The Economics of Ecosystems & Biodiversity

CLIMATE ISSUES UPDATE

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TEEB Climate Issues Update

Executive summary

This update from our TEEB study presents a sub-set of early conclusions which relate to climate change. A fuller report on these and several other areas of relevance to national and international policy-makers will be published in November 2009. However, in view of the climate change conference in Copenhagen, Denmark, in December 2009, we thought it appropriate to publish our climate-related conclusions and recommendations more urgently for policy-makers, negotiators, and the general public.

At the close of the first phase of TEEB, in May 2008 we presented our preliminary conclusions as an 'Interim Report'. In this report, we assessed the economic magnitude of the human welfare impacts of losing natural areas, especially forests. We described in economic terms the fundamental links between eliminating poverty and conserving biodiversity and ecosystems. We highlighted ethical issues underlying the choice of discount rates to evaluate the benefits of wild nature for human welfare. We also prepared the ground for Phase 2 of TEEB with some preliminary analysis of the policy implications of available economic evidence. Lastly, we spelt out our main ambition for Phase 2 of TEEB, which is to help 'mainstream' the economics of ecosystems and biodiversity. To this end we are preparing a comprehensive study of the ecological and economic foundations of knowledge in this arena, together with four publications targeted at key groups of end-users: policy-makers, administrators, businesses and citizens (see box on the TEEB process, page 4).

In September, we will place on our website (www.teebweb.org) for public comment draft chapters on the ecological and economic foundations of TEEB. However, this draft does not (and is not meant to) address topical issues of the 'science-economics-policy' interface with which we are also dealing in TEEB. Hence this *TEEB – Climate Issues Update*.

The negotiations in Copenhagen in December 2009 could be a watershed for three issues addressed by TEEB in our forthcoming report for policy-makers:

- We face the imminent loss of **coral reefs** due to climate change, with all the serious ecological, social, and economic consequences this will entail.
- Forests perform a valuable function in capturing and storing carbon. An early and appropriate agreement on **forest carbon** would be a significant opportunity to mitigate climate change. It would also set the stage for related mechanisms to reward other ecosystem services from forests.
- There is a compelling cost-benefit case for public investment in **ecological infrastructure** (especially restoring and conserving forests, mangroves, river basins, wetlands, etc.), particularly because of its significant potential as a means of adaptation to climate change.

[1]At the 9th Conference of the Parties of the United Nations Convention on Biological Diversity in Bonn, Germany.

Coral reef emergency

Coral reef losses accelerated significantly once atmospheric concentrations of CO_2 reached around 320 ppm due to temperature-induced coral bleaching. These losses were compounded by excessive CO_2 dissolution in sea water. This caused ocean acidification, which in turn hampers reef regeneration. Scientific consensus has emerged that atmospheric CO_2 concentrations need to be “significantly below 350 ppm” for the long-term viability of coral reefs (Royal Society 2009).

Economic valuations of coral reefs provide stark insights into the value of these natural assets. The potential economic costs of losing coral reefs to climate change are enormous. Furthermore, this is an ecosystem that is close to a threshold of irreversibility, a tipping point beyond which it ceases to perform ecosystem functions. With any such system it is not enough merely to consider the benefits and the costs of marginal changes. At or close to the tipping point, the trade-offs to be made are no longer just ‘marginal cost-benefit’ decisions. They are rather in the nature of ethical choices to be made by society, in full recognition of their far-reaching consequences. And we have reached that point with coral reefs.

Gradual reduction in future greenhouse gas (GHG) emissions may save us from dangerous climate change but it will not stop the imminent loss of coral reefs. Even current levels of atmospheric CO_2 are too high for coral reef survival. We need large and permanent removals of CO_2 from the atmosphere. The task for global leadership in the run-up to Copenhagen is to recognize and address the ethical choice facing humanity when setting new targets for GHG concentrations. Accepting any stabilization target above 350 ppm CO_2 really means that society has made a decision to make do without coral reefs. It is therefore also a decision to accept the serious consequences of coral reef loss on biodiversity, on sea fisheries around the world, and on the half billion people who depend directly on coral reefs for their livelihoods. Removing CO_2 has thus become an imperative for survival.

Explicit plans should be made for significant CO_2 removals by accelerated carbon capture, either by restoring natural ecosystems or by other safe means.

Forest carbon for climate mitigation

The emissions regime today is predominantly a ‘brown carbon’ regime - it controls emissions from fossil-fuel use and industrial processes, but it exposes us to sectoral leakage risks. For example, incentives for biofuels (to replace fossil fuels) can sometimes result in conversion of forest land into biofuel cropland, and cause considerably more emissions from soil and biomass carbon losses than saved by burning less fossil fuels. Terrestrial carbon or ‘green carbon’ and ocean carbon or ‘blue carbon’ are both massive carbon pools which also have significant net fluxes with the atmosphere. Effective control of atmospheric carbon will need this whole 'spectrum' of carbon to be managed, and not just one ‘colour’ of carbon.

Tropical and sub-tropical forests store about 25% of the carbon in terrestrial natural areas. For this reason, we support climate negotiators in their desire to reward developing countries (where most of these are found) for improved conservation, carbon stock enhancement and sustainable forest management (e.g. recent REDD-Plus proposals). In addition, these ecosystems also deliver many other benefits which are highly valuable to society. They provide food, fibre, fuelwood, fresh water and soil nutrients. They prevent flooding and control drought. They form a buffer against natural hazards. They offer scope for eco-tourism, and provide numerous cultural benefits, from rest and recreation to worship in sacred groves. The concept of 'Payments for Ecosystem Services' has evolved to reward forest custodians for some of these values, but there are also challenges: Although widely accepted as a good way to capture the public benefits of conservation, implementation is limited to just a few locations and a handful of ecosystem services.

Forest carbon is potentially a major mitigation option. It is more cost-effective than many alternative measures, and delivers significant co-benefits that reduce net costs still further. However, it has yet another value. Including forest carbon as a major component of a future climate regime sets an important precedent. It can serve as a potential platform for the development of other payments for ecosystem services (PES). From a TEEB perspective, the upcoming climate conference in Copenhagen is the first major, empowered, international opportunity to create a functioning, effective, truly global framework of 'Payments for Ecosystem Services'. For this reason, we believe that the value of such an agreement, if designed accordingly, stretches far beyond carbon, and indeed forests. A successful global agreement would mark society's entry into a new era which 'mainstreams' the economics of ecosystems and biodiversity: not just demonstrating ecosystem benefits, but capturing them through priced rewards. In this way we begin to internalize the vast 'externalities' of natural capital.

TEEB strongly supports efforts to reach consensus at Copenhagen towards accelerated implementation of an appropriate forest carbon agreement that recognizes ecosystem service values.

National accounting for forest carbon

"We cannot manage what we do not measure." This dictum applies generally to ecosystem services and natural capital, which are largely missing from existing systems of national accounts. However, it becomes an immediate necessity for implementing global initiatives to reward ecosystem services, including climate mitigation. To implement a forest carbon Agreement, there must be reliable systems of measurement and accounting for carbon storage and sequestration in a variety of ecosystems. Several transnational initiatives are under way to make national accounting more comprehensive, but there is an urgent need for a global accounting standard to reflect forest carbon values and other ecosystem services in national accounts.

TEEB recommends rapid upgrade of the UN's SEEA (2003) manual to reflect the urgent need to include ecosystem services and especially forest carbon in national accounts.

Ecosystem investment for climate adaptation

Biodiversity and the services provided by ecosystems can contribute significantly and cost-effectively to efforts to adapt to unavoidable climate change. Investment in restoring or conserving ecological infrastructure which delivers ecosystem services can significantly enhance agricultural sustainability, especially in developing countries. It can improve freshwater supplies and reduce future insecurity. It can considerably reduce the impacts of natural hazards and extreme weather events. Such investment can also improve skills and create decent jobs in poor communities. By making due provision in the funds for climate change adaptation, Copenhagen negotiations can facilitate this type of investment.

TEEB recommends significant investment in protecting ecosystem services and biodiversity, fostering the development of ecological infrastructure, as a contribution to both climate change mitigation and adaptation.

TEEB Climate Issues Update

Introduction

This update addresses our ongoing work in four domains which we believe need to be highlighted in the run-up to Copenhagen:

- *Coral reefs*: We now understand that the survival of these ecosystems is at risk.
- *Forest carbon*: Including forests in mitigation is a cost-effective way of preventing further emissions and removing CO_2. Forests also provide co-benefits in the form of other ecosystem services. Giving rewards for these benefits is an important step towards a greener global economy.
- *National accounts*: These currently do not measure natural capital, so it can not be managed well. The most urgent step is to include adequate measurement of carbon storage as this is an institutional prerequisite for a serious payment scheme for tropical forests.
- *Public investment in ecological infrastructure*: This has demonstrable value for adaptation to climate change, not only in terms of relevance and effectiveness but also in terms of cost-effectiveness. In the context of the current economic crisis and the fiscal stimulus packages unveiled by many nations, ecosystems represent an attractive area for high-return investment. Our 'natural capital' can be a much-needed source of growth in a time of recession, a provider of new and decent jobs in a time of increasing unemployment, and a solution to persistent poverty, a vast human problem which we cannot ignore.

The process of TEEB phase 2

In Phase 2, there are five TEEB deliverables planned. The study is underpinned by a volume on the ecological and economic foundations of TEEB (TEEB D0), for which draft chapters will be online for comment on our website ***www.teebweb.org*** in September. This is followed by four 'end-user' reports:

TEEB D1: TEEB for international and national policy-makers, to be published in a first version in November 2009
TEEB D2: TEEB for local policy-makers and administrators, to be published in spring 2010
TEEB D3: TEEB for business, to be published in summer 2010
TEEB D4: TEEB for citizens, a website to be launched in summer 2010.

