ecosystems degradation is a global issue requiring solutions at the local to global scale (the aims being to stabilise CO_2 emissions at an acceptable level and to halt biodiversity loss), the international climate negotiations provide a unique opportunity to come to grips with ecosystems loss. The UNFCCC CoP15 should feed ecosystem management considerations into the negotiations.

Fourthly, if policy is to be designed and implemented properly, it must be based on high quality information, appropriate governance and institutional structures. Existing ecosystem monitoring and assessment programmes are either incomplete or only partially integrated. The money spent on ecosystems research and monitoring does not reflect the true value of the services that ecosystems provide. More support for earth and environmental sciences to provide the basis for a comprehensive science-based management approach is required to guide policy decisions and monitor implementation.

5 Living within environmental limits: basis for Sustainability

Parallel to the issue of climate change is the need for human society to adapt to living within the constraints of the global life support capacity that ecosystems provide, in order to achieve long-term sustainability.

Ecosystem services are vital in fulfilling climate change mitigation and adaptation goals. Ecosystems and biodiversity are the foundations and mainstay of agriculture, forests, fisheries and pastoral systems, providing the raw materials for livelihoods, sustenance, medicines, trade, tourism and industry. Forests, grasslands, freshwater, marine and other natural ecosystems provide a range of services that are not recognized in economic accounting systems, but are vital to human welfare, including water flow and water quality regulation, flood control,

[29] Reducing Emission from Deforestation and Degradation - REDD. See: http://www.undp.org/mdtf/un-redd/overview.shtml

pollination, decontamination, carbon sequestration, soil conservation, nutrient and hydrological cycling. These are all public goods and services we all benefit from. This presents a particular problem when considering negotiations for treaties on their protection as there is no direct monetary value associated with the ecosystems.

The challenge is therefore to devise an economic and policy framework whereby ecosystems are either appropriately valued in monetary terms, or there is a fundamental shift to absolute environmental protection around which all other economic activity has to be based.

In reality, a mix of both approaches is more feasible and likely to achieve goals for climate change mitigation and adaptation leading to long term sustainability. Given the multitude of ecosystem types, human cultural connections with them and the complexity of inter-relationships between ecosystems (over time and spatial scale), a single solution is unlikely. Instead, solutions need to be developed that are tailored to the particular issue, guided by local and national communities and priorities, but based on global level objectives.

5.1 Valuing ecosystems and the services they provide.

The valuation of ecosystems and the services they provide is problematic. Some people have argued that it is not feasible to put a monetary value on services based on conventional economic valuation methods, whilst others have attempted to assign monetary values. For example, estimates made in 1997 placed the range between US$16 - 54 trillion per year, averaging at about $33 trillion (given as a minimum due to estimation uncertainties), with the average global gross national product being $18 trillion per year[30] (updated to a mean of $38 trillion and GNP of $31 trillion for 2000)[31]. These figures give an indication to the levels at which funding support for ecosystem protection and management can be justified. However, GDP growth does not capture many vital aspects of national wealth and wellbeing, such as changes in the quality of health, the extent of education, and changes in the quality and quantity of our natural resources[32].

In terms of climate change mitigation and adaptation, perhaps more urgent at present is the need to develop methods and mechanisms for life cycle analysis and ‘full GHG accounting’. Such steps will allow us to fully understand the true environmental impact of resource use, which should lead to better financial valuation of the resource and any intervention required to compensate for (or repair) environmental damage. Such accounting would also help establish pre-defined thresholds beyond which the environmental damage is unacceptable, regardless of monetary benefits. In considering the role that ecosystem have in providing services, and how they are managed, it is important to remember that ecosystems exist at multiple spatial and temporal scales (microscopic to global, minutes to millennia). Hence they can transcend national boundaries and the lifespan of governments and individuals. Some ecosystems may have limited capacity for absorbing GHG, or as stores for existing carbon stocks, i.e. deserts, but may be vital in other influences on the climate, such as driving regional scale atmospheric movements and processes. In totality, the public good that the diverse range of ecosystems

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[30] Costanza et al 1997. The value of the world's ecosystem services and natural capital. Nature 387.

[31] The IPCC Fourth Assessment Report Working Group II Chapter 4 page 245 gives an overview of ecosystem valuation.

[32] The Economics of Ecosystems and Biodiversity: an interim report (2008). See: http://ec.europa.eu/environment/nature/biodiversity/economics/pdf/teeb_report.pdf

and the services they provide is truly global, benefiting all individuals in the world.

Regardless as to whether a monetary value can or cannot be assigned to an ecosystem or its services, the fundamental fact is that they provide the essential means of life support, and without them functioning properly human society will not be able to sustain itself. For example, the world's poor are most at risk from the continuing loss of biodiversity, as they are the ones that are most reliant on the ecosystem services that are being degraded[33]. For the purposes of this paper therefore, ecosystems and the services they provide are seen to underpin not just the practical and physical aspects of life, but also the foundation for the economic basis for human societies. The CoP 15 process provides the opportunity to include discussions on valuing ecosystems and services as part of an integrated approach to tackling climate change, poverty alleviation and long term sustainability. ***The question then becomes IF ecosystems and services are NOT part of the negotiation process, then what other mechanisms exist to integrate efforts for these three vital inter-related goals?***

6 What is the ecosystems management approach?

The ecosystems management approach is supported by many national and international organisations including UNEP, World Bank[34], IUCN[35], WCMC[36] and many others. Various definitions exist for the ecosystems approach, for example;

'An Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way' [37]. It is a holistic way of dealing with natural resource management, where integration between issues is the key element. The following describes the ecosystem management approach (see Appendix A for further details).

Ecosystem management (EM) is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function[38]. The IUCN Commission on Ecosystem Management[39] defines EM as "a process that integrates ecological, socio-economic, and institutional factors into comprehensive analysis and action in order to sustain and enhance the quality of the ecosystem to meet current and future needs". The central goal of ecosystem management is sustainability, where the emphasis is on delivering ecosystems services for current use without compromising the ability to provide them in the future. A fundamental aspect within EM is the need to protect sources of resources[40]; that is, ecosystems require appropriate protection to ensure the provision of ecosystem services[41]. As such takes a holistic, inter-disciplinary

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[33] The Economics of Ecosystems and Biodiversity (TEEB). See: http://ec.europa.eu/environment/nature/biodiversity/economics/

[34] See: http://siteresources.worldbank.org/ENVIRONMENT/Resources/ESW_EcosystemBasedApp.pdf

[35] See: http://www.iucn.org/about/work/programmes/ecosystem_management/

[36] See: http://www.unep-wcmc.org/EAP/espa.aspx

[37] United Nations Convention on Biological Diversity (2000). See: http://www.cbd.int/

[38] Christensen et al (1996) Ecological Applications 6 (3) 665-691. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecological Applications: Vol. 6, No. 3, pp. 665-691. See: http://www.esajournals.org/toc/ecap/6/3

[39] See http://www.iucn.org/about/union/commissions/cem/cem_about/

[40] Grumbine (1997) Conservation Biology 11 (1) 41-47.

[41] See http://www.iucn.org/about/work/initiatives/climate_news/_/climate_change_and_ecosystem_management/

integrated approach that recognises the inter-connectivity between ecological, social-cultural, economic and institutional structures.

However, the pressures brought about by climate change require that an additional burden be placed upon ecosystems: to become management tools to regulate the climate through GHG control. As such we need to move beyond just thinking about ecosystems (and their associated management) as sources to ensure sustainable resource supply and use, but now look towards them as the backbone of all aspects of global climate regulation as well.

A great advantage of an ecosystems-based management approach is that it can utilise existing knowledge, both scientific and Indigenous, to realise the potential for bio-sequestration. By providing education for the rationale and incentives to support the protection and management ecosystems to optimise bio-sequestration, local communities can integrate their existing knowledge to achieve the multiple objectives for ecosystem use, including food and water security. This can be done in a cost effective way that is rapidly deployable.

It must be stressed that EM is not a single concept that can be applied to all ecosystems together. Instead it is a concept that, for successful practical management application, must be developed and tailored to suite individual ecosystem and societal resource use requirements (governed by the relevant goals, policies, protocols and practices). A protocol within EM is to use risk assessment frameworks, considers the climatic hazards, exposure, sensitivity and adaptive capacity of biophysical and socio-economic systems, and identify adaptation responses that can minimize potential risks. Whilst EM can be tailored to 'local solutions' they can work towards shared goals at the global level, to meet 'local needs within global level objectives'. Overall EM is, when applied at the global scale, one of as much an ethos as a scientific concept.

