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Metaforum paper 5

Conservation and Management of Forests for Sustainable Development: Where Science Meets Policy

Position paper working group Metaforum Leuven, presented at the Forests2011 symposium of 24 November 2011

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EXECUTIVE SUMMARY

The **Forests2011 Position Paper** aims to increase awareness on the importance of forests for ecosystem services worldwide, and to make an updated contribution from science to the forest policies of the future. It discusses the conservation, management and sustainable development of forests, i.e. the central themes of the United Nations International Year of Forests 2011, in a European and global context.

The importance of **forest ecosystem services** for human prosperity and well-being is an increasing motivation for protecting the forest. The ecosystem services (ES) framework is an interesting basis to develop concepts of protection and sustainable use of forest resources, in part because the ES framework unifies and extends the existing concepts of sustainability and multifunctionality. Although forest management and forest policy may benefit a lot from adopting the ecosystem services framework, ecosystem services need to be fully quantified and trade-offs between ES well understood before it can be fully translated into practice. National developing standards such as the traditional GDP should be adjusted so that the value of ecosystem services is recognized. Payment schemes for forest ecosystem services should be established.

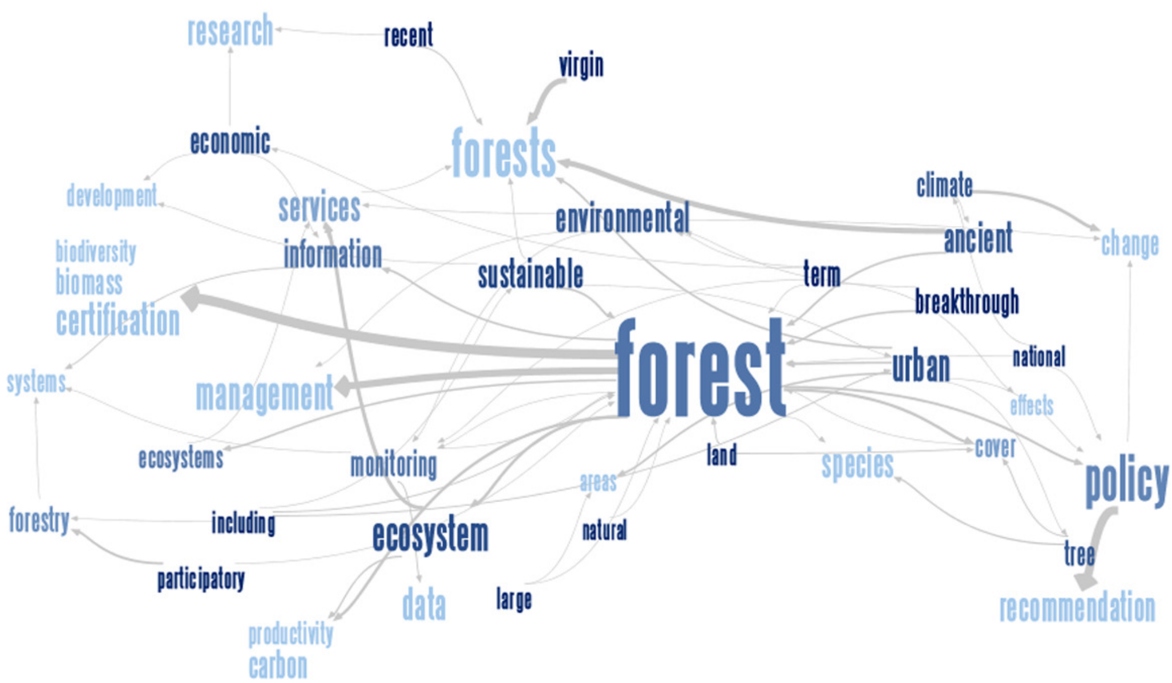

Figure 1 The relationship between the most widely used words (42 of 1136 terms) in the Forests2011 Position Paper, highlighting with larger arrows, among others, the concepts 'forest management', 'forest certification', 'forest biodiversity', 'forest biomass' and 'forest ecosystem services'.

There is accumulating evidence that **forest biodiversity** has functional significance for sustained delivery of ecosystem services to human society. Testing diversity/functioning hypotheses in different forest types will become feasible in the near future thanks to new large-scaled research facilities. In the mean time, attention should be given to create awareness and capacity on the functional aspects of biodiversity and the value of forest biodiversity for human well-being. We warn however that biodiversity function cannot be used as an alibi for neglecting non-functional values of biodiversity.

Afforestation and deforestation, and subtle land cover changes like forest degradation and spontaneous tree cover restoration are **forest transitions** of which we need to describe and understand the causes. Forest transition models revealed the drivers of deforestation and allowed developing a typology of countries based on forest cover and deforestation rate. Large scale detection and mapping of forest degradation is still very difficult due to the patchy nature of the resulting landscapes with many 'transitional' land cover types. In regions of the world with strong deforestation pressure the development of intersectoral platforms at national and subnational level is a first step towards deforestation avoidance. In areas like Europe where forest restoration took place in the last decades there is a need for growing awareness and state-of-the-art tools to detect and remedy postmodern forest degradation due to continued urbanization and upcoming unsustainable biomass use.

Environmental changes cause major productivity changes in forests and may compromise future benefits from ecosystem services, in particular if forest productivity decline due to climate change may be bigger and more widespread than expected.

Surviving **virgin forests** are a unique source of information about the biodiversity, composition, structure, dynamics and overall functioning of natural forest ecosystems, but a complete inventory of virgin forests that remain in temperate Europe has never been conducted. At least a selection of the last virgin forests of Europe should be declared as UNESCO Natural Heritage Site.

Ancient forests – under forest cover since immemorial time but not necessarily virgin – offer a unique source for studying ecological processes like how species disperse and recruit, or how fragmentation affects their colonisation capacity. Although their importance for forest conservation has been accepted widely, in many countries of the temperate climate ancient forests and their associated species have not been studied in detail. Ancient forests must appear more prominently on European and national nature conservation agendas, in forest management plans and in forest certification procedures.

Planning of forest management and wood resources is becoming a challenge in a rapidly changing world with a highly uncertain future. Forests are complex non-linear systems susceptible to regime shifts. To develop early warning systems for catastrophic shifts in forest ecosystems there is a need for powerful computational tools able to derive threshold indicators from long-term monitoring data. In forest planning, predictive tools based on trend extrapolation and linear models must be complemented with new sophisticated tools based on monitoring and early detection of these thresholds or change-points.