The final findings of the complete TEEB study will be presented in the autumn of 2010 at the CBD COP10 Meeting in Nagoya, Japan. The draft chapters of TEEB D0 will be online in September 2009, and the TEEB D1 report will be issued in November in order to facilitate ongoing dialogue for TEEB final findings. For further information go to ***www.teebweb.org***

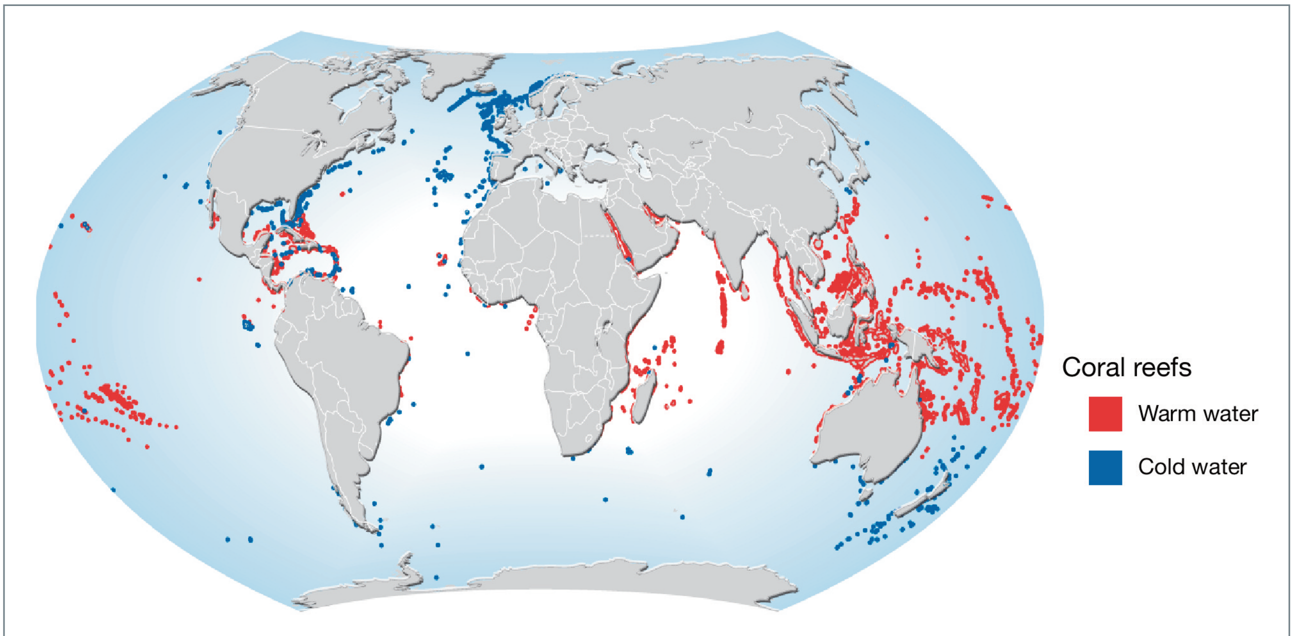
CORAL REEF EMERGENCY

One important ecosystem that we risk losing due to climate change is coral reefs. Current levels of CO_2 are already above levels which generate ocean warming for long enough periods to cause mass coral bleaching globally - a phenomenon increasingly observed since CO_2 concentrations exceeded 320 ppm. Accumulating scientific evidence is also suggesting that reef regeneration (which happens naturally over years) is hampered by increasing ocean acidification due to increased dissolved CO_2, an effect that will become increasingly severe in future years.

There are not one but two major problems facing society today in relation to greenhouse gas (GHG) emissions (Stern 2008). The first is a 'flow' problem: too much GHG flowing into the atmosphere due to human activities. And the second is a parallel but distinct 'stock' problem: CO_2 concentrations are already at levels which will destroy coral reefs. Current scientific consensus is that targeting stabilization levels above 350 ppm CO_2 will not prevent the catastrophic loss of coral reefs from the combined effects of higher temperatures and ocean acidification (see box 1). Levels are currently at 387 ppm. To ensure the long-term viability of coral reefs the atmospheric CO_2 level must be reduced to "significantly below 350 ppm." (see box 2). Therefore, significant CO_2 removals now and an aggressive global resolve to cut future emissions drastically are the most important actions we need today to allow coral reef ecosystems to survive.

Coral regeneration is also hampered by human activities, such as overfishing and destructive fishing practices, overexploitation of marine and coastal resources, and destruction due to anchors or careless tourists. There are also factors like poor water quality and sedimentation. For reefs where these impacts are significant, recovery from bleaching may not happen at all. Therefore, in addition to action on emissions, scientists are also advocating conservation and better management of reefs as a parallel strategy for reef survival.

Figure 1: Map of coral reefs *Source: Bryant et al. (1998)*



THE IMPORTANCE OF CORAL REEFS

Coral reefs are an integral part of an extensive and vital landscape of coastal ecosystems which includes estuaries, marshes, mangrove forests, dunes, seagrass beds and lagoons. These ecosystems are biologically highly productive. Around half of the world's cities with more than half a million inhabitants lie within 50 kilometres of the coast (Agardy and Alder 2005) and are thus direct beneficiaries of the many valuable ecosystem services provided by coastal environments, including protection from floods and storms, erosion control and coastal fisheries.

Estimates of the total number of people reliant on coral reefs for their food resources range from 500 million (Wilkinson 2004) to over one billion (Whittingham et al. 2003). Some 30 million of the world's poorest and most vulnerable people in coastal and island communities are totally reliant on reef-based resources as their primary means of food production, sources of income and livelihoods (Gomez et al. 1994; Wilkinson 2004).

Tropical coral reef ecosystems cover just 1.2 per cent of the world's continental shelves but are the most biodiverse of all marine ecosystems. They are home to an estimated 1-3 million species, including more than a quarter of all marine fish species (Allsopp et al. 2009).

Box 1: Ocean acidification and its effect on coral reefs

The absorption of CO_2 by the oceans leads to increasing ocean acidification. This alters the carbonate chemistry of seawater as pH decreases. Ocean acidification has already led to a decrease of pH of about 0.1 pH units and a resultant decrease in the availability of carbonate ions in seawater. This trend is projected to reduce pH by a further 0.3-0.4 units under a 'business-as-usual' scenario by the end of this century. Corals and other marine species that are critical structural or functional components of marine ecosystems, build their skeletons from calcium carbonate. The vulnerability of these taxa to acidification depends on the form of carbonate that they secrete. High magnesium calcite is most soluble, aragonite of intermediate solubility and calcite is the most insoluble. Coral skeletons are formed of aragonite. A decrease in coral growth rate of 14% has already been observed on corals of the Great Barrier Reef and is likely to be a response to acidification or a combination of climate change impacts. Coralline algae, key cementing agents that are essential to reef building, secrete high magnesium carbonate and are particularly vulnerable to acidification. Prior to the industrial revolution 98% of the world's coral reefs were found in waters more than 3.5 times saturated with aragonite. At an atmospheric CO_2 concentration of 450ppm only 8% of coral reefs will be surrounded by waters with this saturation level. At CO_2 concentrations of more than 560ppm it is projected that all reefs will be in an erosional state (atmospheric CO_2 double the pre-industrial value). Under these conditions coral reefs ecosystems will collapse and become dominated by algae and microorganisms. This will be accompanied by extinctions of reef-building coral taxa and reef-associated fish and invertebrate species.

Source : Tittensor et al. 2009

Coral reef productivity and ecosystem services:
Coral reefs are often likened to 'oases' within marine nutrient deserts. Hatcher (1988) recorded that in the open sea surrounding coral reefs, productivity may fall as low as 0.01 gC/m^2/day, although it may be many thousands of times higher within coral reefs (40 gC/m^2/day). This high productivity of coral reefs within these otherwise unproductive waters makes coral reefs critical to the survival of both marine and coastal ecosystems. This is also the underlying reason why they contribute so significantly to human welfare.

Economic valuation of human welfare benefits:
Estimates of the overall human welfare benefits from these ecosystem services are significant – one estimate puts them at $172 billion annually (Martinez et al. 2007). At regional level the values range widely, mainly due to variations in who benefits directly, and in the type and size of the coral reef systems. For example, in South East Asia, the total potential sustainable annual net benefits per km^2 of healthy coral reefs are estimated to range from $23,100 to $270,000. These benefits arise from fisheries, shoreline protection, tourism, recreation, and aesthetic value (Burke, Selig and Spalding 2002). In the following table values estimated by different studies have been compiled according to the ecosystem services provided by coral reefs (table 1).

Assessment of coral reef losses:
Various scientific studies show that we have been losing corals at an alarming rate. Experts state that 19% of the original area of coral reefs has been effectively lost since 1950 (Wilkinson 2008). The Millennium Ecosystem Assessment (MA) reported that more than 20% of corals were badly degraded or under imminent risk of collapse (MA 2005). Detailed studies done at the World Resources Institute in 1998 suggest that while in global terms 58% of the world's reefs are threatened by human activities, in South East Asia it is 80% of corals that are under medium to high threat, and these reefs are also the richest in biodiversity.