Ecosystem management is not a rejection of an anthropocentric for a totally biocentric worldview. Rather it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems[42].

6.1 What supports healthy ecosystems?

A key misconception is that biodiversity is itself an ecosystems service. It is not. Instead biodiversity is the key to supporting resilient, productive, and healthy functioning ecosystems and therefore underpins the provision of ecosystems services. Healthy ecosystems generally have a higher capacity to absorb GHGs. For example, in terrestrial ecosystems, species rich plant communities sequest more carbon than in communities where species loss has occurred[43]. Even greater potential for absorption lies is in restoring degraded ecosystems, due to rapid increase in net primary production.

It is a well recognized ecological science principle that ecosystems with high levels of biodiversity are more resilient to external shocks, such as extreme climatic events. Functional integrity is a key factor in healthy ecosystems, of which nutrient cycling plays an essential role. In terrestrial systems this is primarily determined by soil micro-organisms and fungi, hence it is vital that these communities of organisms are well researched and understood in order to adequately protect them.

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[42] Christensen et al 1996. See: http://www.esajournals.org/toc/ecap/6/3

[43] i.e. Brown University (2008, April 27). Biodiversity Is Crucial To Ecosystem Productivity.

However, the last 50 years have seen a substantial, unprecedented and irreversible loss of biodiversity due to human activities (land use change, habitat destruction and landscape fragmentation, agricultural practices etc). This extinction rate caused by humans is as much as 1000 times greater than the background rate that is typical over the Earth's history[44]. Some 10-30% of mammal, bird and amphibian species are threatened by extinction, and 38% of all described species of the major groups of organisms are currently considered as under threat[45]. The current decline in biodiversity and the related loss of ecosystem services will continue and in many cases even accelerating, a situation likely to worsen given climate change impacts and increasing human pressure. Some ecosystems are likely to be damaged beyond repair. Current trends in the loss of ecosystem services on land and in the oceans demonstrate the severe dangers that biodiversity loss poses to human health and welfare[46]. **These threats to biodiversity pose substantial risks to the functional ability of ecosystems to provide ecosystems services to humans, including climate regulation capacity**.

7 Climate change impacts on Ecosystems and vice versa

Ecosystem degradation, biodiversity loss, and consequent changes in ecosystem services lead to a decline in human well-being. The impacts of climate change on ecosystems are complex, threatening the very biological resources and ecosystems services on which humankind depends. The drivers include temperature increases, climatic zone shifts, melting of snow and ice (another form of positive feedback) , sea level rise, precipitation changes, droughts, floods and other extreme weather events. For immediate human well-being, the combined effects of climate change, land degradation and cropland losses, water scarcity and species infestations, mean water and food security is threatened. For example, projected changes in the frequency and severity of extreme climate events have significant consequences for food and forestry production, and food insecurity, in addition to impacts of projected mean climate (high confidence)[47]. Projected food yields may be between 5 to 25% short of demand by 2050 (with corresponding 30 to 50% increase in prices)[48].

The Arctic is witnessing reductions in perennial sea ice which is thinning and being replaced by seasonal ice. Tundra habitats are expected to become highly fragmented and reduced. Furthermore, enormous volumes of hydrocarbon gases (including methane – a potent greenhouses gas at 24 times more effective than CO_2), will likely escape once the sea rises above an as yet uncertain temperature threshold[49]. Protection of these sea beds from drilling and exploration is an imperative. On the southern extent of the Arctic, tundra will be replaced by coniferous boreal forest and scrublands. The reduction in tundra snow and ice cover is also expected to reduce the reflectance of solar radiation: dark soil and vegetation absorb more heat, whilst snow and ice reflect it. Warming will also most probably release carbon stored in the permafrost (see Figure 4).

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[44] Mooney and Larigauderie 2009 p15, in Richardson et al 2009 Synthesis Report. Climate Change: global risks, challenges and decisions Conference, 10-12 march 2009, Copenhagen

[45] IUCN Red Data List see: http://www.iucnredlist.org/static/stats#

[46] TEEB Interim Report 2009. See: http://ec.europa.eu/environment/nature/biodiversity/economics/

[47] Easterling et al 2007. Chapter 5, IPCC WGII AR4. See: See http://www.ipcc.ch/ipccreports/ar4-wg2.htm

[48] Nelleman et al 2009. The environmental food crisis – the environments role in averting future food crises. UNEP. See: http://www.grida.no/publications/rr/food-crisis/

[49] Richardson et al 2009. See: http://climatecongress.ku.dk/

7.1.1 Example of perspectives:

Soils hold in the region of 1500 Gt of carbon to a depth of one metre [50]. Mean yearly human emissions of carbon to the atmosphere from fossil fuel burning were 8.2 Gt of carbon in 2006[51]. The stock of carbon in soils is therefore many times greater than that of annual carbon emission by humans, and small changes in soil carbon stocks, especially in the highly organic soils in the north, could greatly increase yearly emissions of carbon to the atmosphere.

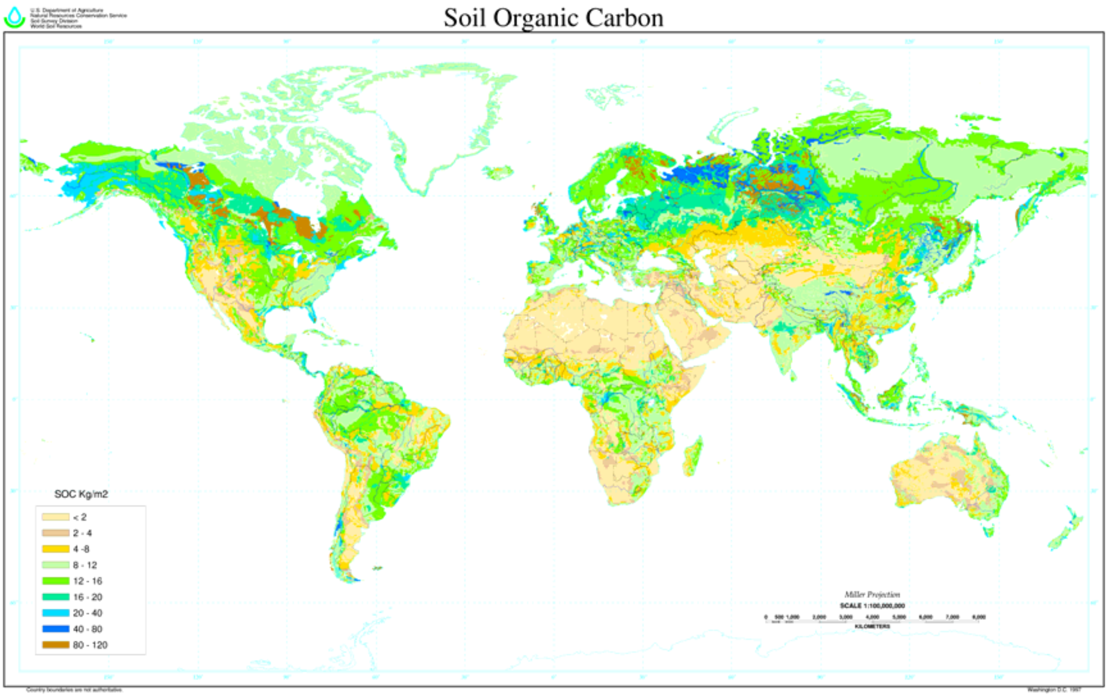

Figure 4. Global soil organic carbon distribution (to 1m depth)[52]

The map of soil organic carbon (Figure 3) shows the spatial distribution of carbon stocks around the world. The majority lies to the north of the Northern hemisphere, which is in contrast to the stocks of carbon in above- and below-ground vegetation (Figure 5 below) where the majority is within the tropics (and also areas of high biodiversity). Both these areas have high potential to become sources of GHG if managed inappropriately, but can also act as carbon sinks. The total amount of carbon stored in living organisms, soil organic matter and litter is estimated to be about 2100 Gt[53] (see Figure 6), or about 250 years worth of fossil fuel emissions (based on 8.5 Gt in 2007). Northern peatlands store about 450 Gt of carbon in c. 400 million hectares, and represents about one third of all soil carbon stocks, but can be sources of CO_2 and methane[54]. Hence the biotic components of Earth have substantial roles as stocks, sources and sinks of GHGs.

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[50] NRCS, see: http://soils.usda.gov/use/worldsoils/mapindex/soc.html
[51] CDIAC, see: http://cdiac.ornl.gov/ftp/ndp030/global.1751_2006.ems
[52] NRCS, see: http://soils.usda.gov/use/worldsoils/mapindex/soc.html
[53] Ruesch and Gibbs, 2008; IGBP-DIS, 2000
[54] Strack 2008. Peatlands and climate change. International Peat Society, Finland.