Sustainability monitoring needs an international standardized evaluation approach. The forestry sector has been at the cradle of several breakthroughs in sustainability assessment and monitoring throughout history. The last frontier in forest sustainability assessment is the monitoring of biodiversity and its inclusion in impact assessment and forest valuation to create a sensitive instrument to compare changes in time and differences in space.

Forest-related databases must be documented and harmonised to enable trans-boundary sharing and re-use of the data they contain. To develop regional, national and global, functional forest data infrastructures, there is a need to better specify the data involved and standardise the data models so that resulting databases can be interoperable and a sound basis for trans-boundary applications and services. The ongoing efforts to establish data infrastructures in the environmental domain at all levels, from local to global, must be consolidated and taken further.

Social scientists have recently raised important questions about the level of involvement in **participatory forestry**, and the unifying and exclusionary tendency behind the concept of 'community' in community participation. Little is known about the ways in which forest governance may go beyond political gains of a few, and ways in which different levels of government may successfully share information about the whole range of actors and institutions involved in forest governance. A new approach to participatory forestry needs to embrace complexity at many levels and extend the concept of communities and participation. Participatory forestry methods are still in an exploratory phase and therefore need to be monitored and evaluated in order to transform participation from being an empty promise to being a workable tool.

Forest conservation and management has increasingly converged with commercial interests during the last decades, and scholars have warned about the possible negative aspects of this trend. It is not sure whether the **marketing of forests** actually conserves the forests and improves the well-being of local people. Forest commodification needs to be monitored and wisely guided in an interdisciplinary effort between foresters and anthropologists.

Increased **harvesting pressure** on forest ecosystems might harm future productivity. There is urgent need for large-scale quantitative information on sustainable harvest levels in different forest ecosystems. European targets for woody biomass production should be revised, and new production potential outside current forests stimulated.

Interest in the benefits and costs of **urban forests** and trees and the quantification of these is growing. Apart from these relatively well accepted benefits, the effects on human health and well-being are less well known or quantified. A systematic collection and organisation of basic data on urban green, including forest and trees is essential to estimate benefits and costs. The effect of green on human health and well-being should be investigated. In general, a more pragmatic ecological science, which delivers solutions to our crowded planet is wanted. In view of the current environmental problems of pollution and climatic change, action for urban forests and trees should become an essential part of sustainable urban development of all urban areas whatever their size and population.

Originating from the industry, **life cycle thinking** successfully established its place and gains importance in the forestry sector. No scientific consensus is found on the inclusion of land use, and effects of direct and indirect land use change in life cycle assessment. Life cycle approaches must be promoted as the essential tool to analyse the environmental sustainability of new management and production scenarios of the biobased economy. Further standardization in life cycle analyses is necessary to make results comparable and suitable for trade-off analyses and policy advice.

The **spill-over effect of deforestation avoidance** has been quantified for some countries. But for many countries it is still unknown to what extent sustainably grown domestic timber will be able to compete with – and substitute – illegally imported timber. There is a need for 'full carbon accounting' to avoid leakage and spill-over effects at international level.

During the climate change negotiations a lot of time has been spent – and will be spent – on establishing a **forest definition for REDD**. There is probably no single definition of forest that can apply in the continuum of landscapes with trees. This is why we believe that the current focus of the international REDD negotiations and related (sub)national case studies on forest carbon alone needs to be broadened to ecosystem carbon.

Integrated policy approaches and tools to realize the **mitigation, adaptation and development** objectives are increasingly available and being promoted. Reconciliation between mitigation, adaptation and development can be easy in the case of clear win-win situations, but more action research is needed to find opportunities in those cases where trade-offs seem to exist. Development, mitigation and adaptation projects and programs should not be conceived on a separate sectoral basis, but jointly.

Apart from their direct economic benefit, **forests ethics** considers the higher values of forests at the level of the global ecosystem. Since not only humans benefit from sustainable forests, all ecosystem services need to be quantified. Providing an acceptable method for valuing ecosystem services of forests would facilitate a global forest policy management beyond carbon calculation.

Forest certification is an important non-state market regulatory governance tool. An important scientific gap concerns the assessment of the effectiveness of forest certification. To advance forest certification as a governance tool the effectiveness of forest certification should be assessed, forest certification schemes should be independently certified and adoption be supported.

PREFACE

Forests cover 31% of the total global land area. They provide a home to 80% of the earth's terrestrial biodiversity and the livelihood of 1.6 billion people around the world depends on them. Recognizing their global importance, the United Nations declared 2011 as the International Year of Forests. During this year Metaforum Leuven, the interdisciplinary think tank of K.U.Leuven together with the K.U.Leuven Division Forest, Nature and Landscape took the initiative to launch a Metaforum Leuven Working Group on Forests. The objectives of the working group were to increase awareness on the importance of forests for ecosystem services worldwide, and to **make an updated contribution from science to the forest policies of the future**.

The Metaforum Leuven Working Group on Forests studied and discussed the **conservation, management and sustainable development of forests**, i.e. the thematic of the International Year, in a European and global context. The working group was composed of senior scientists from K.U.Leuven with interest and experience in forest related research, together with some invited scientists from other institutions. It was made sure that the discussed **issues** were **of high societal relevance** by inviting some key stakeholders of the international forest policy scene to the first meetings of the working group. Our exercise had no ambition to be exhaustive, but it handled the topics for which our expertise allowed to tackle the problems from a fresh angle.

This Forests2011 Position Paper is the outcome of **a truly interdisciplinary process, with an active participation of social scientists**. It reveals **scientific breakthroughs**, identifies **knowledge gaps**, and formulates **policy recommendations** for a number of hot forest topics. These topics cover **the domains of forest protection, forestry and society, and international forest policy** and as such aim at supporting the follow-up of the Green Paper on Forest Protection and Information in the EU, the review of the EU Forestry Strategy, and the European policy on global forest resources (REDD and FLEGT). We believe that most sections of the position paper are of interest to a Flemish, European and international audience. We also hope it will become a source of inspiration for future research agendas in the forest realm.