Table 1: Benefits from ecosystem services in coral reef ecosystems

CORAL REEFS	Value of ecosystem services (in US$ / ha / year – 2007 values)		
Ecosystem Service	**Average**	**Maximum**	**Number of Studies**
Provisioning services			
Food	470	3,818	22
Raw materials	400	1,990	5
Ornamental resources	264	347	3
Regulating services			
Climate regulation	648	648	3
Moderation of extreme events	25,200	34,408	9
Waste treatment / water purification	42	81	2
Biological control	4	7	2
Cultural Services			
Aesthetic information / Amenity	7,425	27,484	4
Opportunities for recreation and tourism	79,099	1,063,946	29
Information for cognitive development	2,154	6,461	4
Total	**115,704**	**1,139,190**	**83**
Supporting Services			
Maintenance of genetic diversity	13,541	57,133	7

Note: these estimates are based on ongoing analyses for TEEB (TEEB Ecological and Economic Foundations, Chapter 7). As the TEEB data base and value-analysis are still under development, this table is for illustrative purposes only.

A study in 2007 on the effects of climate change and acidification on coral reefs summarized: "Climate change … exacerbates local stresses from declining water quality and overexploitation of key species, driving reefs increasingly toward the tipping point for functional collapse" (Hoegh-Guldberg et al. 2007). This study outlined the effects of three scenarios for the next few decades. In the first, at 380 ppm CO_2, coral reefs continue to decline with a further loss of about 10% of live coral cover. In the second scenario, with stabilization at 450 ppm CO_2, due to ocean acidification, coral cover declines by about 50%; colonization by temperature-tolerant macro-algae, pollution, and over-fishing drives coral reefs toward a tipping point. Lastly, with stabilization at above 500 ppm, coral reefs become extremely rare with the loss of live coral cover approaching 100%. Further research has resulted in an even more pessimistic view that CO_2 concentrations need to be "significantly below 350 ppm" to ensure the long-term viability of coral reefs. The overall impact of current levels of atmospheric CO_2 is summarized by this recent statement by scientists at the Royal Society, London (see box 2).

VALUING ECOSYSTEMS CLOSE TO A THRESHOLD OF IRREVERSIBILITY

In essence, the latest science tells us that we already have an ecosystem crisis on our hands: the imminent loss of tropical coral reefs. When an ecosystem is close to a critical threshold, it may become impossible to value because of uncertainty or even ignorance about the potential consequences of non-linear behaviour. Traditional valuation under these circumstances is risky at best (Pritchard et al. 2000; Limburg et al. 2002). It may be possible to develop early warning indicators to anticipate proximity to tipping points, but with the ecological knowledge available we are still far from having developed a system to anticipate shifts with any precision (Biggs et al. 2009). The risk of threshold effects coupled with uncertainty (or even ignorance) means that safe minimum standard approaches and the precautionary principle should be adopted in order to sustain the resilience of the system (TEEB D0 forthcoming, chapter 5).

Monetary analysis may be misleading if we do not know how close a system is to a threshold. Care needs to be taken not simply to extrapolate using an underlying assumption of continued incremental losses in the ecosystem function. To illustrate with an extreme example, if the marginal quantum of benefits being valued happens to be the last available of its kind, then scarcity and ethics would set a completely different 'price' on that last quantum. What we face with coral reefs is not a 'marginal' problem, and the economics needs to reflect this. The reported science suggests that anthropogenic emissions have brought the coral reef ecosystem to the brink of potential irreversible collapse. Thus we may have encountered our first major global ecosystem 'threshold'. As pointed out earlier (TEEB 2008) we need to move beyond marginal cost-benefit analysis and consider other dimensions of value: the ethical and social as well as the economic. We need to assess survival risks for this entire biome and its implications for ocean and coastal productivity and for human welfare.

The imminent demise of tropical coral reefs is predicted to be an extinction event of proportions never before witnessed by humankind. The loss of this critical ecological infrastructure will damage the productivity of global fisheries and the chances of stock survival. It could thus lead to future food crises. It will impoverish over 500 million people who depend on coral reefs for their livelihoods.

Box 2: Scientific statement on climate change and coral reefs

- *Coral reefs are the most biologically diverse habitats on Earth and provide essential eco-systems goods and services to hundreds of millions of people.*
- *Temperature-induced mass coral bleaching causing widespread mortality on the Great Barrier Reef and many other reefs of the world started when atmospheric CO_2 exceeded 320ppm.*
- *At today´s level of 387ppm CO_2, reefs are seriously declining and time-lagged effects will result in their continued demise with parallel impacts on other marine and coastal ecosystems.*
- *Proposals to limit CO_2 levels to 450ppm will not prevent the catastrophic loss of coral reefs from the combined effects of climate change and ocean acidification.*
- *To ensure the long-term viability of coral reefs atmospheric carbon dioxide level must be reduced significantly below 350ppm.*
- *In addition to major reductions in CO_2 emissions, achieving this safe level will require the active removal of CO_2 from the atmosphere.*
- *Given the above, ecosystem-based management of other direct human induced stresses on coral reefs, such as overfishing, destructive fishing, coastal pollution and sedimentation will be essential for the survival of coral reefs on which we are all dependent.*

(Royal Society Meeting, 6th July 2009)

Against this background TEEB urges global political leaders and their climate negotiators to recognize and address the risks of irreversible loss of most of the world's tropical coral reefs by:

- **providing explicitly for coral reefs in measures for coherent climate change adaptation solutions for coastal areas when establishing climate adaptation strategies and agreeing adaptation funds;**
- **work towards agreeing on more ambitious CO_2 reduction, that will improve the chances of survival and recovery of coral reefs.**

FOREST CARBON FOR CLIMATE MITIGATION

An emissions regime that fully integrates forest carbon is both an urgent imperative and a major opportunity. It is urgent because of the significant risks – economic, social and environmental – if forests continue to be marginalized in climate mitigation policy. It is an opportunity because of the largely untapped potential of carbon capture and storage through afforestation, reforestation, and enhanced forest conservation. Including forest carbon as a major component of climate mitigation will also have a significant demonstration effect, boosting efforts to 'internalize' the value of other ecosystem services into the economy. At the same time, any new agreement on forest carbon needs to take account of the many other ecosystem services provided by forests, such as freshwater enhancement, soil conservation, biodiversity conservation, etc.

This section explores some of the policy, economic and market issues related to forest carbon, in the context of the economics of ecosystems and biodiversity. We first examine the wider values of forests before focusing on the role of tropical forests in climate mitigation. We briefly consider different approaches to integrating forests in climate policy, as well as the risks of not doing so. This section concludes with reflections on how finance for forest carbon could be linked to funding for other forest ecosystem services.

THE VALUE OF FORESTS

Forests are a unique economic asset. They are the lungs of our planet and also offer a range of valuable ecosystem services. They are essential to the water cycle, supplying and purifying water. They create and

Table 2: Values of ecosystem services in tropical forests

TROPICAL FORESTS	Value of ecosystem services[2] (in US$ / ha / year – 2007 values)		
Ecosystem Service	**Average**	**Maximum**	**Number of Studies**
Provisioning services			
Food	75	552	19
Water	143	411	3
Raw materials	431	1,418	26
Genetic resources	483	1,756	4
Medicinal resources	181	562	4
Regulating services			
Improvement of air quality	230	449	2
Climate regulation	1,965	3,218	10
Regulation of water flows	1,360	5,235	6
Waste treatment / water purification	177	506	6
Erosion prevention	694	1,084	9
Cultural Services			
Opportunities for recreation and tourism	381	1,171	20
Total	**6,120**	**16,362**	**109**

Note: these estimates are based on ongoing analyses for TEEB (see chapter 7 TEEB D0 forthcoming). As the TEEB data base and value-analysis are still under development, this table is for illustrative purposes only.

[2] Excluding some extreme site-specific cases that are not representative.

maintain soil fertility for agriculture and agro-forestry. They are reserves of genetic diversity useful for crops and medicines. They provide habitats for wildlife and food and energy for rural communities, as well as timber for construction and fibre for packaging. They are a place of recreation and spiritual renewal. And of course forests also play a critical role in stabilizing the global climate, as discussed below. Focusing on one of these values only, like timber or carbon, may not be in the best interests of society. Preliminary estimates of the values of ecosystem services in tropical forests are provided in the table below, based on on-going work by TEEB (see table 2). This research highlights the importance of considering all services when making decisions about any ecosystem. Policies should not focus on a single ecosystem service, such as carbon, but should aim to ensure that other services and their values are also taken into account.

Climate regulation, which includes carbon capture and storage as well as local climate effects, is just one major forest ecosystem service. In addition to the listed services directly benefiting human wellbeing, forests provide essential supporting services, such as the maintenance of soil fertility, pollination or the maintenance of genetic diversity. The average value of these supporting services is estimated at 900 US $ per ha per annum (TEEB D0, forthcoming).

THE SPECIAL SIGNIFICANCE OF TROPICAL FORESTS

Forests in the tropics are a particular concern. Most tropical forests are in developing countries (see figure 2). These countries face many challenges that put intense pressures on forest land and other natural resources, including high population growth, uncontrolled and often unplanned development, and rapidly changing consumption patterns. Deforestation in the tropics is running at a rate of about 12.5 million hectares per annum, mainly due to the expansion of agriculture.