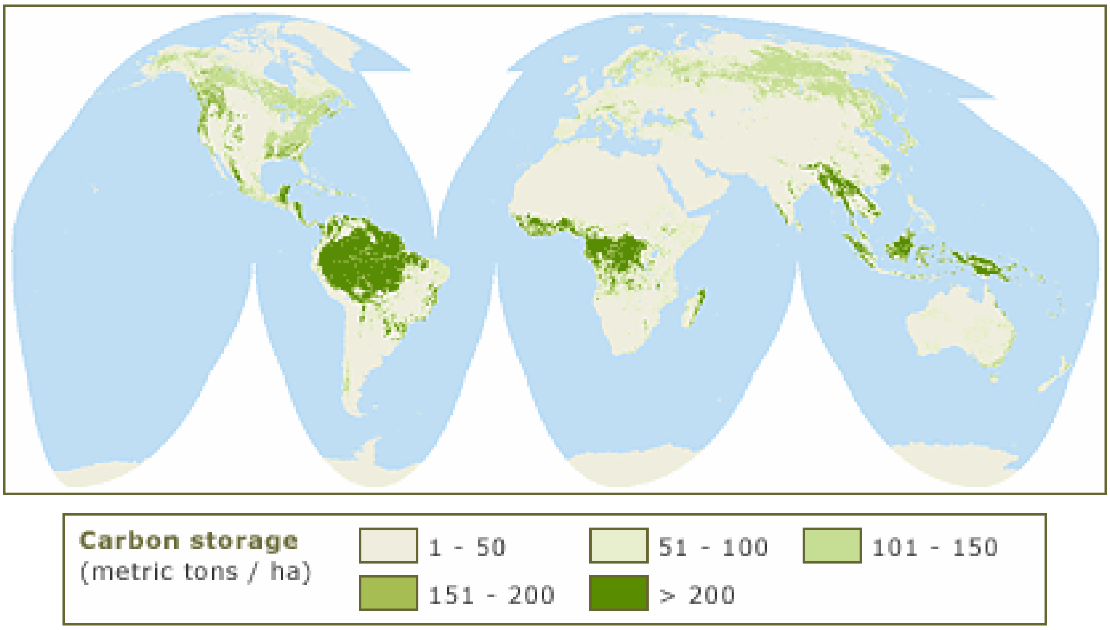

Figure 5. Global carbon storage in above and below ground vegetation (maximum of 250 tons / ha achieved in the tropics) [55].

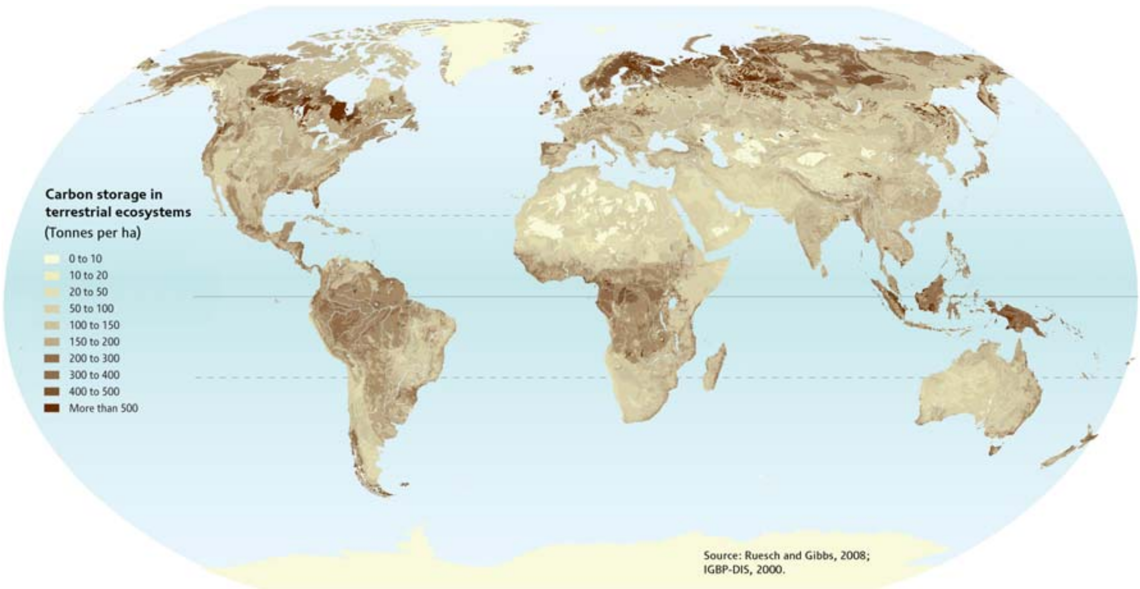

Figure 6 Terrestrial carbon storage, totalling about 2100 Gt in living organisms, soil organic matter and litter[56].

7.2 Ecosystem vulnerabilities

At the extreme of the altitudinal gradient, mountains have been identified as being very vulnerable to climate change. The Alps will experience warmer and wetter winters and dryer summers. The snow pack on mountains is close to its melting point and therefore particularly sensitive to temperature change. The Mediterranean, Africa, as well as western North American and Andean communities, will suffer from water scarcity and heat stress. Droughts will increase the incidence of wildfires, adding more CO_2 to the atmosphere.

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[55] Source: WRI, http://earthtrends.wri.org/maps_spatial/maps_detail_static.php?map_select=225&theme=3
[56] Ruesch and Gibbs, 2008; IGBP-DIS, 2000. Graphics; Riccardo Pravettoni, UNEP/GRID-Arendal

Climate change and its consequences present one of the most important threats to ecosystems and their functions and services. The current stress is far beyond the levels imposed by global climatic changes in the evolutionary past. Natural systems have limited adaptive capacity to such changes over a short period of time. Climate change will often alter and aggravate the impact of other pressures on ecosystems such as habitat fragmentation, degradation and loss, soil erosion, invasive species, pollution and over-exploitation. Ecosystem functions are not linear and there is a risk that continuing pressures will lead towards excedence of critical thresholds.

From a human perspective, key properties of ecosystems that are or will be affected by climate change are the values and services they provide as life support mechanisms. These include timber production, where the response to climate change depends on resource population characteristics as well as local conditions and may include large production losses. The impact on coral reefs threatens the vital ecosystem services these systems provide through fisheries and coastal protection. Climate change also affects the ability of terrestrial ecosystems to regulate water flows, and critically reduces the ability of many different ecosystems to sequester and/or retain carbon, which can feed back to intensify climate change. Healthy ecosystems, less stressed by “traditional” pressures such as pollution, over-exploitation, invasive species or habitat change are usually more resilient to climate change. For example the chances for bleached corals to recover are higher in unpolluted areas, where other environmental pressures are low.

Climate change is disrupting species interactions and other ecological relationships. For example temperature changes lead to earlier spring flowering, which comes too early for the pollinating insects. Such impacts threaten managed ecosystems on which many sectors depend, including agriculture, forestry, fishery, tourism, industry and others.

Temperature increase impacts on freshwater and marine ecosystems, which are often already weakened by over-exploitation and pollution. In the oceans, acidification due to absorption of atmospheric carbon dioxide adds an additional pressure, as it can interfere with calcium carbonate metabolism crucial to corals, molluscs, crustaceans, and many phytoplankton and zooplankton.

As ecosystem health declines, so do their resistance and resilience. A healthy and diverse forest is more resistant to storms, for example. Ecosystems with low resilience, when subject to shocks and disturbance, may reach thresholds at which abrupt change occurs. Similarly, the loss of reef protection against storm surge, together with sea level rise, will create socio-economic catastrophes in low lying islands and coastlines worldwide. The loss of reefs also leads to economic loss in the tourism sector which often constitutes an important source of income in these places.

Ecosystems play a direct role in climate regulation via physical, biological and chemical processes that control fluxes of energy, water and atmospheric constituents including the greenhouse gases. Peatlands (approximately 400 million hectares, or 3% of the land surface) and wetlands provide the most below ground carbon storage and tropical forests store the most above-ground biomass. Boreal forests, grasslands and agricultural land also play an important role.

Continuing, accelerating degradation of ecosystems will compromise their long term ability to regulate climate, may accelerate and amplify climate warming and could lead to additional, unforeseen and potentially irreversible shifts in the earth system.