1 FOREST PROTECTION

This chapter starts from the concept of forest ecosystem services as the major motivation for protecting the forest (1.1). After that the importance of biodiversity for forest ecosystem services is explained (1.2). Then the different aspects of forest protection are highlighted, being the custody over the forest area, and the maintenance of vitality and quality of the forest resource (1.3). Finally two sections follow on monitoring (1.4) and information systems (1.5) as key instruments in the support of forest protection.

1.1 FOREST ECOSYSTEM SERVICES

Why is the Ecosystem Services (ES) framework (figure 2) an interesting basis to develop concepts of protection and sustainable use of forest resources?

Breakthrough

The ES framework unifies and extends the existing concepts of sustainability and multifunctionality.

During the last decades, but in particular since the publication of the Millenium Ecosystem Assessment in 2005 (www.maweb.org) an exponential increase of publications on ES has been observed [1]. The publication of The Economics of Ecosystems and Biodiversity report of 2010 (www.teebweb.org) has even added more interest to this field. Both reports, together with other seminal contributions (e.g. [2]) have significantly advanced the conceptual framework, modelling and valuation of ES and the development of instruments to incorporate ES concepts in management practices and policy making. Also for forest management and forest policy, ES science provides an added value as it further extends and operationalizes existing concepts of multifunctional and sustainable forest management brought forward in global (e.g. United Nations Forum on Forests), regional (Ministerial Conference on the Protection of Forests in Europe) and (sub-)national policy documents (e.g. Forest Decree of Flanders, 1990). Compared to these previous frameworks the ES concept adopts a more holistic landscape view in which the interconnections with other land-uses are made more explicit. Furthermore, ES science has initiated the development of new tools to quantify, map and value the relevant services for a given area, and to reward sustainable land-users for the ES they provide through different payments schemes (REDD+, CDM).

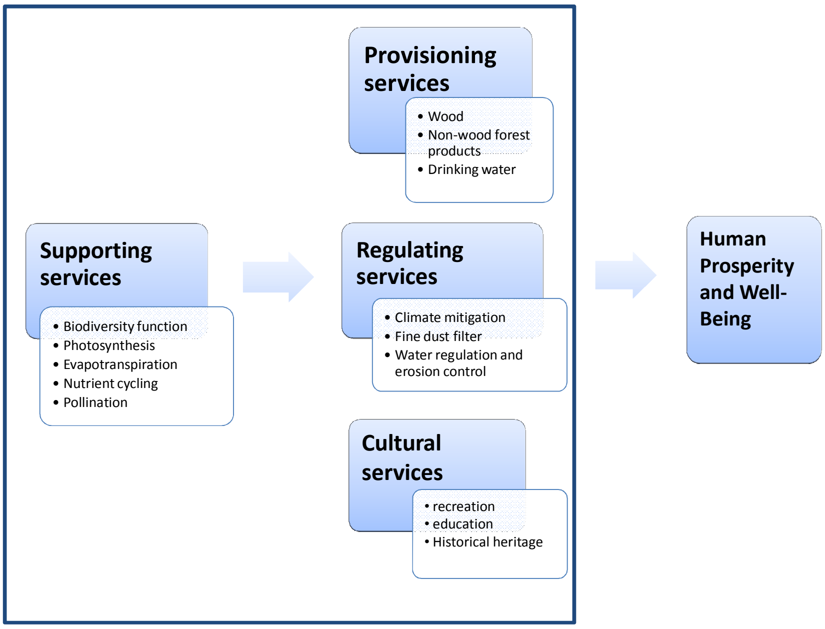

Figure 2: the Ecosystem Services framework according to the Millenium Ecosystem Assessment with examples added of forest ecosystem services.

Knowledge gap

Although forest management and forest policy may benefit a lot from adopting the ES framework, several conceptual and methodological challenges need to be overcome before it can be fully translated into practice. Further research is needed into status and, especially, process indicators for forest ecosystem functioning and ecosystem service delivery [3]. Better insights in the ways to deal with spatio-temporal scaling issues are needed too, i.e. what is the most appropriate scale to quantify a particular ES service and what are the interactions between different scales and between different ES (trade-offs vs. synergistic effects). Ecosystem service valuation, and especially turning values into prices, is still very challenging and a matter of debate (e.g. [4]). Especially non-use values are difficult to monetarize, but also for the quantification of direct and indirect use values several questions remain. For example, the quantification and valuation of cultural ES largely depend on the spatial distribution of substitutes and the socio-economic characteristics of ES beneficiaries. Given the geographical distribution/clustering of socio-economic characteristics, it remains a challenge to properly control for spatial effects by combining advances in GIS and econometric techniques. Another challenge lies in determining comparable scales and the proper ES radius for quantification and valuation of ES as local, regional, European and Global studies typically yield different outcomes [5]. Compared to principles, criteria and indicators that have been put forward for sustainable forest management, the ES approach has the disadvantage that it focuses on the unidirectional benefits from ecosystems to society, but that it takes far less the distribution of wealth among ecosystem service beneficiaries into account (e.g. labour conditions of forest workers). Hence, maximizing the monetary value of ES may not be the only goal of the economy. Certain natural capital components are essential to human survival because they are hardly substitutable. On the other hand, rich people can easily substitute the loss of ES at higher price while poor ones have no choice and are thus first affected by the loss of ES so that this may not be socially sustainable in the long run. Therefore, there is a need to develop a sustainable development concept that maximizes monetary values of ES while at the same time taking into account the preservation of the critical natural capital, and social and ethical sustainability. Finally, a novel mix of informative, financial and juridical instruments needs to be developed to assure that forest owners and managers are rewarded for the ES that they deliver.