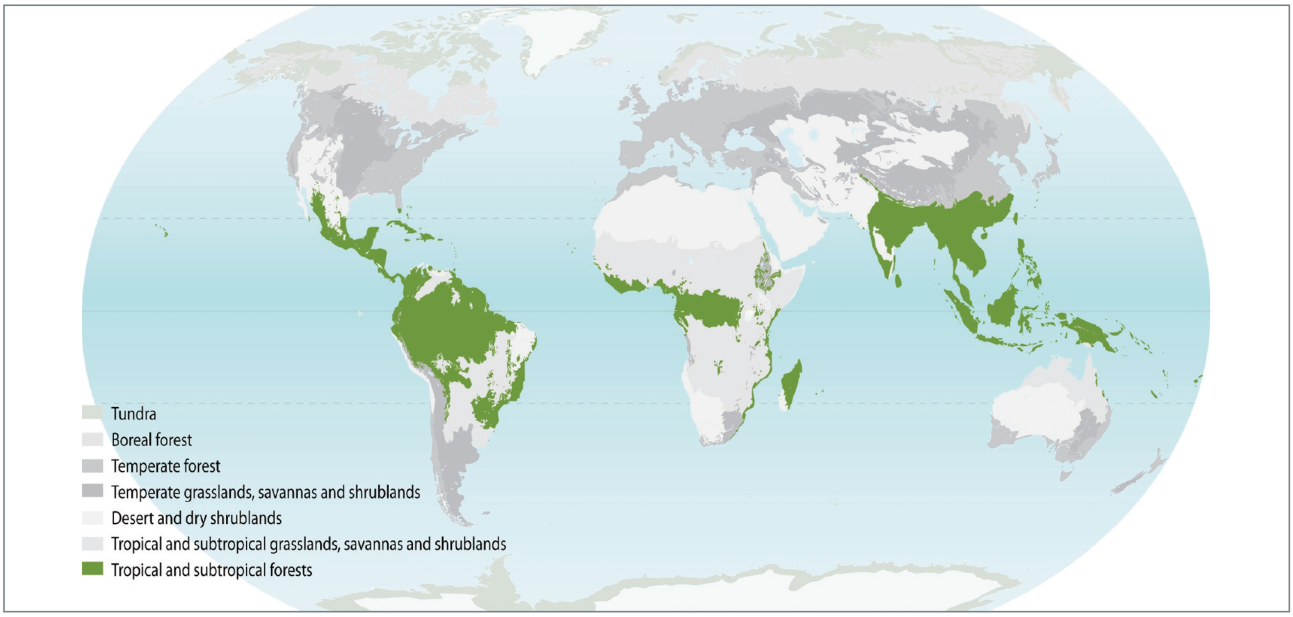
At the same time, large segments of the population in developing countries are highly dependent on forests for their livelihoods. Forests contribute directly to the livelihoods of 90 percent of the 1.2 billion people currently living in extreme poverty and indirectly sustain nearly half the population of the developing world, by providing ecosystem services that underpin agriculture (World Bank 2002; The Nature Conservancy 2009). In the Cost of Policy Inaction study undertaken during Phase 1 of TEEB, we estimated a value of USD 3.4 trillion for the total benefit flows from tropical forests (Braat and ten Brink 2008).

THE ROLE OF TROPICAL FORESTS IN CLIMATE CHANGE

As seen in table 2, above, one major service provided by tropical forests is climate regulation. Tropical forests store a fourth of all terrestrial carbon, i.e. 547 gigatonnes (Gt) out of 2,052Gt of CO_2 (Trumper et al. 2009). In addition, recent research suggests that tropical forests may capture as much as 4.8 Gt of CO_2 per annum (Lewis & White 2009). This is a major departure from the view that climax forests are emissions-neutral, and could help account for a large part of the difference between annual GHG emissions due to human activities (about 32 Gt) and the observed rate of increase in atmospheric concentrations (about 15 Gt). Conserving tropical forests is thus a vital tool for managing the climate, as well as a means of securing livelihoods and reducing poverty.

Economic arguments for avoiding deforestation as a means of mitigating climate change have been provided by the Stern Review (2007) and, more recently, by the Eliasch review (Eliasch 2008). The latter study estimated the costs of halving deforestation at around $17bn-$33bn per year to 2030, but also found that this investment would generate long-term net benefits of about $3.7 trillion, in present value terms, including only the avoided damage costs of climate change.

Figure 2: Geographical distribution of tropical forests *Source: adapted from Olson et al., 2001.*



The Eliasch review also showed that delaying action on REDD would significantly increase the costs of achieving near-term emission reductions.

SCOPE OF ACTION REQUIRED

One key question in discussions of how to integrate forest carbon in climate mitigation policy concerns which activities to reward. International discussions focused initially on how to avoid deforestation. However, there is emerging consensus that broader efforts are required, including reduced deforestation and degradation, but also stronger incentives for afforestation, reforestation and sustainable forest management (see box 3). Among other benefits, such an approach could provide some recognition and reward to those developing nations which have been 'early movers' in slowing deforestation and supporting sustainable forest management.

Developing countries are major players in international forestry debates and their cooperation is essential for integrating tropical forest carbon in any climate agreement. However, developing countries also need external financial support and support to develop institutional frameworks that can create positive incentives for forest conservation in line with local development plans, while also ensuring equitable participation of a diverse set of stakeholders in tropical forest management.

In this context, measuring the effectiveness of conservation is an important component of an inclusive global forest carbon agreement, in addition to measuring reductions in greenhouse emissions from deforestation and forest degradation against agreed reference levels (see section on accounting below). Indicators of conservation effectiveness may include efforts to develop non-agricultural income-generating activities in forest dependent communities, improving the management of existing protected areas by increasing staffing and equipment as well as agreements with forest communities, expanding protected areas through new legislation, or promoting independent verification of protected area management.

Box 3: REDD and REDD-Plus

Deforestation accounts for around 20% of global greenhouse gas emissions, making it the second largest anthropogenic source (IPCC 2007). Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries is a financial mechanism proposed as part of the post-2012 climate change regime, under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC).

The Bali Action Plan (§ 1b) also laid the basis for "REDD-Plus", further incorporating conservation, sustainable management of forests and enhancement of carbon stocks in developing countries. This expands the concept of reducing emissions from deforestation and forest degradation. Recent deliberations (e.g. in the UNFCCC Ad hoc Working Group on Long-term Cooperative Action) emphasize REDD-Plus and the more programmatic approach it requires at national level, compared to REDD.

Agreement on REDD-Plus at the UNFCCC would significantly contribute to recognizing and rewarding carbon capture & storage by forests: incentivizing less deforestation and degradation whilst also promoting forest conservation. Mitigation action could be improved by expanding REDD to REDD-Plus (Zarin et al. 2009), not least because of the restoration potential of degraded forests: REDD would only halt further degradation – not incentivize restoration.

THE RISKS OF INACTION

As outlined above, conserving and enhancing carbon stocks in tropical forests is an essential component of an effective response to climate change. However, excluding or limiting the contribution of forests to climate mitigation efforts is not only ill-conceived, but potenially counterproductive. The current climate policy regime is largely focused on industrial emissions from the combustion of fossil fuels, or 'brown carbon' (see box 4). There is a non-negligible risk that the expansion of a regime focused exclusively on fossil fuels and industrial emissions could come at the expense of forests and food security (Clarke et al. 2007). This risk arises from efforts to encourage the development of bio-energy as a substitute for fossil fuels in transport and other industries (Crutzen et al. 2008). Recent studies show that increased production of biofuels can result, either directly or indirectly, in the conversion of forests, and may also result in higher prices of food and other commodities (Gurgel et al. 2007; Gillingham et al. 2008; Searchinger et al. 2008). For example, the conversion of forests, peatlands, savannahs and grasslands to produce biofuels in Brazil, Southeast Asia and the United States would result in net CO_2 emissions 14 to 420 times greater than the emission reductions achieved by using these biofuels in place of fossil fuels (Fargione et al. 2008). In contrast, biofuels produced from waste biomass and crops grown on degraded agricultural land do not have this problem (Wise et al. 2009; see also Schmer et al. 2008).

REWARDING THE 'CO-BENEFITS' OF FOREST CARBON

In addition to their significant role in carbon capture and storage, tropical forests offer enormous opportunities to deliver other positive social and environmental outcomes. Current challenges, such as wildlife poaching, illegal logging, unsustainable harvesting and other environmentally destructive activities, generally result from weak administrative capacity and inadequate finance, as well as failure to fully understand the true worth of forest biomes. At a wider level, such problems reflect the lack of motivation in many bureaucracies to rank forest protection alongside rural and regional development, which is usually understood in terms of industrial growth.

Carbon finance can change this equation by creating a revenue stream that is attractive to national and regional governments, cost-effective for industrial polluters seeking to meet their emission reduction targets, and potentially beneficial to local communities and the rural poor. Critically, the provision of finance for forest carbon, if carefully designed and implemented can help strengthen the rights of forest resource owners, users and managers.

Box 4: The colours of carbon

The carbon cycle and the water cycle are perhaps the two most important large-scale bio-geological processes for life on Earth. While the latter is widely appreciated, we are only just beginning to appreciate the size, complexity and significance of the former.

*Climate change has driven increased understanding of atmospheric CO_2 as the main greenhouse gas, and how CO_2 emissions from human energy use and industry affect the climate. We refer to these emissions as '**brown carbon**'. The Emissions Trading System of the European Union is essentially a 'brown carbon' regime, as it does not currently recognize forestry credits.*

The carbon stored in terrestrial ecosystems, e.g. plant biomass and soils in natural forests and plantations, agricultural lands, wetlands and pasture, may be referred to as 'green carbon'. The importance of 'green carbon' is increasingly acknowledged as a key agenda item for negotiation in the UNFCCC, specifically in relation to forest carbon and mechanisms such as REDD and afforestation, REDD-Plus, or others.

*Moreover, the world's oceans bind an estimated 55% of all carbon in living organisms. Most of this is stored in mangroves, marshes, sea grasses, coral reefs and macro-algae. This has been dubbed '**blue carbon**' by UNEP (Nellemann et al. in press). Note that these ecosystems are also being degraded; in some cases faster than rainforests (see more explanations in the coral reef section).*

*Finally, a potent climate forcing agent, so called '**black carbon**' may be significantly reduced if clean burning technologies are employed. Black carbon is formed through incomplete combustion of fossil fuels, bio-fuel, and biomass and is emitted as soot. Black carbon warms the planet by absorbing heat in the atmosphere and by reducing the ability to reflect sunlight, when deposited on snow and ice.*

In short, by halting the loss of 'green' and 'blue' carbon, the world could mitigate as much as 25% of total GHG emissions, with co-benefits for biodiversity, food security and livelihoods (IPCC 2007; Nellemann et al. in press) . This will only be possible, however, if the policy regime for climate mitigation accommodates the entire spectrum of carbon, not just one colour.