8 Ecosystems' role in mitigation and adaptation to climate change

Healthy ecosystems are essential for climate change mitigation and adaptation, and currently perform services as fundamental life-support systems upon which human civilization depends. Many of those services we take for granted. However, climate change and other pressures including land-use change, pollution and over-exploitation adversely affect these mechanisms. If ecosystems collapse under climate-induced and other stresses, they may turn from sinks to sources of GHGs, which according to the last IPCC report may happen at a temperature increase between 2-2.5°C, the consequences are likely to be dramatic. This could nullify our efforts to reduce emissions. Specific measures will be necessary to allow ecosystems to adapt to climate change. Improved ecosystem management can enhance resilience to climate change, protect carbon stores and contribute to adaptation strategies.

Human society needs to learn to live within the constraints of ecosystem life support capabilities. Working with nature is an essential part of the solution. Maintaining and enhancing the resilience of natural ecosystems is our best and most cost-effective defence against climate change and a route towards long term sustainability. The two major tools for working with nature are ecosystem protection in the form of legally designated, effectively managed protected areas, and ecosystem management, in the form of sustainably managed land and seascapes that continue to ensure the provision of a wide range of ecosystem services.

Healthy ecosystems can go a long way towards mitigating the impact of extreme events such as floods, droughts and hurricanes, whilst also providing other services essential for human livelihoods. Protecting upper-catchment forests and restoring wetlands, for example, can reduce the risks from climate related floods and droughts, thereby protecting people's water supplies, welfare and helping to minimize catastrophes like landslides, and associated loss of life and properties and other assets. Investment in ecosystem resilience is likely to be highly cost-effective relative to alternative structural adaptations, such as dams and dikes.

8.1 Role of agriculture

Agriculture is a key component of both mitigation and adaptation, whilst also providing the essential food services to society. Agriculture emits greenhouse gases, particularly nitrous oxide (N_2O) and methane (CH_4) (about 296 and 24 times more effective than CO_2, respectively). Agriculture accounted for an estimated emission of 5.1 to 6.1 $GtCO_2$-eq/yr in 2005 (10-12 % of total global anthropogenic emissions of GHGs. Methane contributes 3.3 $GtCO_2$-eq/yr and nitrous oxide 2.8 $GtCO_2$-eq/yr. Of global anthropogenic emissions in 2005, agriculture accounted for about 60% of nitrous and about 50% of methane[57] emissions.

Despite large annual exchanges of CO_2 between the atmosphere and agricultural lands, the net flux is estimated to be approximately balanced, with CO_2 emissions around 0.04 $GtCO_2$/yr only. Emissions from land use clearance for agriculture are usually accounted for in the forestry sector (as deforestation), but if these emissions are added to the direct agricultural emissions,

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[57] Smith et al 2007. Chapter 8: Agriculture. WGIII, IPCC AR4. See: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter8.pdf

agricultural activity contributes 17-30% of all human greenhouse gas emissions[58] (Figure 7).

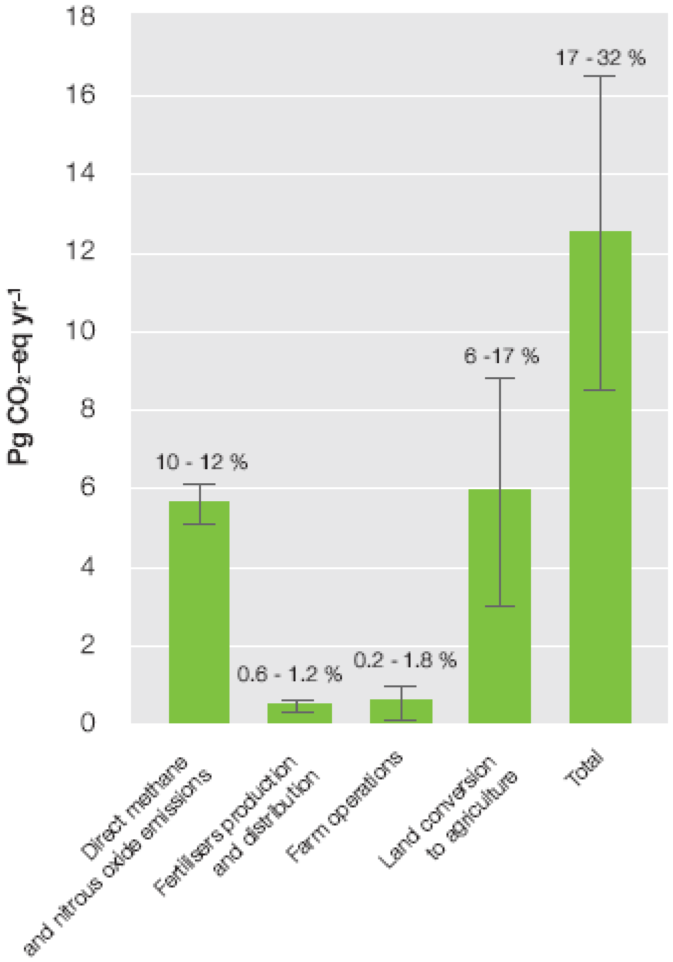

Figure 7. Greenhouse gas emissions associated with agriculture.
(Source Bellarby et al 2008)

Agriculture may also contribute to land degradation, genetic erosion, species loss and conversion of natural habitats[59]. Other impacts of agriculture on climate include indirect effects though surface albedo (the light reflected from the earth's surface), but the global impact is small compared to the radiative forcing from greenhouse gas emissions.

There is a significant potential for decreasing greenhouse gas emissions, and for creating carbon sinks, in agriculture. Considering all gases, the global technical mitigation potential from agriculture (excluding fossil fuel offsets from biomass) by 2030 is estimated to be ~5500-6,000 MtCO_2-eq/yr. Economic potentials are estimated to be 1500-1600, 2500-2700, and 4000-4300 MtCO_2-eq/yr at carbon prices of up to 20, 50 and 100 US$/t$CO_2$-eq, respectively (Figure 8). About 70% of the potential lies in developing countries, 20% in developed countries and about 10% in countries with economies in transition[60]. This potential

[58] Bellarby et al 2008. Cool Farming: Climate impacts of agriculture and mitigation potential. Greenpeace International, Amsterdam, The Netherlands. 43pp

[59] Nelleman et al 2009. The environmental food crisis – the environments role in averting future food crises. UNEP. See: http://www.grida.no/publications/rr/food-crisis/

[60] Smith et al 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society, B.

arises from carbon emission reduction / sequestration (89%), with mitigation of methane and nitrous oxide emissions from soils accounting for 9% and 2%, respectively, of the total mitigation potential[61].

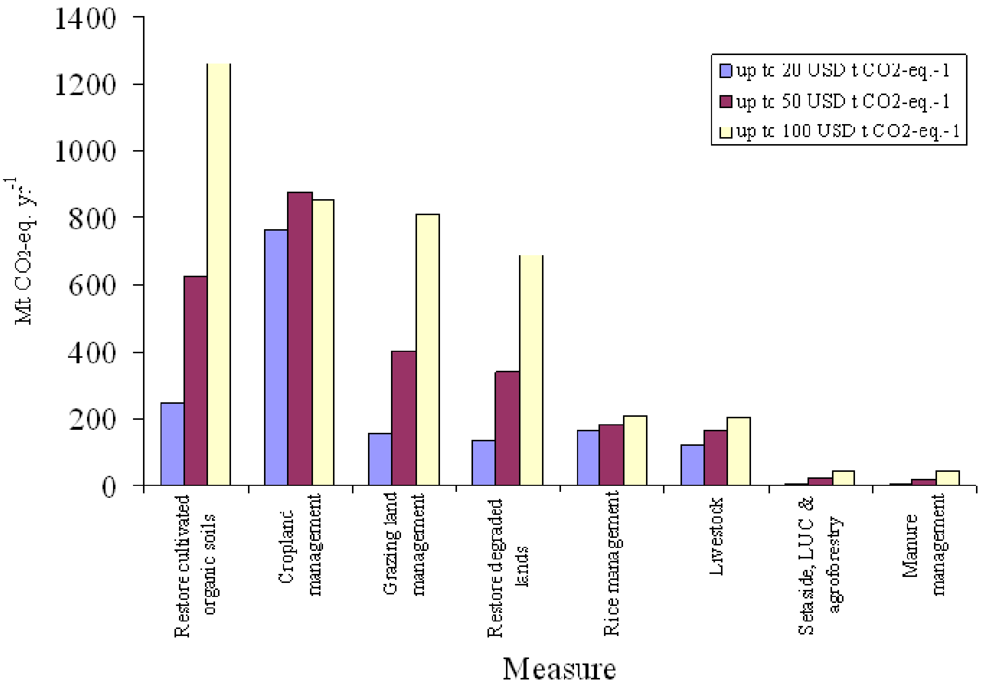

Figure 8. Global economic mitigation potential in agriculture at different carbon prices