Policy recommendation

The awareness and interest for multifunctional and sustainable forest management has a long history in the forest sector and by translating this knowledge into the more holistic ES framework, the sector can serve as an example for other sectors. **Forest policy and forest management should make links between its concepts and programs on multifunctional and sustainable forest management and the ES framework.** This exercise obviously requires a close and continuous collaboration between scientists, stakeholders and decision makers. Sustainability standards should be adjusted so that the value of ES is recognized. **National developing standards such as the traditional GDP should be adjusted so that the value of ES is recognized and payment systems for the services forests provide should be established.**

1.2 BIODIVERSITY FUNCTION

Forests hold large parts of the terrestrial biodiversity and the conservation of this unique heritage is a matter of culture and ethics. **But is there also evidence that forest biodiversity is important for ecosystem services to human society?**

Breakthrough

Cutting-edge research is unravelling the functional significance of forest biodiversity for sustained delivery of ecosystem services. At least since the 19th century foresters have wondered whether mixed forests would be more productive than monocultures, but so far without conclusive answers (see e.g. [6] for an overview). Many stand-level observations worldwide on important timber species reported higher productivity in monocultures compared to mixed stands including the same species [7], but few studies also report positive effects of species mixture on productivity of up to 10 to 20% ([8, 9] and [10]). Species interactions can indeed be negative, neutral, or positive. Positive species interactions can be explained by facilitation or by complementary use of resources. The problem to extract positive biodiversity signals from observational studies is that they are strongly confounded by environmental factors and management practices. This underlines the need for species diversity experiments with sophisticated designs and evaluation statistics. Such experiments in grasslands during the last two decades showed strong positive diversity/productivity relationships [11, 12] that were at least partly explained by species complementarity in accessing soil resources (e.g. [13-16]). Only in recent years similar research has started in the forest realm [17] with large scale tree diversity experiments in Germany, Finland, Belgium, France, Panama, Malaysia, China and Canada (www.treedivnet.ugent.be). Next to an experimental platform, the FP7 project FunDivEurope (www.fundiveurope.eu) also includes an exploratory platform, where over 200 plots with different tree species diversity levels were carefully selected in mature forest distributed over six contrasting regions ranging from Finland to southern Spain. This network of plots forms the backbone of forest biodiversity function research, the most significant innovation in biodiversity studies in recent years.

Knowledge gap

It is waiting for published results from the new large-scaled research facilities that will allow testing diversity/functioning hypotheses in different forest types. In the coming years the new research platforms will start to generate huge datasets allowing to test the effect of tree species diversity levels and species functional traits on a whole range of indicators related to forest composition (associated biodiversity, abundance of pest and disease species), forest structure (biomass allocation) and forest function (energy budget, net primary productivity, water use). Additional research will have to elucidate the underlying mechanisms of the observed relationships, which is very relevant in a context of climate change adaptation (see [6]). A very recent study in grasslands shows that considered over many times, places, functions and environmental changes a large part of the species diversity is needed to maintain ecosystem services [18]. This important finding needs to be verified for forests.

Policy recommendation

There is a need for creating awareness and capacity on the functional aspects of biodiversity and the value of forest biodiversity for human well-being. Although far from well understood it is obvious that diverse forest ecosystems provide many advantages over monocultures, especially when considering multiple functions that should be maintained at different places and times [18]. Economic valuation of biodiversity function will contribute significantly to a better recognition of biodiversity value. In addition to conservation values it can form a basis for payment for ecosystem services related to biodiversity (see also section 1.2). It should be warned, however, that biodiversity function should not be used as an alibi for neglecting 'non-functional values' of biodiversity – the so-called intrinsic value of nature [19]. Both are different and complementary arguments for preserving biodiversity [20].

1.3 THREATS TO FOREST ECOSYSTEM SERVICES

1.3.1 FOREST TRANSITION TRENDS

How to describe and understand the causes behind trends in forest area, including afforestation and deforestation, but also more subtle changes like forest degradation and spontaneous tree cover restoration?

Breakthrough

Forest transition models revealed the drivers of deforestation and allowed developing a typology of countries based on forest cover and deforestation rate [21, 22]. A widely accepted framework for analysis of driving factors of deforestation and their impact on forest cover (hence carbon) is available

[23]. Reinforcing loops can accelerate deforestation: further infrastructure development combined with high population densities and rising incomes that boost capital accumulation and the demand of wood and land resources. Two forces eventually stabilise forest cover, economic development leading to better paid, off-farm jobs pulling people out of agriculture, thus reducing the agricultural rent and the profitability of deforestation; and forest scarcity, where low forest cover increases forest rent (the value of forest products and environmental services) and stimulates tree planting [24]. Related to the forest transition theory new concepts arose like the distinction of 'core forests', 'forest margins' with rapid loss of forest cover and contests over land-use rights, and 'mosaic forests' in the (partial) recovery phase after land rights were established [25, 26].

Knowledge Gap
Forest transition not only includes the widely lamented deforestation, but also more subtle changes like forest degradation and 'agroforestation' (i.e. a trend where trees increasingly play a prominent role in the agricultural landscape). This results in relatively complex landscapes with untouched forest fragments, clearcuts and a range of patches with degrading and regenerating forest, fallow and agroforest in various stages. While deforestation can be relatively easily monitored using satellite imagery and remote sensing techniques, mechanisms as deforestation or forest degradation due to indirect land use change are not well understood (also see 2.4). **Large scale detection and mapping of forest degradation is still very difficult due to the patchy nature of the resulting landscapes with many 'transitional' land cover types. Also more socio-economic research is needed, not only into the factors that impede necessary policy change, also into possible alternatives**. There is a need to better disentangling global from local factors that control forest transition. The different land tenure systems of large areas are not only poorly documented, but reliable maps are even more scarce.

Policy recommendation
It is clear that the dominant factors that control and stimulate deforestation – or reforestation – are often outside the forest sector. For some areas extensive research on drivers and alternatives has been carried out, but the adoption of these policy recommendations is lagging behind. Governments often operate on a sectoral basis, making the development of cross-sectoral policies challenging. **In regions of the world with strong deforestation pressure the development of intersectoral platforms at national and subnational level is a first step towards deforestation avoidance**.
Context is crucial regarding policy adoption. Improved accessibility and investments in infrastructure can have disastrous effects on forest cover and stimulate a 'race for land' in remote, often forest rich areas. In other regions an improved road network can be beneficial to restore tree and forest cover, when it stimulates the mobility of a population away from an often detrimental subsistence agricultural system with limited added value, and when there is little forest value left.
In areas like Europe where forest restoration took place in the last decades there is a need for growing awareness and state-of-the-art tools to detect and remedy postmodern forest degradation due to continued urbanization and upcoming unsustainable biomass use.