More generally, forest carbon is a prime opportunity to spearhead new international payments for ecosystem services (IPES). In this regard, it is especially important that any agreement on forest carbon negotiated under the UNFCCC is 'upwardly compatible' to fit into a wider framework of incentives for forest ecosystem services. The guiding principles and operating framework for forest carbon will have significant influence on the development of other environmental markets – for freshwater enhancement, soil conservation, biodiversity conservation, etc.

A more immediate priority is to develop eligibility and performance criteria for forest carbon initiatives that reflect not only their carbon capture or emission reduction potential, but also a range of ecological, socio-economic and biodiversity criteria that more fully reflect the true economic value and development role of forests. Such information can be used to differentiate forest carbon in the marketplace, in the form of a 'premium' grade of forest carbon that would attract higher prices and generate additional revenue for the supply of co-benefits (see Annex 1 on how a 'premium' forest carbon can be set up in the various phases of a REDD-plus framework). Ultimately, such criteria could form the basis of entirely new classes of forest ecosystem services (e.g. freshwater quality, biodiversity offsets) that can be 'sold' alongside or separately from carbon credits, generating yet more revenue for forest conservation and sustainable rural livelihoods.

To sum up, climate mitigation efforts to date have focused largely on reducing industrial emissions of GHG. Putting a price on CO_2 emissions from industry was an obvious starting point for the creation of carbon markets. Today, however, it is increasingly understood that 'green carbon' and especially tropical forests have a key role to play in future efforts to mitigate climate change. Reasons for integrating tropical forest carbon in a new climate policy regime are that:

i. deforestation not only contributes a fifth of global emissions but also reduces the significant carbon capture potential forests offer;
ii. notwithstanding the tremendous efforts and progress towards curbing industrial emissions and the need to continue these efforts, the net costs of halting deforestation (in dollars per tonne) can be significantly lower than some of the alternative mitigation options such as renewable energy or Carbon Capture and Storage; and
iii. protecting forests from deforestation, conserving them against degradation and going even further by restoring them generates co-benefits in the form of public goods and services which, if valued explicitly rather than being treated as externalities, further improve the benefit-cost ratio of forest carbon.

It is essential that forests are fully integrated in any new international climate regime, but most importantly that forests are included in ways that maximize synergies with biodiversity conservation and the supply of other ecosystem services, while also respecting the rights, livelihoods and potential stewardship role of indigenous peoples and rural communities. If this is achieved, forest carbon can truly be a stepping stone to heightened recognition and reward for the full economic value of forests. This would mark the beginnings of the change in our global economic model that TEEB is recommending in all its reports.

URGENT REFORM OF NATIONAL INCOME ACCOUNTING

There is a growing appreciation that national economic accounts need to be complemented by natural capital accounts, and that the existence and value of ecosystem services need to be better reflected in national accounting processes and policy-makers' decision-making.

At the moment ecosystems are poorly recorded in the national economic accounts. At best they figure as an economic resource only in proportion to their private benefit. A range of ecosystem services supporting production are just considered as 'externalities'. All the free amenities and regulating services supplied by thriving ecosystems are absent from the picture. Depreciation of the ecosystem capital is not recorded in the price of products. Similarly there is a still poor use of physical natural capital accounts to help policy-makers understand the natural resource stock available (land, water, soil, biodiversity, biomass), the changes to this stock, the delivery of ecosystem services from the stocks, and the changes of service provision relating to changes of stock.

There is, however, a growing recognition of the importance of addressing these limitations, and increasing amount of practical experience upon which to build. As part of the efforts to integrate the environment into national accounts countries have been developing air accounts, water accounts, land accounts, soil accounts, emission accounts, waste accounts, and so on, which includes the releases of greenhouse gases. Of these accounts, forest accounts figure in almost all resource accounting exercise. Some countries have also measured the carbon sequestration services provided by the forests. The measurement of carbon sequestration (flow) by forests seems to be rather well established and accurate, whereas the measurement of carbon sequestration by soil, water and other biota (flows) and the stock of carbon are less developed and still not standardized. The linkages across the wider set of ecosystems services are also still very weak. Although there is a growing wealth of experience that follows different specific foci, and a range of important parties are making progress, more still needs to be done to integrate or at least appropriately link different natural capital accounts to cover the range of services. There must also be more political commitment to take these tools to a more formal level, with full development and integration alongside national accounts.

The task of developing and implementing environmental accounting has been a shared international effort. At international level, the London group is in the process of preparing a handbook on integrated environmental and economic accounting (SEEA), the draft version of which was approved by the United Nations Statistics Commission (UNSC). The SEEA (2003) is currently being revised by UNSC in conjunction with the London Group under the auspices of the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA). The aim is to prepare a statistical standard covering all aspects of environmental accounting. It is expected to be approved by the UN Statistical Commission in 2012. It was suggested that carbon sequestration by forests (flows) should be included in Volume 1 of the revision, while carbon sequestration by other resources and carbon stock should be discussed further. The valuation of carbon stocks should be included in Volume 2 together with its valuation results.

In addition to the London Group, other important work is being done by other partners. In Europe, Eurostat and the EEA are the key parties taking natural accounting forward. Internationally, it is the OECD that is active, together of course with the UN bodies. Progressive country commitments have been made by India, Norway, Australia, and Sweden to name just a few (compare Annex 2 for details and further examples).

Without good natural capital accounts or extended economic accounts that include the value of ecosystems and biodiversity, the importance of natural resources to economies are likely to be under-appreciated so that sub-optimal use is made of these assets, economically, environmentally and socially. So assets are underperforming, natural capital is being run down, and future benefits streams get smaller as the asset base is eroded.

Another consequence is that product prices do not reflect their full costs. As a result there is an accumulation of the environmental debt to future generations and/or to the exporters of commodities extracted from degrading ecosystems. For low-income groups, which rely more than others on the free services supplied by the ecosystem and on so-called ancillary products with little or no market value, the image given by the current system of GDP, National Income and Household Consumption aggregates is seriously misleading. The flaw is that valuable commodities are too often extracted from ecosystems at the expense of those free services and ancillary products, and no heed is given to depreciation of natural capital and the resulting decline in future services. In terms of total welfare, the rural poor can get poorer; even though their monetary income may actually increase in real terms, the degradation of the natural capital that provide the biggest part of the goods they need (food, fibre, water, etc) for their survival is actually reducing their substantially their welfare. By measuring the virtual costs not covered by market prices, it would be possible to measure the 'GDP of the poor' and how far it declines in proportion to the share of conventional GDP growth based on ecosystem degradation (see chapter 3 TEEB D1 forthcoming) .

TEEB suggests the development of adequate indicators for all ecosystem services, which countries could start implementing as data availability their institutional capacities permit. TEEB thus supports fully the efforts for developing fully fledged ecosystem accounts (in the future work of UN SEEA (Volume 2) planned for 2013), which should include physical accounts for ecosystem stocks, degradation and services and valuation rules. TEEB also recommends moving towards the implementation of the full SEEA ecosystem accounting at country level.

TEEB supports fully the creation of natural capital accounts following an integrated approach across ecosystem services. While initially this may take place as pilot projects and can take an approximate form, the efforts can gradually be expanded with the ultimate goal to have full natural capital accounts of all ecosystems, covering all key ecosystem services.

As one important first step, TEEB sees the development of harmonized accounting on carbon and biomass on the country-level as important basis for REDD and other climate-related work. Carbon-biomass accounts should not be prerequisites for REDD-Plus but tools that help develop confidence in REDD and allow it to develop into an increasingly important instrument.

ECOSYSTEM INVESTMENT FOR CLIMATE ADAPTATION

The Stern Review emphasized that climate change is a reality and that reducing the impact through response policies like adaptation and mitigation makes good economic sense (Stern 2007). Whether we mitigate or adapt is "equivalent to a decision on having seat-belts and air-bags versus installing anti-lock brakes in a car and having speed limits on the road. Anti-lock brakes and speed limits reduce the likelihood of an accident (mitigation) whereas seat-belts and air-bags prevent catastrophe if an accident occurs (adaptation) (Mc Kibbin and Wilcoxen 2004). With both options available, few would choose only one as both help reduce the risk of injury.

For developed countries, the Stern Review points out that "government can contribute through long-term policies for climate-sensitive public goods, such as natural resources protection, coastal protection and emergency preparedness". For developing countries, the review primarily points towards economic diversification as a means to adapt to climate hardship. A safer environment in the face of climate change is also recommended. The knowledge that TEEB is gathering strongly supports this approach.

WHAT IS ECOLOGICAL INFRASTRUCTURE?

Where there is uncertainty, it is wise to apply the precautionary principle and adopt a strategy which is sustainable and aims at protecting both human and natural habitats. This means investing in 'ecological infrastructure', as a way to both 'mitigate' and 'adapt'. The term 'ecological infrastructure' refers both to natural ecosystems, and to nature within man-made ecosystems. Natural ecosystem functions include those which are responsible for the delivery of ecosystem services, such as providing freshwater, regulating climate (forests, wetlands, inland water bodies like rivers), preventing soil erosion (forests and natural grasslands), and natural hazard risk management (forests, wetlands, mangrove forests and coral reefs). Natural elements within ecosystems altered by humans (farmlands and fields) include those which improve soil fertility and reduce soil erosion (forest and grassland patches), and provide freshwater (streams and aquifers). The maintenance or restoration of these ecological resources is of major importance for adaptation.