8.2 Role of fresh water

Fresh water is *the* fundamental unit for life support in terrestrial systems. The impacts of climate change on water are vital both for human wellbeing and the functional processes of ecosystems. Changes to precipitation distribution patterns, frequency and magnitude of events (coupled with changes to other weather variables) impacts on the hydrological cycle and will determine water availability for both human and biodiversity use. Soil moisture has a strong influence on gaseous exchanges processes within many terrestrial ecosystems. For example, in peatlands, being wet or dry can make the difference between being a source or sink of GHGs[62]. Similarly, soil moisture determines vegetation growth capacity and hence the ability to capture CO_2. With human systems, climate change affects the function and operation of existing water infrastructure as well as water management practices (very high confidence)[63]. This illustrates the need for careful integration of multiple considerations (a trait of the ecosystems approach) to first establish the trade-offs between objectives, i.e. water supply versus maintaining wet soils to prevent GHG loss, and then devise appropriate management interventions, given that

363, 789-813

[61] Smith et al 2007. Chapter 8: Agriculture. WGIII, IPCC AR4. See: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter8.pdf

[62] Strack 2008. Peatlands and climate change. International Peatlands Society. Finland.

[63] Kundzewicz et al 2007: Freshwater resources and their management. Chapter 3, Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II IPCC AR4. See: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter3.pdf

climate change is only one of many pressures on freshwater systems. For example, 70% of global water withdrawals are for irrigation, as situation likely to increase given higher temperatures and lower rainfall in areas where irrigation occurs.

Ecosystems management complements the Integrated Water Resource Management (IWRM) approach, which amongst other things calls for the protection and restoration of natural systems. Examples include combining farming practices with biodiversity conservation and hydrology to manage river systems, helping to prevent flooding[64]. However, of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change[65].

Hence protection of water resources and the ecosystems that provide them needs to be a priority.

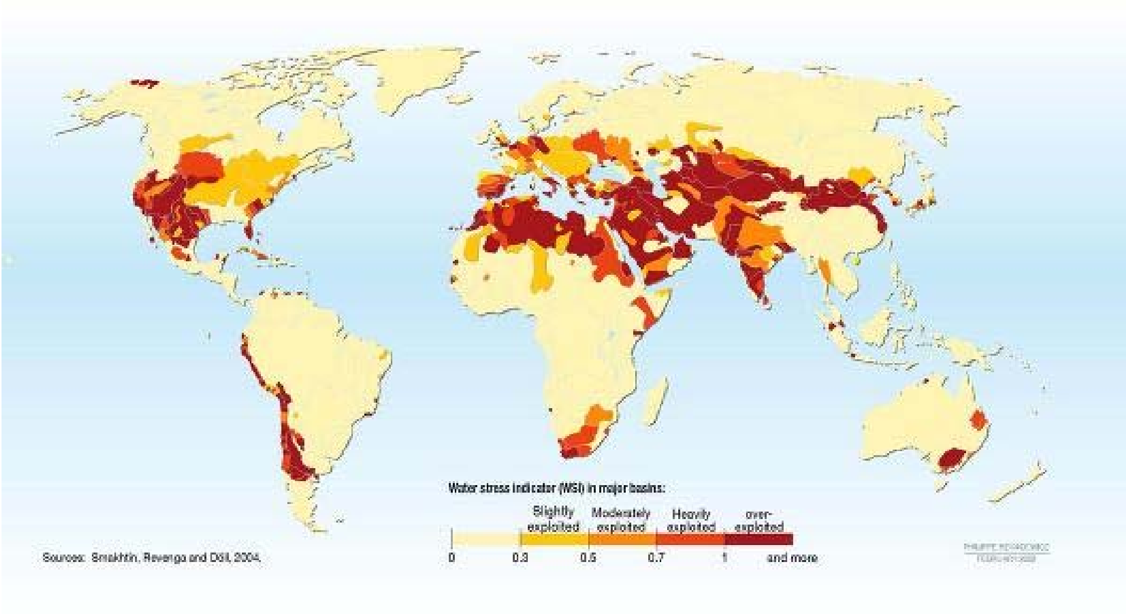

Figure 9. Water Stress Indicator illustrating over-exploitation.

Water stress and overuse is damaging the environment in many major basins. High overuse tends to occur in regions heavily dependent on irrigated agriculture, such as the Indo-Gangetic Plain in south Asia, the North China Plain and the High Plains of North America, and in areas undergoing rapid urbanization and industrial development. An estimated 1.4 billion people now live in river basin areas that are 'closed' (in that water use exceeds minimum recharge levels) or near closure. As millions of people in water-stressed areas are discovering, the environment is foreclosing on unsustainable water debts on an extensive scale[66]. Careful ecosystem management can help retain soil and ground water resources.

[64] Aquarius project. See: http://www.northsearegion.eu/ivb/projects/details/&tid=90

[65] Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, 155 pp. See; http://www.millenniumassessment.org/en/Synthesis.aspx

[66] UNEP. See: http://www.grida.no/publications/vg/water2/page/3240.aspx

9 Solutions

It is important to emphasise that the solutions are attainable. Some are relatively straight forward and could be developed immediately and at low cost[67], whilst others will need careful planning, development and large investments. Given the scale and complexity of the climate change issue, there is a risk that a 'no hope' impression is gained by society. Instead, as part of the CoP 15 negotiation process, there is need to inspire society to adapt to changes and take up the arising challenges. A vital step to achieve this is for the outcomes of the Copenhagen conference to inspire society to adapt by presenting a shared vision of the future where by human society has a sustainable relationship with the worlds' ecosystems.

Appropriate management of terrestrial and aquatic habitats can, therefore, make a significant contribution to reducing GHGs. For example, deforestation accounts for some 20% of global CO_2 emissions[68]. Reducing emissions from deforestation will be essential for our objective of limiting global warming to 2°C. It is a cost-effective way to combat climate change, and clearly benefits ecosystems conservation, ecosystem services and the livelihoods of the poor.

A clear example of this comes from the Eliasch Report, which states "The cost of halving global carbon emissions from 1990 levels could be reduced by up to 50% in 2030 and by up to 40% in 2050 if the forest sector is included in a [carbon] trading system. This is due to the relatively low cost of forest abatement compared to mitigation in other sectors. These lower costs could also allow the international community to meet a more ambitious global emissions target".

Four complementary strategies must be pursued:

1). Political commitment. There must be a sense of urgency to raise the profile of ecosystems in climate change policy setting at local, national and international levels.

2). Investment. There must be explicit inclusion of investments related to ecosystem management and ecosystem protection, especially as part of a Global Climate Change Fund. The scale of investment must be commensurate with the value of the ecosystems services.

3). Incentives. There must be a deliberate focus on introducing incentives to reduce emissions, ease existing pressures on ecosystems and support technological changes that increase environmental resilience and resource sustainability, including incentives for increased land and water protection.

4). Information. There must be a solid commitment to establishing comprehensive information, while at the same time fostering closer links between ecosystem management, climate-change adaptation and disaster risk reduction communities, as well as between science, economics and policy. In addition, there must be increased information sharing between countries, including North-South and South-South exchanges. Monitoring of crucial environmental variables and processes related to ecosystem-based climate change adaptation and mitigation must be expanded and supported over the long term.

The following are seen as some of the fundamental solutions in support of the four complementary strategies above:

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[67] Illustrated by marginal abatement cost curves, i.e. Kammen 2007. The benefits of decarbonising the economy. In Richardson et al 2007. See: http://climatecongress.ku.dk/

[68] Parry et al 2007. WGII IPCC AR4. See: http://www.ipcc.ch/

- Addressing market failures through appropriate valuation of ecosystems and the services they provide[69]. A fundamental shift is required away from valuing *private* goods and services towards valuing public benefits of ecosystems (*All strategies*).
- Continue development of funding mechanisms to support inclusion of ecosystem-based solutions for mitigation and adaptation, capacity building and innovation[70]. (*Strategy 2 – Investment*).
- Greater integration between knowledge of economics, ecosystems and their management at governmental level, recognizing the limitations on human activity posed by ecosystem capacity. (*Strategy 1 – Political commitment*).
    - Greater balance within governments' knowledge capital between traditional economics and ecological economics.
- Foster approaches of 'local solutions for global problems', and 'meeting local needs within global level objectives'. This requires a global over-arching ethos of conservation, sustainable resource use and knowledge of ecosystem functions and processes influencing GHG fluxes. (*Strategy 3 - Incentives*)
- Promote public education. People need to know the consequences of their actions in order to know how to make informed decisions affecting their lifestyles and consumer choices. Society also needs to be better aware of why governments aim to change individuals' behaviour, through better up-dates on the state of the climate and ecosystem health. (Strategy 4 – Information).
- Assured funding for environmental protection. To ensure appropriate protection of ecosystems and services, a secured funding mechanism is needed to insure against variation in the global economy. It must provide long-term support for protection and restoration efforts. (*Strategy 2 – Investment*).
- Ensure livelihoods of people affected by changes in ecosystem management are compensated.