1.3.2 TRENDS IN FOREST GROWTH AND VITALITY

Forest growth and vitality determine productivity, and are related to many supporting, regulating and provisioning services of the forest. **How is forest productivity impacted by changing environmental factors, and does this compromise future benefits from ecosystem services?**

Breakthrough

Environmental changes cause major productivity changes in forests. New insights in forest productivity are facilitated by increased data availability from long-term forest monitoring networks (e.g. National Forest Inventories), retrospective tree ring analysis, availability of long-term environmental time series and improved analytical and statistical methods [27]. It is now widely acknowledged that forest productivity changed during the 20th century throughout Europe and worldwide [28-31]. The rate and direction of these changes vary between species, regions and forest types. Forest productivity changes have been related to environmental changes at varying spatial scales. Increased nitrogen deposition often seems to have a positive effect on growth, although in regions with high deposition loads also negative effects have been observed [32, 33]. Also atmospheric CO_2 increase may cause growth increases by its effect on water use efficiency, especially in arid areas [34]. Finally, changing temperature and drought trends often have been related to growth increases, growth declines or even major tree dieback [35-37].

Knowledge Gap

Future forest productivity decline may be bigger and more widespread than expected, and may impact on many ecosystem services. Although growth declines due to environmental changes are often thought to be limited to boundary areas of species' distribution ranges, recent studies indicate that also important productivity decreases can arise for species at the heart of their distribution range, even on the best sites. This is for example the case for common beech in Flanders, for which a growth decrease of 15% since the 1960s could be related to the decreasing relative air humidity in summer [38]. Other species like oaks may profit from increasing temperature trends in the short-medium term, although increasing drought and disturbance risks may cause adverse effects [39]. Therefore, future trends in forest productivity may be less optimistic than assumed, even in the temperate and boreal zone. Moreover, as primary production lies at the basis of many provisioning, regulating and cultural ecosystem services, there is an urgent need to understand potential effects of future growth declines in forests on provisioning of ecosystem services.

Policy recommendation

Take European action to maintain sustainable production of ecosystem services from forests. Impacts from environmental change on forest ecosystems are expected to be biggest in Mediterranean and Temperate Continental zones of Europe, but also Temperate Oceanic and Boreal regions will probably be affected. To limit these impacts on forest productivity and ecosystem services, Europe-wide and coordinated action is required. This should be focussed on (1) long-term mitigation of environmental changes, and (2) short-term investment in adaptive management approaches.

1.4 FOREST MONITORING

1.4.1 VIRGIN FORESTS IN ANTHROPIZED LANDSCAPES

Forests of temperate Europe have been managed and exploited for centuries. Huge expanses of these forests have been turned into plantations of fast-growing often exotic tree species. Only small fragments of the original virgin forests have survived, mostly in remote areas inaccessible for exploitation. **Where are these last virgin forests? What can we learn from them and how can we better protect them?**

Breakthrough

Scientists have investigated some of the remaining virgin forests to gain knowledge which cannot be obtained elsewhere. A good example is the Boubín Virgin Forest in South Bohemia, Czech Republic, where scientific research started as early as in 1847 [40]. The study of this and other virgin forests has provided a lot of precious ecological data. As self-sustaining ecosystems, these remaining virgin forests represent centuries of forest memory –s omething that has been completely lost in commercial forests. A good understanding of their ecology is helpful in the ongoing conversion of commercial forest plantations into more natural forest ecosystems **Surviving virgin forests are a unique source of information about the biodiversity, composition, structure, dynamics and overall functioning of natural forest ecosystems.**

Knowledge Gap
The diversity of virgin forest remnants is considerable over the wide range of environmental conditions throughout temperate Europe. In some countries of temperate Europe, forest scientists and owners, who were aware of their extraordinary value, avoided their destruction by declaring them as nature reserves. **A complete inventory of virgin forests that remain in temperate Europe has never been conducted**. Inventories organized by a group of Dutch scientists in Romania, Bulgaria and the eastern part of the Transcarpathian region of Ukraine proved to be very promising: more than 200,000 ha of remaining virgin forests in Romania; 130,000 ha in Bulgaria and 60,000 ha in the eastern part of Transcarpathia [41]. There is no doubt that remnants of virgin forests can also be found in other countries of temperate Europe.

Policy recommendation
There are hopeful indications that the Interest in the last virgin forests of Europe is rising. In May 2011 the Parties to the Carpathian Convention approved a protocol to protect Carpathian natural forests. However, i**t remains urgent to carry out a general inventory of the remaining virgin forests in Europe.** A suitable form of an EU program or project should be developed to cover this task. Selected virgin forest sites should then be protected as nature reserves to avoid their commercial exploitation. They should be scientifically researched using standardized methods. **Based on the full inventory, a representative selection of virgin forests in temperate Europe should be declared as UNESCO Natural Heritage Sites.**

1.4.2 UNDERSTANDING AND CONSERVING ANCIENT FORESTS

A lot of European forests have been used as agricultural land in the past, but others, even if they are no virgin but managed forests, have not. Ancient forests are defined as forests that have existed since at least a number of centuries, compared to recent forests which are much younger in origin. Most of them have been traditionally managed. Ancient forests do have a specific group of mainly plant species only occuring in these forests. **How much ancient forest remains in Europe? Why are many plant species associated with ancient forests? Are also other taxa (e.g. animal species) confined to these ancient forests? In a climate change context, do we need to help forest species to migrate (assisted migration = managed relocation)?**

Breakthrough
Particularly in Europe, and to some extent also in North America, there is a tradition in research looking at the impact of former land use on the plant species composition and diversity (e.g. [42-45]). Hermy et al. [42] found, based on 22 studies from 8 European countries, that about 30% of the plant species found in forests are limited to ancient forests (so called ancient forest species), making them valuable for conservation purposes [46]. Further research indicated that apart from dispersal also long-term establishment played a key role in understanding why these species only occur in ancient forests [47], indicating and confirming that many forest plant species are slow plants in rapidly changing landscapes.