Thus, in the context of the Copenhagen negotiations, investment in ecological infrastructure should be included in the projects that can be funded from a climate adaptation fund. In addition, each country can take action by investing in ecosystems as support for adaptation. In many cases, these approaches will be found to be more cost-effective than technological solutions using built infrastructure (e.g. the well-known case of the natural Catskills Reservoir, New York) even before accounting for externalities such as the social costs of the carbon emissions for the construction the infrastructure.

Here, it is worth highlighting three broad and important arenas for adaptation: agricultural productivity, freshwater supply, and natural hazard management, all of which are directly affected by climate change. All three areas illustrate one important aspect of such actions: often investments in ecological infrastructure also benefit other sectors which are directly dependent on ecosystems and their services.

RESOURCE CONSERVATION FOR AGRICULTURAL RESILIENCE

Agricultural productivity is affected as temperatures rise and drought increases. Agricultural resilience is thus a key part of adaptation, especially in countries which have large populations dependent upon subsistence farming.

A recent study illustrated this potential. Agricultural sustainability centres around the world respond to the need to develop 'best practice' and deliver technologies which do not adversely affect the supply of environmental goods and services, but still improve yields and livelihoods. Pretty et al. (2006) shows in a study of 286 recent 'best practice' initiatives in 57 developing countries covering 37 million hectares (3% of cultivated area in developing countries) across 12.6 million farms how productivity was increased with improvement to the supply of ecosystem services (e.g. carbon sequestration and water quality). The average yield increase was 79%, depending on crop type, and all crops showed gains in efficiency of water use. Examples of the initiatives were:

- pest management: using ecosystem resilience and diversity to control pests, diseases and weeds,
- nutrient management: controlling erosion to help reduce nutrient losses,
- soil and other resources management: using conservation tillage, agroforestry practices, aquaculture, and water harvesting techniques, to improve soil and water availability for farmers.

FRESHWATER SECURITY AND NATURAL HAZARD DEFENSE

Natural hazards are expected to increase with the onset of climate change. There are likely to be increases in the severity and frequency of floods, droughts, storms, and sea-level rise. Natural hazard prevention is an ecosystem service which benefits human populations in many biomes. Thus, conserving the according ecosystems is a major investment in preventing new vulnerabilities towards natural hazards. For example, the floodplains found in most river basins reduce the impact of flood damage. Mudslides and landslides can be considerably reduced by maintaining or restoring forest ecosystems to enhance their buffering capacity. Forest cover helps to reduce flooding, increase the supply of freshwater and prevent soil erosion (Kumar et al. 2007). Coastal vegetation such as mangroves reduces potential damage from storms and tidal swells. For example, planting mangroves along part of the coastline in Vietnam cost USD 1.1 million, but saved USD 7.3 million annually in dyke maintenance. (GRID-Arendal 2002; Reid and Huq 2005). The livelihoods of an estimated 7,500 families benefited from this mangrove planting, maintenance and protection project.

A contrasting and interesting example from the 'developed world' at the other end of the spectrum is the Everglades in Florida. They are of enormous natural beauty and are also the primary source of water for the region, and they provide protection against floods and hurricanes. Much of the area was drained in the early 1900s to make way for the cities of Miami and Fort Lauderdale. The remaining wetlands, outside the 600 000 square kilometre Everglades National Park, have suffered heavily from pollution and further drainage in the last two decades (Salt et al. 2008). In order to improve the quality and secure the supply of drinking water for all of south Florida, and to protect the dwindling habitat for approximately 69 species of endangered plants and animals, the Comprehensive Everglades Restoration Plan was designed in 1996 and finally enacted by the US Congress in 2000. The total cost of the ongoing 226 projects in south Florida, which aim to restore the natural hydraulic functions of this ecosystem, is estimated to be close to 20 billion USD (Polasky 2008). The returns from this investment are social returns, in different areas such as agricultural water supply, urban water supply, flood control, habitat protection, recreation, and commercial and recreational fishing. But many of these benefits, such as natural hazard protection, can only be measured indirectly, since no markets exist for these public services. One study shows that the benefits for the Everglades would be in about the same range as the restoration costs, depending on the discount rate used (Milon and Scroggins 2002).

EXCEPTIONAL SOCIAL RETURNS ON ECOLOGICAL INVESTMENTS

Direct conservation, e.g. via protected areas, or sustainable use restrictions, are means of maintaining our ecological infrastructure healthy and productive, delivering ecosystem services. Very high benefit-cost ratios are observed, so long as we include amongst benefits a valuation of the public goods and services of ecosystems, and compute social returns on investment. For example, for protected areas an additional investment of $45 billion could secure nature-based services worth some $ 4.5 - $5.2 trillion a year (Balmford et al. 2002). In many cases though, when degradation has been excessive, restoration efforts will be needed to regain productive potential, as the example of the Everglades shows.

Unfortunately, cost-benefit analysis of restoration projects is rarely done. Even recording of the costs of restoration is rarely seen. In a review of over 2,000 case studies on restoration, only 95 studies were identified which provided meaningful cost data (see chapter 9 TEEB D1 forthcoming). However, none of them provided values or detailed analysis of the achieved or projected benefits. For the biomes covered in these case studies with cost data approximates, the TEEB team therefore estimated potential benefits based on a 'benefits transfer' approach. Table 3 below gives examples for these cost data and preliminary benefit estimates for several biomes.

Typical cost values: As noted, the sample of studies providing meaningful cost data is small. Therefore in order to avoid underestimating costs, systematic categorization was applied. Typical projects with comprehensive recorded costs were selected by biome rather than an average. Furthermore, in order to avoid underestimation, 'typical project costs' were set at 20% higher. Furthermore, allowance was made for annual operational costs,

Table 3: Estimates of costs and benefits of restoration projects in different biomes

	Biome/Ecosystem	Typical cost of restoration (high scenario)	Estimated annual benefits from restoration (avg. scenario)	Net present value of benefits over 40 years	Internal rate of return	Benefit/cost ratio
		US$/ha	US$/ha	US$/ha	%	Ratio
1	Coral reefs	542,500	129,200	1,166,000	7%	2,8
2	Coastal	232,700	73,900	935,400	11%	4.4
3	Mangroves	2,880	4,290	86,900	40%	26.4
4	Inland wetlands	33,000	14,200	171,300	12%	5.4
5	Lakes/rivers	4,000	3,800	69,700	27%	15.5
6	Tropical forests	3,450	7,000	148,700	50%	37.3
7	Other forests	2,390	1,620	26,300	20%	10.3
8	Woodland/shrubland	990	1,571	32,180	42%	28.4
9	Grasslands	260	1,010	22,600	79%	75.1

Note: Costs are based on an analysis of appropriate case studies; benefits have been calculated using a benefit transfer approach. The time horizon for the benefit calculation are 40 years (consistent with our scenario analysis horizon to 2050); Discount rate = 1%, and discount rate sensitivity by flexing to 4%, consistent with TEEB 2008). All estimates are based on ongoing analyses for TEEB (see chapter 7 TEEB D0 forthcoming). As the TEEB data base and value-analysis are still under development, this table is for illustrative purposes only.

at 10% of the original capital cost, from year 2 and beyond.

The estimation of values of benefit was based on the results of 104 studies with 507 values covering 9 major biomes, which are the best evidence currently available. For 22 ecosystem services an average of the available values was calculated. These values were then added to provide the estimation of total benefit per biome presented in table 3. Recognizing that flows of benefits take time to be restored by such projects, an appropriate accreting profile was modelled for annual benefits, growing initially and then stabilizing at 80% of undisturbed ecosystem benefits (see chapter 7 TEEB D0 forthcoming). When calculating the potential benefits for the biome in question, we found that all biomes showed potential for exceptional internal rates of return and thus a high return for restoration of ecosystems and their services.

Against this background, TEEB recommends that Copenhagen recognizes the crucial role that ecosystems can play in climate change adaptation efforts. It is essential to identify effective and cost-efficient measures involving the conservation and restoration of ecological infrastructure and to promote their financing from appropriate adaptation resources.

As can be seen from table 3, the value of restoration projects can be tremendous, especially for coral reefs and coastal ecosystems. However, the costs are also quite high, hence it is much better to conserve these ecosystems rather than letting them degrade and restoring them.

To have the best chance of success, such restoration projects should be implemented using a landscape-related holistic approach to ensure long-term pay-offs. Many countries have begun to develop appropriate programmes. Ecuador currently has two such programmes: the six-year old Pimampiro municipal watershed-protection scheme and the 13-year old Profafor carbon-sequestration programme (Wunder and Albán 2008). Costa Rica (Janzen 2002; Morse 2009), Indonesia (Pattanayak 2004; Pattanayak and Wendland 2007) and South Africa are also making significant strides in this area. Many more are getting underway elsewhere in Latin America, Asia, and, more slowly, Africa and Madagascar.

IN CONCLUSION

The genesis of TEEB, our global study on the economics of ecosystems and biodiversity, lies in climate change. The 'G8+5' meeting of environment ministers at Potsdam, Germany, in 2007, proposed a study to assess the economic impact of the global loss of biodiversity in order to present a convincing economic case for conservation. Their inspiration was the Stern Review, published in autumn of 2006, which built upon the science of the IPCC and presented a powerful economic case for early action on climate change.

'Phase 1' of TEEB identified climate change as the second-largest driver – after land use change – of the loss of terrestrial biodiversity over the period 2010-2050 (TEEB 2008; Braat and ten Brink 2008). It comes as no surprise therefore that the most significant ecosystem and biodiversity losses requiring urgent policy attention - coral reefs and forests - are also fundamentally linked to climate change. But while climate change is damaging ecosystems, protecting and restoring ecosystems can do much to mitigate climate change. Preventing further deforestation, for example, is a cost-effective mitigation option, and one that ensures the continued supply of valuable ecosystem services.