Terrestrial systems:

- Develop and enforce appropriate ecosystem protection measures.
- Understand and live within the constraints of ecosystems and services.
- Reduce rates of deforestation and support active restoration.
- Link ecosystem management with an Integrated Water Resource Management approach.
    - As a priority, protect fresh water resources and ecosystems processes that provide them.
- Support farmers and other land managers in developing diversified and resilient eco-agriculture systems that provide critical ecosystem services[71].
- Improve food energy efficiency to reduce pressures on ecosystems.

[69] TEEB – The Economics of Ecosystems and Biodiversity.
[70] World Bank. http://siteresources.worldbank.org/ENVIRONMENT/Resources/ESW_EcosystemBasedApp.pdf
[71] Nelleman et al 2009. The environmental food crisis – the environments role in averting future food crises. UNEP. See: http://www.grida.no/publications/rr/food-crisis/

- Comprehensive monitoring of ecosystem health and functional processes.

Oceans:

- Develop a better understanding of oceanic processes:
  - Circulation, ocean-atmospheric exchanges.
  - Species responses to altered temperature and pH.
- Use natural systems for sea level rise and storm surge defence.
- Regulate the transfer of materials from land to sea, such as pollution and eroded soil.

The key to many of these solutions in terms of practical application, is using local indigenous knowledge. Fundamentally, people adopt new ways of doing things if,

a. There is an economic benefit,
b. There is a clear rationale as to why change is needed.

To making effective change there is the need for investment and education.

The following are recommended:

- Ensure ecosystem-based adaptation is an integral component of climate change discussions, at international, national and regional scales.
- Recognize and fully value the role of healthy ecosystems in climate change mitigation and adaptation.
- Emissions from ecosystems and the GHG stocks they store need to be included in the sectors reported by the UNFCCC (adding to the human induced sectors).
- Existing stocks of carbon in ecosystems (soils, vegetation) must be protected and prevented where possible from causing further emissions.
- Enhance ecosystem sink potential and avoid source risk (i.e. reduce deforestation).
- Recognise the global 'public good' of ecosystem interactions and ecosystem services which transcend national boundaries.
- Align climate change policies with other relevant conventions, including habitat, water and biodiversity conventions.
- Incorporate ecosystem-based adaptation into National Adaptation Plans of Action (NAPAs).
- Encourage funding for national and local level projects that strengthen ecosystem resilience and help build adaptation capacity in human systems.
- Emphasize strategies that promote:
  - Legally-designated and effectively managed protected areas.
  - Integrated landscapes of sustainable land uses, as the two primary vehicles of ecosystem-based climate change adaptation.
- Support research and action on:
  - Climate-ecosystems interactions and feedbacks.
  - Ecosystem processes and functions.
  - Developing education, training and communication.

10 Investing in Ecosystem management- gate way to "greening" economies

The sustainable use and conservation of ecosystems must be integrated into all sectors. These include agriculture, forestry, fisheries, the built environment, river and coastal flood management, tourism and leisure, health, and particularly energy and economic development programmes, policies and practices. This integration (alongside new developments in energy production and use) can foster the establishment of a "green economy" (low carbon) to achieve connectivity in the wider landscape and seascape, which is crucial to the maintenance of healthy, resilient ecosystems capable of providing the services on which we depend. Green Infrastructure networks ensure that critical habitats are connected and help to sustain forests, farms and other working lands. Another asset of the green economy is its multi-functionality. For example, a wetland provides water regulation and purification, CO_2 storage and provides natural wildlife habitats and a place for recreation and leisure.

Developments in non-fossil fuel based energy and a reduction of society's dependence on fossil fuels will alter existing economic models. This provides opportunities to re-target job growth in a world where leveraging natural capital is both an increasing constraint and an under-invested opportunity. Jobs can be created in sustainable agriculture, forestry and fishing, along with conservation-based businesses. There is some progress in "greening" parts of the world, for example in Africa, despite the continent's many challenges. The Kenyan government is taking steps to address the Mau Forest which is severely stressed. Afforestation (and other forms of habitat restoration) is about enhancing life, peace and hope and creating livelihoods for the poor. It can help stabilize availability of fresh water so critical to people and to agriculture.

Beyond the recent bailout of financial firms and the design of the future international financial planning and infrastructure, world leaders must take bold measures to resolve the multiple crises plaguing humankind. A total of around one percent of global GDP, that is around $750 billion, invested in such greening initiatives over the next two years would provide the critical mass of investment needed to kick start a 'green economy' across many nations. This is essential as a vital step to over-come the 'north-south' divide in dealing with the climate change issue, which is seen as primarily caused by the north.

11 The climate change-ecosystems nexus: from Science to Policy and to Action.

The facts shown above make clear the central role of ecosystem management in climate change mitigation, adaptation, disaster risk reduction and sustainability, which are significant priorities in the international environmental and political agenda such as that of the UNFCCC. However, while the scientific basis is clear, corresponding policies need to be more explicit and action on the ground needs to be enhanced.

The science is clear and calls for action, yet there is no explicit recognition of the role of ecosystems or actionable policies set in the UNFCCC or its Bali Action Plan agreed at COP13. Though ecosystem management has been recognized as an essential element of reducing underlying risk factors, efforts at environmental management for disaster risk reduction/climate change adaptation have been largely ad hoc. Amongst the multilateral environmental agreements, only the Convention on Biological Diversity (CBD) through its Ad

Hoc Technical Expert Group on biodiversity and climate change has started addressing the linkages between ecosystem management, climate change adaptation and disaster risk reduction. Also the Ecological Society of America (ESA) in its latest statement on economic growth highlighted the importance of ecosystems and why it should feature in all economic decisions[72].

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

Crucially, the Copenhagen outcomes need to signal explicitly an intention towards adopting an ecosystems approach so as to attract both public and private investment.

11.1 Human Dimensions

The debate of GHG emission reductions from human activity is primarily focused on industrialised countries and those with high energy consumption. Many people from such countries are based in urban environments and may have limited scope for pro-active ecosystem management. To balance this, there is a requirement for a large shift in an individuals' behaviour in terms of consumer choice and lifestyles, aspirations and expectations. Conversely, there is a very large percent of the world population who contribute little to GHG emissions and are primarily involved in agriculture in developing countries. There is need therefore to implement a Treaty that contains outcomes that people (particularly in developing countries) can relate to in terms of their use of the environment. Ecosystem management relates to such peoples' realm of decision making. Therefore policies need to address their needs whilst providing them with the opportunity and reason (through education) to utilise their skills and management practises to activate ecosystem mitigation potential and minimise emissions risks.

When the ecosystems approach becomes part of the CoP 15 negotiation process, it will be necessary to be cognisant of issues of governance (such as the cultural theory concept) and land tenure. It will be necessary to understand how different people will respond to the dynamics of developments (climate change impacts, policies, economics) and how efforts to mitigate and adapt need to vary according to the social groups. Hence there is an important need for integration between social and environmental sciences and economics and policy analysis.

11.2 Need for a 'Globally Inclusive process'

Emphasis should be put on Win-Win and no regret measures, for example, the development of "green infrastructures/economy". This implies intense collaboration between the ecosystems, climate change and Disaster Risk Reduction communities on local,

[72] See http://www.esa.org/pao/economic_activities.php

regional, national and international levels. Ecosystems affect many economic sectors such as energy, agriculture, forestry, fisheries and water. Therefore we need a conceptual framework to develop localised policies aimed at international level objectives. This also requires appropriate resources for policy implementation. It is essential to make sure that the climate change-ecosystem nexus is fully recognized across all sections of society and that there is complementarity with other policies to contribute to conservation and sustainable use of ecosystems. This reduces our vulnerability to climate change, increases ecosystem resilience and maintains future options to manage climate change impacts.