There are indications that also in other taxa (e.g. beetles) some species are associated with ancient forests [48]. Ancient forests only form a small proportion of the total forest area (e.g. Flanders, 15.7% or ca. 23.000 ha; [49]). **Ancient forests offer a unique source for studying essential processes like how species disperse and recruit, or how fragmentation affects their colonisation capacity.**

Knowledge Gap

Although ancient forest and their species have received a lot of attention in NW Europe and to some extent also in the NE of the USA, there remains a lot to be done. **Although their importance for forest conservation has been accepted widely [50], in many countries of the temperate climate ancient forests and their associated species have not been studied at all** (e.g. NE China, N Japan, eastern Europe). Only in Great Britain and Flanders the extent and distribution of the ancient forest resource is well known [49, 51]. In some countries, studies on the distribution just started (e.g. France, [52, 53]). The knowledge whether some animal species or fungi are also confined to ancient forests is extremely limited. Recent studies [47] showed that the establishment and long term survival of transplanted ancient forest plant species into recent forest is more problematic than considered before. This probably suggests that other factors are at play in the establishment and survival of ancient forest plant species when they colonize recent forests (e.g. mutualistic relationships with micro-organisms, microbial diversity). In view of climate change, it is clear that many of forest (plant) species will not be able to migrate. Therefore their migration rates, estimated at about 10-100m per century (e.g. [54]), are far too low. This asks for research and procedures concerning assisted migration [55], particularly in view of the vast changes in land use and climate the extinction-prone ancient forest species are exposed to.

Policy recommendation

Ancient forests are threatened by fragmentation and climate change. Given their huge importance in terms of gene and heritage conservation there is an urgent need to give ancient forests a significant place in forest policy. Ancient forests are extremely valuable for the conservation of forest species and serve as reference for comparison with recent afforestations. They also form a valuable field laboratory for studying fundamental ecological processes. Often they form the last resort for the protection of archaeological and geomorphological heritage in a modern landscape. **Ancient forests must appear more prominently on European and national nature conservation and forest policy agendas. They should also receive attention in forest management plans and forest certification procedures.** A broader debate on the need, risk and good practice of assisted migration in the context of climate change is needed.

1.4.3 EARLY INDICATORS OF FOREST DESTABILIZATION: UNDERSTANDING FORESTS AS COMPLEX NON-LINEAR SYSTEMS SUSCEPTIBLE FOR REGIME SHIFTS

In a context of rapid climatic and environmental changes the forecasting of trends in forest vitality, forest production and delivery of forest ecosystems services using conventional model predictions has become highly uncertain, if not illusive. **How to deal with planning of forest management and wood resources in a rapidly changing world with a highly uncertain future?**

Breakthrough

We start to understand forests as complex non-linear systems susceptible to regime shifts. Complexity science is an emerging interdisciplinary field between physics, ecology and sociology (e.g. [56, 57]). Forests can be considered good examples of complex self-organizing adaptive systems. Interaction, sometimes co-evolution, between the entities (e.g. tree species, ground vegetation, pollinators, seed dispersers, predators) in the system improves the performance of these entities and strengthens complexity [58]. Complex systems like forests and human society are operating far from thermodynamic equilibrium [59, 60] and are characterized by synergies and feedback mechanisms, and typically consist of scale-free networks: it are networks where the frequency distribution of the number of links per node follows a power law. Scale-free networks have hubs, it are crucial but vulnerable network nodes like dominant trees in a forest, or large airports in the air transport system of the human society. Such systems typically evolve through adaptive cycles of growth, stability, catastrophic shift and reorganization [61]. Catastrophic shifts are gradually built-up by internal or external stress factors, but the exact time and space of regime shift is extremely hard to predict. After reorganization the system can find a new equilibrium which might be very different from the previous one. Such regime shifts are often characterised by hysteresis, it means that they are irreversible unless the stress factor causing the shift decreases until a surprisingly low critical level [62]. Box 1 reveals examples of regime shifts in forests.

Box 1 - Regime Shifts in Forests

The adaptive cycle concept of Holling is popular in the social sciences (e.g. [63]), but found its origin in forest succession research [64]. Holling observed that fast growing pioneer forests can gradually develop to old growth forests, which build up so stable humid microclimate that the probability of burning down is near zero, while the biomass accumulation so high that in the rare case of extreme drought a tiny spark can be sufficient to create an inextinguishable fire which destroys the system over large area (recent examples Yellowstone National Park 1988, Indonesia 1997 and 2006, Amazon Forest 1997-98, Russia 2010, Texas 2011). A recent paper in *Science* shows that climate driven fire-tree cover interactions make savannah an alternative state of forest even for large parts of the Amazon and Congo Basin [65]. With increasing standing biomass and increasing incidence of summer drought it is possibly only a matter of years to have large forest fire events in North-West or Central Europe, where forest fire is still today considered an insignificant risk.

Knowledge gap

To develop early warning systems for catastrophic shifts in forest ecosystems there is a need for powerful computational tools able to derive threshold indicators from long-term monitoring data. There is a need to develop early warning indicators of upcoming catastrophic shifts, but this is still in its infancy. Conventional empirical forecasting methods are not suitable for strategic planning of systems identified as complex [66]. Even sophisticated mechanistic models, today commonly used to study forest ecosystems under climate change scenarios, are rarely effective to forecast non-linear phenomena. The problem is that most current methods are not able to detect thresholds or tipping-points before they actually occur. Suding & Hobbs [67] claim that since many managed ecosystems are functioning this way, development and application of threshold models for ecosystem management should be generalized. More particularly, statistical methods for change-point detection in time-series, developed in ecology, climatology and econometry offer promising paths to this goal [68].

Policy recommendation

In forest planning predictive tools based on trend extrapolation and linear models must be complemented with new sophisticated tools based on monitoring and early detection of change-points. Long time and large space forest planning (including sustainable yield assessment, risk analysis) using linear approaches or simple trend extrapolations is doomed to fail given the complex structure and the sometimes extremely non-linear behaviour of the forest ecosystem and the human system managing it. As a consequence, forest planning should be flexibly adjusted by monitoring and early detection of change, rather than too rigidly based on conventional prediction tools [69]. Use should be made from the computational tools being developed for ex ante detection of thresholds from time series.