This update explains the link between preventing deforestation and saving coral reefs, one of our most diverse and impressive ecosystems. To save the coral, we will need much more ambitious CO_2 targets than those currently discussed – targets below 350 ppm. This may seem utopian today, but, besides reducing industrial emissions (brown carbon) significantly, making full use of the mitigation potential of forest carbon capture (green carbon) would be a first and essential step in the right direction. Scientific advancements might permit society to realize the full potential of capturing carbon by playing the full hand of carbon colours, once the dynamics of soil and ocean carbon (blue carbon) capture are better understood and adequate measures developed.

TEEB shows how paying more attention to the economics of ecosystems and biodiversity can help address the challenge of climate change. It can also help move our institutions towards a greener economy. By setting prices for ecosystem services, demonstrating their value to society, and beginning to capture these values, it is easier to justify funding for local actions and international agreements. Some of the most cost-effective 'climate change adaptation' options involve conserving and restoring ecological infrastructure. Similarly, one of the best value 'climate change mitigation' strategies would be a global agreement on forest carbon.

In the view of TEEB, three priorities are vital components of a successful outcome in Copenhagen: more ambitious carbon reduction targets as a response to recent findings on coral reefs, a forest carbon agreement, and more investment of adaptation funds in ecological infrastructure. We hope that this 'TEEB Climate Issues Update' will help world leaders in their commitments to tackling climate change in Copenhagen. It is essential that they take this decisive opportunity to help safeguard and restore our ecosystems, and the services they provide for humanity.

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Annex 1:

Rewarding the co-benefits of forest carbon

On how a 'premium' forest carbon mechanism could be set up to reward ecosystem services alongside a REDD-Plus framework implemented for forest carbon.

TEEB sees a forest carbon agreement not only as an important precursor to a broader Terrestrial Carbon regime, but also as the bedrock for emerging frameworks of payments for a range of ecosystem services. This Annexure describes an example of a framework for a typical three-phase 'REDD-Plus' implementation for a forest carbon regime, which also addresses the opportunity to reward 'co-benefits' of forest carbon capture and storage.

Phasing in a forest carbon regime

Consensus is emerging around a forest carbon regime that will be implemented in three phases, similar to those described in a recent options assessment report prepared by Meridian Institute for the Government of Norway (Zarin et al. 2009). As outlined below, the approach involves a gradual transition from public/donor funding of capacity building and demonstration projects, through competitive funding of new projects in a 'clearing house fund' mechanism, to eventual market-based trade in forest carbon certificates.

A phased approach to forest carbon could ensure the much needed preparation of supportive institutional and legal arrangements, building capacity and providing adequate incentives for investors, while also broadening the funding base for forest conservation and management. Three distinct phases typically are envisaged, for example:

Phase 1 could focus on supporting the development of 'Forest Carbon National Strategies & Action Plans' by first-mover countries, building capacity to implement forest carbon actions in these countries. Bilateral and multilateral arrangements to set up a number of demonstration projects, such as arrangements proposed by UN-REDD and the World Bank's Forest Carbon Partnership Facility (FCPF) are examples of Phase 1 activities. Another key priority in this first phase will be to support appropriate policy frameworks and frameworks for long-term measurement, verification and reporting (MRV) of forest carbon actions and project outcomes.

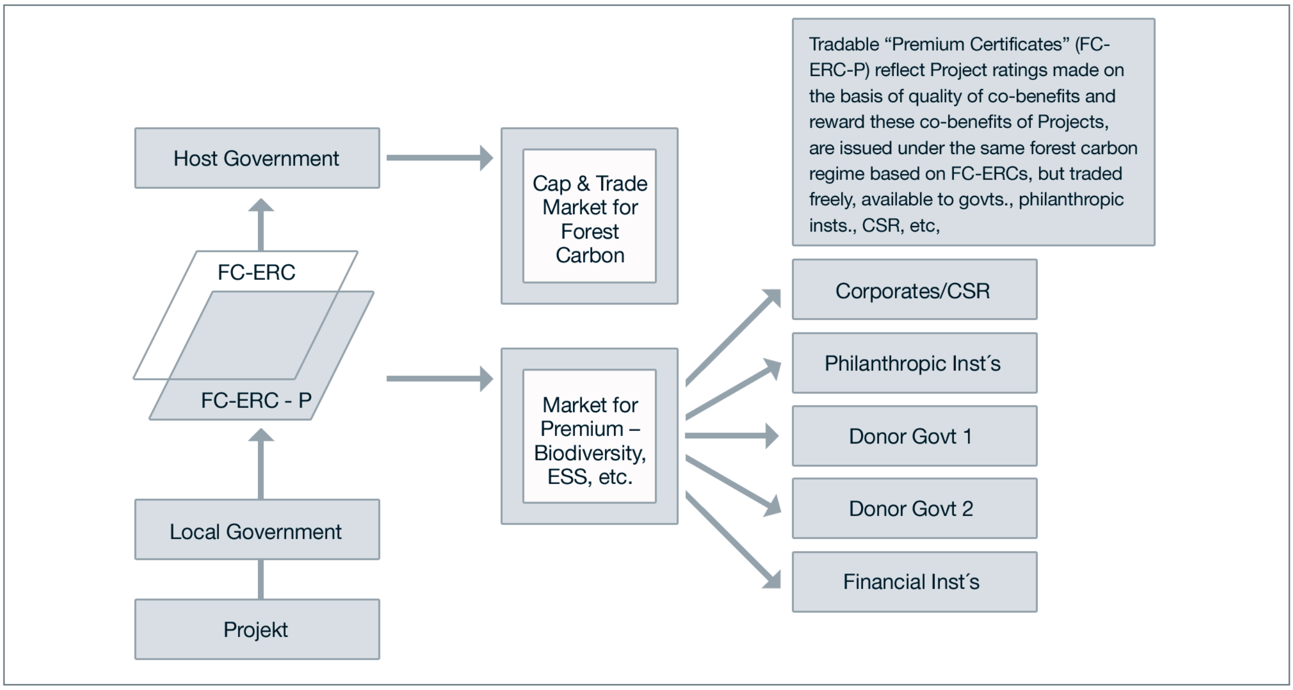
Phase 2 involves the implementation of forest carbon strategies within participating 'host' developing countries, with tropical forests, which meet the basic readiness requirements (e.g. MRV standards, project and national carbon accounting systems, enabling legislation, etc.). Further capacity building in Phase 2 would, crucially, include efforts to integrate forest carbon and other ecosystem values in national income accounting frameworks, in such a way that forest carbon transactions (and other payments for ecosystem services) are ultimately reflected in national income statistics. Project performance during this phase would be measured and rewarded against reference levels (e.g. historic deforestation and degradation rates, current forest cover, per capita income, etc) agreed between project proponents, country governments and/or project funders, thus establishing an initial benchmark for subsequent market transactions. Phase 2 would possibly rely on international funds and donors, supported ideally by a 'clearing house' to ensure transparency while also strengthening incentives for higher quality (lower risk) projects and country frameworks through a dedicated International Fund with specific 'inclusiveness' objectives, in order to bring up capacity and participation from those countries less able to attract bilateral donor funding in Phase 2.

Phase 3 would be the 'mature' phase of Forest Carbon, in which national reference levels are subject to a global cap-and-trade agreement, the additionality of actions is guaranteed, and international leakage is addressed explicitly. Liability and penalties for non-performance during this phase could however be negotiated bilaterally between funders and project proponents. In this phase we would also hope to see efforts to integrate other forms of terrestrial carbon (e.g. soils, wetlands), closer integration of forest and industrial carbon markets, and the development of regulatory structures and financial products based on other forest ecosystem services.

Example: a 'premium' scheme for rewarding co-benefits of forest carbon

Eligible projects which have agreed to be rated in Phase 1, and have had their 'co-benefits' performance rated in Phase 2, can in Phase 3 (when they issue Forest Carbon – Emissions Reduction Certificates - FC-ERC's) also simultaneously and for the same project and year issue a rated tradable debenture or 'Premium Certificate' (FC-ERC-P). This 'Premium' Certificate reflects the year's ranking for the assessed quality of their Project's performance on the Co-benefits front, (i.e. for the extent of ecological service benefits, livelihood benefits, biodiversity conservation). This Premium can be 'stripped' and sold to various investors in the open market to realize further gains for successful high-quality projects, and effectively this will achieve a small open market in the other ecosystems services from the same forest carbon projects such as REDD-Plus projects within a national forest carbon regime.

Phase 3: Adjunct market for premium FC-ERC-Ps *Source: GIST, www.gistindia.org*



Some of the success factors that apply to schemes such as this are generic and relate to the overall success of the regime. Some however are process-specific, and relate to how this 'Premium Emissions Reduction Certificate' mechanism interacts and works in context of a REDD-Plus or similar scheme.

Generic success factors for the forest carbon regime

Fungibility: Some are concerned that green carbon and brown carbon (forest carbon and fossil fuel / industrial GHG) are different commodities within the GHG family, and that there would be a problem if they evolve into different cap-and-trade markets within an overall regime, trading at a spread to each other. TEEB thinks that fungibility is not an impeding factor for REDD success and certain conditions and safeguards can minimise fungibility in a case of unique global GHG market. Evidences suggest that two main commodities – (like in the case of oil market the WTI and Brent Crude) – can be successfully traded in pairs in the same market. In the case of oil market, WTI and Brent Crude are traded as a pair with a fluctuating spread for over 30 years.