Improved integrated scenarios and simulation models to increase our knowledge on climate change impacts on biodiversity and ecosystems are key assets. Good models require long-term monitoring of real systems and data collection, appropriate calibration and validation, output data sharing and meaningful dialogue on the the probable outcomes. We also need fundamental process investigations of synergistic effects of climate change and other pressures on ecosystems. Better knowledge is also needed on ecosystem functions underlying the regulation of climate with a view to positive feedbacks and tipping points in the climate system.

12 Key messages: What the UNFCCC and its parties can do in the Copenhagen process

It is clear that many countries have been quick to show commitment to climate change adaptation and disaster risk reduction. However, the role of ecosystem management, though central to both climate change adaptation and disaster risk reduction, has yet to be well recognized at the political level in all countries. In recent years, several Parties to the UNFCCC have started to recognize the central role of ecosystem management in climate change adaptation and disaster risk reduction, and called for ecosystem-based adaptation in the context of the Long-term Cooperative Actions (LCA) at the 14th Conference of the Parties in December 2008. More work however needs to be done before this recognition becomes the consensus of all the Parties to the UNFCCC. CoP 15 in Copenhagen in December 2009, from which the world is eagerly expecting a post-2012 climate change agreement, will provide a crucial opportunity for increasing the profile of ecosystem management and highlighting its important role in climate change mitigation, adaptation and disaster risk reduction and ultimately, long-term sustainability.

Under the Ad hoc Working Group- Long-term Cooperative Actions (AWG-LCA) Parties should:

- Intervene to ensure that ecosystem management should be integrated, along with community-based adaptation and valuing traditional knowledge, into the ‘Enhanced Action on Adaptation’. Approaches that help to maintain the integrity of ecosystems, their functions and the services they provide need to be embedded within the objectives, scope and guiding principles, in implementation of adaptation action including technology transfer, linked to risk reduction and management, and institutional arrangements.
- Call for the importance of healthy ecosystems to be acknowledged in ‘A Shared Vision For Long Term Cooperative Action’, drawing on Article 2 of the UNFCCC.
- Parties should call for relevant aspects of negotiations under the UNFCCC, such as

adaptation, REDD[73] and LULUCF[74] to be better informed by and aligned with ongoing climate change work and agreements under the Convention on Biological Diversity (CBD), the UN Convention to Combat Desertification, the Ramsar Convention on Wetlands and other relevant international commitments.

- Within guidelines for adaptation funding, Parties should ensure that the value and importance of ecosystems is effectively recognised and addressed to safeguard the fundamental earth processes upon which we all depend, and to help prevent mal-adaptation and deliver no regret and multiple benefit measures, particularly in support of developing country needs.
- Developed and Annex 1 countries must meet their current commitments and provide the resources necessary for immediate implementation of the NAPAs, and with this support 'learning by doing', including on the role of ecosystems in adaptation.
- Encourage the Adaptation Fund Board and governments to allocate funds to community-level projects that strengthen local ecosystem resilience and reduce local peoples' vulnerability to climate change. Here there is need to fund capacity building for adaptation within diverse human society groups.
- Emphasize strategies that promote a) legally-designated and effectively managed protected areas and b) integrated landscapes of sustainable land uses, as the 2 primary vehicles of ecosystem-based climate change adaptation.

People, biodiversity and ecosystems are at the heart of the climate system and therefore, must be part of the solution. Urgent action now to halt further loss and degradation of ecosystems will help to maintain future options for reducing the extent of climate change and managing its impacts. Working with nature offers opportunities to engage people on a large scale and opens up ways for economic development in a sustainable manner. ***UNFCCC Parties need to build this principle into the adaptation outcomes from Copenhagen and into national strategies for delivery.***

13 Conclusions

The imperative at the UNFCCC Conference of the Parties 15 in Copenhagen is to negotiate a viable Treaty for the reduction of greenhouse gas emissions from human activity. However, in this paper we have shown that due consideration is required to the role that ecosystems play in supporting all life on Earth, including climate regulation. Ecosystems have the capacity to act as both sources and sinks of greenhouse gases. It is clear that utilisation of this natural capacity of ecosystems to regulate the climate has to be factored into the equation of climate stabilisation (Figure 1). *Without* considering the role ecosystems have and focusing solely on reducing human emissions risks addressing only one side of a three way balance between Human and ecosystem emissions on one side, and ecosystem absorption capacity on the other. Human induced greenhouse gas emissions are increasing while ecosystem absorption capacity is declining. Such a situation increases the probability of inducing positive feedback mechanisms that will lead to further climate destabilisation.

[73] REDD – Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme). See: http://www.undp.org/mdtf/un-redd/overview.shtml

[74] Land Use and Land Use Change and Forestry. See: http://unfccc.int/methods_and_science/lulucf/items/1084.php

Furthermore, ecosystems supply the fundamental units of life support, by providing ecosystem services, principally: clean air and water, food and shelter. These ecosystem services are under increasing pressure and threat of further degradation. As climate change and other pressures bring to bear increasing stresses, we need to ensure that ecosystems no longer degrade. We must ensure that they remain healthy and fully functional in order to provide the vital ecosystem services we rely on.

An ecosystem-based adaptation approach is not a panacea for all these problems. It is one however, that when integrated with other strategies working towards the same goals (climate stabilisation, poverty alleviation and sustainability), forms the foundation for a successful integrated strategy for climate change risk reduction. An ecosystem based approach also serves as the foundation in developing a 'green' economy. Ecosystem management acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems.

The arguments presented in this paper in support of including ecosystem management within negotiations, reinforces the need for a successful Copenhagen Treaty. The inclusion of an ecosystems management approach as part of the Treaty should be seen as complementary to setting emissions targets and regulations. The greatest challenge for governments and global leaders is to adjust national and international economies in line with mitigation and adaptation efforts whilst maintaining financial stability. Use of the climate regulation capacity and other life support services of ecosystems can help economies, financial institutions and societal behaviour to make those adjustments in a transition towards a green low carbon economy. Fundamentally, ecosystems form the foundation of life support and hence require appropriate protection and management.

Imperative

The imperative for the Copenhagen 15th Conference of the Parties still remains to agree a Convention to regulate GHG emissions from human activity. The arguments presented here supporting the inclusion of ecosystem management reinforces the need for a successful agreement. The inclusion of an ecosystems management approach as part of the Convention should be seen as complementary to setting emissions regulations. As climate change brings to bear additional stresses, we need to ensure that ecosystems no longer degrade. We must ensure that they remain healthy and fully functional in order to provide the vital ecosystem services we rely on.

The greatest challenge for governments and global leaders is to adjust national and international economies in line with mitigation and adaptation efforts whilst maintaining financial stability. Use of the climate regulating capacity and other life support services of ecosystems will help economies, financial institutions and societies to make those adjustments in progress towards a sustainable economy. Fundamentally, ecosystems form the foundation of life support and hence require appropriate protection and management.

It is vital therefore that the issue of ecosystem management be included in the CoP15 agenda.

Appendix A. Overview of the ecosystems approach.

The following description of the ecosystems management approach is from Christensen et al (1996)[75]. The concept has been developed by many researchers since 1996, but this extract serves to set the basis for understanding the concept:

Ecosystem management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function. In recent years, sustainability has become an explicitly stated, even legislatively mandated, goal of natural resource management agencies. In practice, however, management approaches have often focused on maximizing short-term yield and economic gain rather than long-term sustainability. Several obstacles contribute to this disparity, including:

(1) Inadequate information on the biological diversity of environments; (2) widespread ignorance of the function and dynamics of ecosystems;

(3) The openness and interconnectedness of ecosystems on scales that transcend management boundaries;

(4) A prevailing public perception that the immediate economic and social value of supposedly renewable resources outweighs the risk of future ecosystem damage or the benefits of alternative management approaches.

The goal of ecosystem management is to overcome these obstacles. Ecosystem management includes the following elements:

(1) Sustainability. Ecosystem management does not focus primarily on deliverables" but rather regards intergenerational sustainability as a precondition.

(2) Goals. Ecosystem management establishes measurable goals that specify future processes and outcomes necessary for sustainability.

(3) Sound ecological models and understanding. Ecosystem management relies on research performed at all levels of ecological organization.

(4) Complexity and connectedness. Ecosystem management recognizes that biological diversity and structural complexity strengthen ecosystems against disturbance and supply the genetic resources necessary to adapt to long-term change.

(5) The dynamic character of ecosystems. Recognizing that change and evolution are inherent in ecosystem sustainability, ecosystem management avoids attempts to freeze" ecosystems in a particular state or configuration.

(6) Context and scale. Ecosystem processes operate over a wide range of spatial and temporal scales, and their behaviour at any given location is greatly affected by surrounding systems. Thus, there is no single appropriate scale or time frame for management.