1.4.4 HARMONIZING CRITERIA AND INDICATOR SETS

Sustainability assessment has become an essential component of today's economic activities, including forestry. It forms inherent part of a modern forest planning process during design, execution, monitoring and feedback. Evaluating and monitoring forest sustainability is undoubtedly one of the main novelties which have completely changed the face of the forestry sector during the last two decades. **But what methodological and political hurdles are still to be taken before an international standardized evaluation approach will be in place, especially in the case of biodiversity monitoring?**

Breakthrough

The forestry sector has been at the cradle of several breakthroughs in sustainability assessment and monitoring throughout history. The concept of sustained yield, formalized by Hans Carl von Carlowitz in his Sylvicultura oeconomica was a first beacon on the way to define sustainable development. It gave rise to a range of inventory methods to monitor standing stock, increment and allowable cut of homogeneous even-aged forest stands, which are still used today. This generally accepted forestry concept also inspired the 1987 Brundtland definition of sustainable development. Soon after the 1992 UNCED conference the forestry sector was pioneering in the development of sustainability standards, based on a hierarchical framework of principles criteria & indicators, often simply called C&I (see e.g. [70, 71] and the criteria of the paneuropean Helsinki process). They form the basis for one of the most prominent innovations in environmental management by the private sector, which is forest certification (see section 3.6). Recent indicator sets are the result of interactive discussion processes between scientists and policy makers (e.g. [72, 73]). In parallel, monitoring networks and protocols have emerged for forest vitality, forest soils, acid and nitrogen deposition and carbon fluxes. Initiatives are underway to integrate these monitoring efforts (see www.futmon.org) in an integrated forest information system (section 1.5). Datamining methods for extracting policy-relevant information from monitoring databases pass a tremendous evolution.

Research gaps

The last frontier in forest sustainability assessment is the monitoring of biodiversity and its inclusion in impact assessment and forest valuation. The global biodiversity alarm due to fast changes in atmospheric composition, climate, soil, land use urges to powerful continent-wide monitoring schemes to detect changes in forest composition over a range of species, including functional groups such as ecosystem engineers (trees), pollinating insects, seed dispersing birds, pest and disease species, litter decomposing earthworms, soil microorganisms, etc. The selection of indicator species baskets is still in its infancy. Indicators of ancient forests seem to be very conservation relevant and powerful as a basis for management strategies (see section 1.4.2).
Meanwhile there is also a growing need for *predicting* sustainability indicators of forests under changing environmental and management conditions. To this goal forest simulator development needs to focus on producing the policy-relevant indicator values of the future, rather than on biophysical variables hard to interpret (e.g. the water footprint instead of the evapotranspiration, the carbon sequestration in stead of the net ecosystem productivity) [74].

Policy recommendations

There is need for a continued common effort at European and international level to harmonize forest monitoring indicators and their measuring protocols as to create a sensitive instrument to compare

changes in time and differences in space. Such effort must be based on reproducibility and cost effectiveness, and will allow better informed forest policy making.

1.5 FOREST INFORMATION MANAGEMENT: FROM DATABASE TO PREDICTION

Wise choices between alternative forest policy and management options require knowledgeable and well informed stakeholders and decision makers. Forest information systems (FIS) are needed to reconstruct and capitalize on the past, assess the present and predict possible futures as a transparent basis for decisions. **How can we assure that Forest Information Systems are accessible and interoperable with other forest, environmental and socio-economic information systems for maximal mutual benefit and minimal redundancy?**

Breakthrough

Forest-related databases must be documented and harmonised to enable transboundary sharing and re-use of the data they contain. The need for thorough documentation, harmonisation and interconnection of monitoring systems, databases and database applications is widely recognised by environmental scientists. They are indeed the key to creating common understanding and promoting timely action by enabling sharing and multiple re-use of reference and monitoring data.

The functionality of any information system (IS), including forest information systems (FIS), can be broadly categorized into data management (editing, transformation) on the one hand and information provision on the other hand. Information is generated by the conversion of the data the IS holds in its databases into answers to the questions users ask, typically through a user interface. To this end, statistical and computational functions complement the IS-functions for querying and viewing the content of the database. For land cover and land use related issues and hence for forest themes, geo-analytical functions like proximity and neighbourhood analysis, overlay analysis, cost-distance analysis, interpolation and map algebra are indispensable [75].

It can be envisioned that one IS exploits several distributed databases. This is the more applicable for transboundary issues like the ones related to environmental quality. In order to provide meaningful information, the data and data models of the various databases must be well documented and harmonised/standardized. In addition to technical elements like the availability of broad internet connections, a range of organizational (who does what when and how?), legal (copyright, privacy, liability) and economic (funding model) issues must be clarified. This is what is covered by the term 'Data Infrastructure', a set of agreements between and within organisations that produce, use or trade data, to facilitate the sharing and reuse of the data [76]. Data infrastructures are meant to allow efficient and seamless access to reference, archived and real time monitoring data as the basis for information services and systems with high added value for society.

Knowledge Gap

To develop regional, national and global, functional forest data infrastructures, there is a need to better specify the data involved and standardise the data models so that resulting databases can be interoperable and a sound basis for transboundary applications and services.

Specifying the data implies the common use of internationally accepted definitions on forest and forest ecosystem components, sampling protocols and classification systems. Accessible metadata should always associate stored data informing the user on how data was collected and how reliable the data actually is.

Data underpinning forest information systems are increasingly provided by remote, proximal and in situ sensors and by their combinations, i.e. by integrated sensing (e.g., [77, 78]). Integrated sensing of forests and the corresponding near real-time information systems are in their infancy though. Important efforts for conceptual and technical developments are required to turn integrated sensing from a potential into an effective and efficient source of data for transboundary forest information systems.

Policy recommendation

The ongoing efforts to establish data infrastructures in the environmental domain at all levels, from local to global, must be consolidated and taken further. There is scope to extend the INSPIRE-directive (2007/2/EC) of the European Union to explicitly cover forest-related data and services.

With the INSPIRE-directive [79], the EU obliges its member states to make geodatasets available for 34 themes, in line with commonly agreed rules and regulations, aiming at seamless data coverage and transparent data availability in policy making from the pan-European to the local level. In the current INSPIRE-directive, forests are only implicitly mentioned through the themes 'Protected sites', 'Land cover', 'Land use', 'Environmental monitoring facilities', 'Bio-geographical regions', 'Habitats and biotopes' and 'Species distribution'. It is recommended to build forest related data infrastructures on existing pan-European monitoring networks (i.e. systematic and intensive monitoring plots of EN/ECE ICP-Forests, NFI observation plots and LTER sites) in order to benefit maximally from earlier investments, data series and already compiled knowledge. International protocols are needed for improved free exchange of forest data, not only among EU countries, but also between countries and European bodies. European efforts should be linked up with the Global Forest Information Service (GFIS) initiated by IUFRO and the United Nations.