Market liquidity: An important goal, it is only marginally a feature of contract fungibility, but mainly of the underlying distribution of demand and supply largely due to the tightness of caps in a cap-and-trade regime, of market depth (i.e. number of price-makers), of speculative opportunity and interest, and controls over speculation. Illiquid markets overall will not be successful, and this is a concern.

Leakage: there is an effectiveness issue arising through intra-regime 'leakage' risks if a global cap and trade accord creates a regime which recognizes one commodity within the GHG family but not the other, and this issue is already impacting the effectiveness of the current regime (see box – The Colours of Carbon)

Terrestrial carbon vs. forest carbon: to include in terrestrial carbon, in a time-bound manner, agricultural lands, plantation forests, pasture lands, soils, etc. is important due to the considerations above, but that the mounting 'costs of inaction' on forest carbon do need to be weighed against the gains from an even further delayed holistic regime of emissions control.

Local communities/ indigenous peoples: must be recognized as a formal 'tier' of beneficiaries, in addition to Sovereigns and State Governments, in a three-tier, 'nested' approach which rewards project performance through National schemes even if Country targets have not been met that year to pass on rewards. It is necessary to ensure consultation with communities at an inception stage, not least so that the mechanisms designed for transferring wealth to beneficiaries at the community level are consistent with the organization of communities, and not just impractical implants of Western structures (Companies, Trusts, etc) onto a community context. Furthermore, the commitment shown by indigenous peoples / local communities towards the overall forest carbon regime, will depend on the process being equitable and seen to be equitable.

Upward compatibility: This is vital to ensure in the context of an evolving global regime of emissions control with phased negotiations and implementations that the legal architecture supporting an emissions market today needs to be flexible enough and robust enough to support future emissions markets like the forest carbon, as well as future markets for other ecosystem services from the same underlying ecosystems.

Specific success factors for a process & market in co-benefits alongside the forest carbon regime

Institutional requirements: It is vital that, as early as Phase 1, the host country should list approved ‘Rating Agencies’ and get them engaged in the task of rating Projects for their ‘Premium’ values. A delay would be costly and the process could be still-born. Phase 2 should see the project's performance being rated, to set the track record for eligibility in the future (market) Phase 3.

Local communities / indigenous peoples: Apart from being recognized as equal participants in the regime, they should also share the rewards (i.e. % of Premium value) for providing benefits especially for biodiversity. Failing that, incentives might perversely favour wildlife gatherering for profit, whilst rewarding biomass conservation for carbon benefits as expected from the main forest carbon regime.

Clearing-house fund: This structure can reflect governance concerns and performance risks effectively. It can thus avoid ‘moral hazard’ if eligibility standards are applied centrally in an overly mechanistic manner. Therefore it is a desirable feature to attract buyers to ‘Premium’ projects. However, this may channel too much funding towards the same ‘Premium’ projects. We need to consider inclusion and capacity development in other (weaker) governance regimes and riskier projects. An (additional) centralized fund structure is able to distribute funding in a manner which is more inclusive and helps build capacity across many more nations less able to build their own capacities or attract bilateral interest – so long as it is sufficiently funded and its objectives are appropriately defined.

‘Reference levels’ When sought within a Clearing-house fund structure in a typical ‘Phase 2’ REDD-Plus regime, these need not be prescribed, as they can be bilaterally negotiated with host country projects, and a common framework can enable a 'market trace' of Reference Levels to form, based on actual projects transacted, which could set useful precedent for Reference Level negotiations when negotiating the value of ‘Premium’ in Premium ERC’s. Since the ‘Premium’ is an open market construct and not itself subject to a ‘cap-and-trade’ regime, it will not require global agreements to set reference levels to measure Premium performance, rather, it will require just an assurance of structural consistency and the continuation of the adjunct ‘forest carbon’ regime.

Annex 2:

Countries where resource accounts exist

Accounts as part of ongoing accounting programmes by government agencies or non-government agencies in collaboration with government agencies

	Minerals	Energy	Forest Asset accounts				Water	Land	Emission (Waste)	Soil	Environmental degradation
			Timber		Nontimber goods and services						
			Asset accounts	Supply & use accounts	Carbon storage	Other goods & services					
Australia[1]	●	●	●	●	●	●	●	●			●
Botswana	●										
Chile	●		●								
Finland		●	●	●	●	●	●	●	●		
Denmark		●	●	●	●	●	●	●	●		
France		●	●	●	●	●	●	●	●		
Indonesia		●	●		●						
Norway[2]	●	●	●	●	●	●		●	●		
Sweden[3]		●	●	●	●	●	●	●	●		
Netherlands[4]		●	●	●	●	●	●	●	●		●
Italy		●	●	●	●	●		●			●
Germany		●	●	●	●	●	●	●			●
Spain		●	●	●	●	●		●			●
Philippines[5]	●		●		●	●	●	●		●	
South Africa	●		●		●	●					
United Kingdom[6]		●	●	●				●	●		
US	●	●									
New Zealand		●	●	●	●	●	●	●			●
Canada[7]	●	●	●	●	●	●		●	●		
Namibia	●										
Swaziland			●	●	●	●					
Thailand			●								
Mexico		●	●		●	●		●			●
Costa Rica			●								
Brazil			●								

Source: Information compiled from various statistical office web page and Glenn-Marie Lange (2002)

Note: The list is not comprehensive and illustrates subset of countries which have undertaken the environmental accounting. For the forest related accounts, not all the countries are at the same stage, Some have compiled physical accounts stocks and others monetary stock accounts while some have compiled the flow accounts (supply or use or both).

[1] The Australian Bureau of Statistics has developed comprehensive accounts for Water (SEEAW), but in physical units. On an experimental basis they have tested monetary accounts for water. They have also developed supply and use accounts for fisheries (although they had a lot of data limitations since they did not have stock data on fish and hence had to make several assumptions) and energy and mineral accounts (physical supply and use and monetary accounts on experimental basis). However, they have not attempted any accounts for carbon.

[2] Statistics Norway as part of the Norway environmental and economic accounting project developed NAMEA accounts (National accounts matrix including environment accounts) to include air emissions (CO2, CH4, N2O, SO2, NOx, NH3, Pb, Cd, Hg, PAH-4, CO, particulates, NM-VOC, dioxins) for the period 1991-2000, Solid waste NAMEA (1993-2000), including 11 waste fractions and divided into 7 economic groupings. The accounts are in physical units using the NAMEA approach.

[3] Statistics Sweden developed a physical set of accounts for water, harmful chemicals released into the environment, hazardous and non-hazardous waste, and emission accounts for CO2, NO2 and SO2 all in physical units as part of the official programme. They developed a comprehensive set of material flow accounts and environmental expenditure accounts. Land and forest accounts are also tested on a pilot basis.

[4] The Dutch environmental accounts are very comprehensive. They cover physical and hybrid flow accounts for air emissions, water quantity and emission accounts and waste accounts; asset accounts for oil and natural gas and crude oil and monetary accounts for environmental protection expenditures and environmental taxes. There are plans to improve the accounts and expand them into material flow accounts, environment industry and climate change accounts, including mission permits and environment subsidy accounts. The accounts are compiled from existing statistics and used to meet several policy and data needs.

[5] Asset accounts for environmental degradation in physical and monetary terms according to the SEEA framework.

[6] Office for National Statistical Office in UK has been publishing satellite accounts (biennial). They have developed the oil and gas accounts (physical and monetary), land accounts (physical units), forests (supply accounts and asset accounts), water accounts (only the use accounts) and emission accounts including the emissions of green house gases.

[7] The Canadian framework focuses on improving the basic environment statistics, including but not limited to the input data for the environmental accounts. Statistics Canada has developed the emission account as part of the waste accounts in physical units (GHG emissions measured in terms of equivalent CO2 emissions by households, industries and sectors).Forests accounts are in physical unites, monetary accounts for timber. A key aspect of the framework is its explicit recognition of quality issues as part of the framework development.

EUROSTAT requires that accounts be compiled for environmental protection expenditure, economy-wide material flow accounts and NAMEA air emissions. These have been developed by six6 countries: Germany, Italy, Austria, Finland, Sweden and United Kingdom. They are already compiling statistics for all three accounts on a regular basis. Another 14 countries (Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Spain, France, Lithuania, Hungary, Netherlands, Poland, Portugal, Slovenia, and Norway) are active in all three areas too. In addition to the efforts by the European Statistical System, the European Environment Agency (EEA) is playing an important role in developing ecosystem and land use accounts, as well as performing analyses of existing data from environmental accounts to identify patterns of sustainable consumption and production. EEA is taking the lead in including the spatial dimensions as well as the functioning and valuation of ecosystems.

Annex 3:

List of acronyms

CBD	Convention Biological Diversity
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
COP	Conference of the Parties
COPI	Cost of Policy Inaction
EEA	European Environmental Agency
ERC	Emissions Reduction Certificate
EU - ETS	European Union - Emission Trading System
FAO	Food and Agriculture Organization of the United Nations
FC-ERC	Forest Carbon - Emissions Reduction Certificate
FC-ERC-P	Forest Carbon - Emissions Reduction Certificate Premium
GDP	Gross Domestic Product
GHG	Green House Gas
GRID	Global Resource Information Database
IPES	International Payments for Ecosystem Services
MRV	Measurement Reporting and Verification
NGO	Non Governmental Organisations
NPV	Net present value
OECD	Organisation for Economic Cooperation and Development
ppm	Parts per million
REDD	Reducing Emissions from Deforestation
SEEA	System of Integrated Environmental and Economic Accounting
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNCEEA	UN Committee of Experts on Environmental-Economic Accounting
UNFCCC	United Nations Framework Convention on Climate Change
UNSC	United Nations Statistics Commission