(7) Humans as ecosystem components. Ecosystem management values the active role of humans in achieving sustainable management goals.

[75] Christensen et al 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecological Applications: Vol. 6, No. 3, pp. 665-691. See: http://www.esajournals.org/toc/ecap/6/3

(8) Adaptability and accountability. Ecosystem management acknowledges that current knowledge and paradigms of ecosystem function are provisional, incomplete, and subject to change. Management approaches must be viewed as hypotheses to be tested by research and monitoring programs.

The following are fundamental scientific precepts for ecosystem management.

(1) Spatial and temporal scales are critical. Ecosystem function includes inputs, outputs, cycling of materials and energy, and the interactions of organisms. Boundaries defined for the study or management of one process are often inappropriate for the study of others; thus, ecosystem management requires a broad view.

(2) Ecosystem function depends on its structure, diversity, and integrity. Ecosystem management seeks to maintain biological diversity as a critical component in strengthening ecosystems against disturbance. Thus, management of biological diversity requires a broad perspective and recognition that the complexity and function of any particular location is influenced heavily by the surrounding system.

(3) Ecosystems are dynamic in space and time. Ecosystem management is challenging in part because ecosystems are constantly changing. Over time scales of decades or centuries, many landscapes are altered by natural disturbances that lead to mosaics of successional patches of different ages. Such patch dynamics are critical to ecosystem structure and function.

(4) Uncertainty, surprise, and limits to knowledge. Ecosystem management acknowledges that, given sufficient time and space, unlikely events are certain to occur. Adaptive management addresses this uncertainty by combining democratic principles, scientific analysis, education, and institutional learning to increase our understanding of ecosystem processes and the consequences of management interventions, and to improve the quality of data upon which decisions must be made.

Ecosystem management requires application of ecological science to natural resource actions. Moving from concepts to practice is a daunting challenge and will require the following steps and actions.

(1) Defining sustainable goals and objectives. Sustainable strategies for the provision of ecosystem goods and services cannot take as their starting points statements of need or want such as mandated timber supply, water demand, or arbitrarily set harvests of shrimp or fish. Rather, sustainability must be the primary objective, and levels of commodity and amenity provision must be adjusted to meet that goal.

(2) Reconciling spatial scales. Implementation of ecosystem management would be greatly simplified if management jurisdictions were spatially congruent with the behaviour of ecosystem processes. Given the variation in spatial domain among processes, one perfect fit for all processes is virtually impossible; rather, ecosystem management must seek consensus among the various stakeholders within each ecosystem.

(3) Reconciling temporal scales. Whereas management agencies are often forced to make decisions on a fiscal-year basis, ecosystem management must deal with time scales that transcend human lifetimes. Ecosystem management requires long-term planning and commitment.

(4) Making the system adaptable and accountable. Successful ecosystem management requires institutions that are adaptable to changes in ecosystem characteristics and in our

knowledge base.

Adaptive management by definition requires the scientist's ongoing interaction with managers and the public. Communication must flow in both directions, and scientists must be willing to prioritize their research with regard to critical management needs. Scientists have much to offer in the development of monitoring programs, particularly in creating sampling approaches, statistical analyses, and scientific models. As our knowledge base evolves, scientists must develop new mechanisms to communicate research and management results. More professionals with an understanding of scientific, management, and social issues, and the ability to communicate with scientists, managers, and the public are needed. Ecosystem management is not a rejection of an anthropocentric for a totally biocentric worldview. Rather it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the functioning of ecosystems.

Appendix B. Examples of existing adaptation programmes

Established adaptation programmes that integrate ecosystems fall into two main categories

- Those that focus on enhancing the adaptive capacity of ecosystems.
- Those that take advantage of the ecosystem services in order to adapt to impacts of climate change on livelihoods.

Adaptation programmes in forest ecosystems include: implementing soil conservation measures; extending rotation cycles in production forests; accommodating forest development to changing conditions; adaptive fire management including maintaining natural fire regimes where possible; enhancing resilience of managed forests by increasing the diversity of species, age, and spatial distribution; protecting primary forests; and identifying and protecting 'functional' groups of ecologically important species.

As an example of the application of adaptation programmes in forest ecosystems, Canada developed its National Forest Strategy to enhance sustainable forest management. In response to threats to forest ecosystems from climate change, including the expansion of diseases and pest species, Canada applied criteria for sustainable forest management including: the conservation of biodiversity, maintenance of forest productivity, maintenance of forest ecosystem health, and conservation of soil and water resources. This was done in order to enhance resilience in the face of projected climate change impacts on forest ecosystems[76].

Adaptation programmes that consider ecosystems within agricultural ecosystems and grasslands include: conserving agricultural genetic resources, reducing other threats to farmland biodiversity, restoring degraded land by reintroduction of native species and reduction of invasive exotics, integrating land and water management, establishing disease control programmes for native livestock, and invasive species management.

In Maharashtra, India, such an approach was applied at the watershed level in response to projected increased frequency and intensity of droughts in arid agricultural ecosystems. Local communities in the area planted native trees and vegetation to stabilize waterways, developed management plans to allow for regeneration of degraded areas and devolved resource management decisions to the lowest level possible[77]. This was done in order to ensure the continued provision of ecosystem services, especially water cycling, despite increased pressures on such services as a result of climate change.

Other adaptations include, changes to cattle feed regimen to reduce methane emissions, zero tillage, organic production systems, anaerobic digesters for energy generation from livestock waste.

Adaptation programmes that consider marine and coastal ecosystems include: improving management of sewage discharge; restoring degraded coastal ecosystems; establishing marine protected areas; enhancing monitoring programmes; developing pollution contingency plans; diversifying livelihoods in coastal communities; and economic valuation of marine and coastal resources.

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[76] Growth and dieback of Aspen forests in north-western Alberta, Canada in relation to climate and insects E.H. Hogget et al. 2002, Canadian Journal of Forest Research, v. 32, p. 823-832

[77] Watershed Management: A Sustainable Strategy for Augmenting Water Resources and Mitigating Climate Changes. Watershed Organisation Trust, 2003

As an example of implementation of such an approach, in the Mekong Delta in Vietnam, following the draining and destruction of wetlands, rehabilitation of the hydrology and functions of the wetland forest system was integrated with a mixed cropping and forest product management system. This approach built on and modified a model that divides the degraded wetlands into 10-hectare units: 7.5 hectares devoted to replanting native wetland species and 2.5 hectares allocated to agriculture[78]. The intact coastal wetlands, in addition to providing habitat and livelihoods, also act as a buffer against storm surges which are expected to become more frequent and intense as a result of climate change.

In Samoa[79], the replanting of mangroves is an integral part of a large restoration project to enhance food security and protect local communities from storm surges. In Uruguay, the development and climate change strategy recognizes that natural resource management is a critical link in efforts to both adapt to and mitigate climate change [80].

In Southern Africa, the tourism industry was valued at US$3.6 billion in 2000. However, the IPCC projects that between 25 and 40% of mammals in national parks will become endangered as a result of climate change. As such, the National Climate Change Response Strategy of the Government of South Africa includes interventions to protect plant, animal and marine ecosystems[81]. Similarly, the Integrated National Adaptation Project in Colombia will implement adaptation measures, including through ecosystem planning and management, to maintain biodiversity assets for the benefit of ecosystem and ecosystem-based livelihoods[82].

Finally, particular adaptation measures in the field of nature conservation include actions to stabilize genetic, species and ecosystem diversity, to preserve natural carbon sinks and to improve local climate. Preserving an abundance of organisms (plants, animals, micro-organisms) and multiple groups performing similar functions is important for maintaining resilience. A diversified portfolio of "insurance" species provides back-up if some species decline. Crucially, higher genetic and species diversity tends to make ecosystems more resistant and resilient to disturbance. This is because species are likely to be present with characteristics that can survive and perform under a range of environmental conditions, allowing the ecosystem to adjust to change and to maintain the provision of critical services such as water purification. Diverse crops and surrounding ecological zones can defend and buffer integrated agro-ecosystems in the face of weather extremes, pest infestations and invasive species. The feasibility and success of these measures depend on the availability of sufficient land areas and water resources reserved for nature conservation measures.

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78 Integrated Marine and Coastal Area Management Approaches for Implementing the Convention on Biological Diversity. Convention on Biological Diversity, 2004

79 Community Based Adaptations: Samoa. See: http://sdnhq.undp.org/gef-adaptation/projects/websites/index.php?option=com_content&task=view&id=252&sub=1

80 Development and Climate Change in Uruguay: Focus on coastal zones, agriculture and forestry. OECD 2004.

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