2 FORESTRY AND SOCIETY

This chapter deals with the management and use of forests by human society. Forests are managed for people, but stakeholders are often excluded from management decisions. In a first section we visit therefore the state-of-the-art in stakeholder involvement to forest management (2.1). In a next section we focus on the sustainable provisioning of wood and other products from the forest in the near future (2.2). Living in an increasingly urbanized world it is also important to give more attention to the essential role of trees and forests in the urban zone (2.3). We conclude this chapter with a background on life cycle thinking as an approach to get forest management and use more environmentally sustainable (2.4).

2.1 ENHANCING PARTICIPATORY FOREST MANAGEMENT

Today, national and international institutions widely accept and promote that common pool forest resources (Box 2) are at best managed by local communities, for participatory forest management is more effective in terms of forest cover, social equity and economic benefits than top-down forest management. Recent studies demonstrate that community-managed forests are less subject to forest degradation than non-community managed forests (see for example [80, 81]). The shift towards participatory forestry is, however, far from complete. **The question remains how participatory forestry can be enhanced in terms of social equity, and what the role of the community should be?**

Box 2 – Common Pool Resources

Decentralization and people's participation in forest management have been rightfully pointed out to be conditions for improving environmental sustainability. However, participatory approaches frequently evade the issue of bundles of rights and overlapping uses which characterize most tenure systems of common pool resources, such as forests [82, 83]. Forests are, just like many other natural resources, under control of nested authorities. Moreover, several users hold different rights to the forests and its trees, and all of these tenure relations and property rights are the dynamic objects of intricate struggles between various stakeholders. This needs to be understood in its full complexity in order to feed participatory forestry.

Case-studies on developing countries demonstrate that the privatization of forest management has been increasing tenure insecurity, uncertainty and conflict among local residents, rather than being a prerequisite for investment and development [84-86]. In other contexts, such as in the Democratic Republic of the Congo, market-based approaches to forest management may partly provide a solution to the problems faced by residents to sustain their livelihoods [87]. Therefore, learning how to manage common pool resources with multiple and nested uses is key to the future of participatory forestry.

Breakthrough

In the last decade, social scientists have raised important questions about the level of involvement in participatory forestry, and the unifying and exclusionary tendency behind the concept of 'community' in community participation. Research has shown that many participatory forestry projects and programs turn out to be difficult to implement, and outcomes turn out to be different than envisioned [88]. Therefore, scientists have brought charges against the delimitation of participation to consultation, without a devolution of rights, benefits and responsibilities, as well as against the lack of actual involvement of participants in the decision-making process [89, 90]. For in many cases, citizens have access to involvement in forest management on paper, but not in reality [91]. Furthermore, decentralized forest management faces problems of empowerment, representativeness and accountability of the local institutions who have to defend the stakes of their interest groups [92, 93]. Certainly in REDD (Reducing Emissions from Deforestation and forest Degradation, see 3.3), which seems to confirm national governments as principal forest stakeholders, it is a major challenge to integrate decentralized and participatory strategies into forest management [94, 95]. Also, social scientists have demonstrated how participatory forest management projects in developing countries have deepened social cleavages and increased exclusion of the less powerful in society, such as women or pastoral people [96-98]. Partly this is due to the fact that the target group in developing countries is mainly defined in terms of 'the indigenous people' of the area, excluding those who cannot claim autochtony [99-102]. Besides, this is due to the false assumption that participant groups and communities are homogenous groups with similar interests and networks. To address them in this way makes them into 'imagined' [103] or 'mythic' [104] communities.

Knowledge Gap

We grope in the dark after ways to address citizens and embrace their stakes. This has to do with the fact that the complexity of local realities is simplified, and questions as "who is the community?", "what are people's stakes?" are not uniformly answered. If community is not a good concept to address the citizens and to reach social equity, one should think about other concepts which lead to a more sustainable, participatory forest management.

Little is known about the ways in which forest governance may go beyond political gains (grabbed both by civil society organisations, individuals and politicians), and ways in which different levels of government may successfully share information about the enormous range of actors and institutions involved in forest governance. That is why for instance the International Union of Forest Research Organizations proposes to set up a global platform to steer forest governance at an international level [105]**.** However, this platform needs to be supported and fed with information at a national and local level too.

Policy recommendation
A new approach to participatory forestry needs to embrace complexity at many levels and extend the concept of communities and participation. The mapping of the historical, political, institutional and socio-economic background of all actors and institutions involved is a start to enhance participation. Furthermore, communication tools through which the public may be reached and involved need further development. Interestingly, for this topic there is a need for knowledge transfer from developing countries to Europe.
Participatory forestry methods are still in an exploratory phase and therefore need to be monitored and evaluated in order to transform participation from being an empty box to being a workable tool (see Box 3). New promising tools, like for instance the open-ended Long Term Mitigation Scenarios technique employed in South-Africa to involve small stakeholder groups in the design of national climate change regulations [106] need to be tested and compared with other examples of participatory techniques.

Box 3 - Angai Village Land Forest Reserve: Experiences from Community Participation in Forest Management in South Eastern Tanzania

Angai forest in South-Eastern Tanzania is an example where a Village Land Forest Reserve is successfully being established, albeit with some difficulties. The area consists of woodlands where hardwood timber (mainly, *Pterocarpus angolensis* and *Dalbergia melanoxylon*) was getting overexploited. District authorities therefore intended to establish a district forest reserve but, as they lacked staff and means for managing the 1400 km² large area, the involvement of the 13 surrounding villages was promoted by the Rural Integrated Development Support programme. A first challenge the project had to overcome was to develop methods of forest inventories with which villagers could develop sound forest management plans. In each of the villages, Natural Resource Management committees were created, but these only acquired both internal and external legitimacy once they had also be unified into an inter-village union. The reluctance of some local government officials to devolve authority to villagers on forest management has also been a cause of many delays. The experience shows that despite a conducive legal framework and official support at national level, such a project could only succeed thanks to the long term involvement of external donors.

More at http://vimeo.com/dondeynevideo/angaiforest and [107-109]

2.2 SUSTAINING THE PRODUCTION FUNCTION OF FORESTS

2.2.1 FOREST COMMODIFICATION

During the last two decades, forests have increasingly been subjected to market strategies in order to manage them in an economical way, or to support their conservation through income-generating activities. Analysis showed that this is not always a success story for forests and society. Therefore, we need to better understand **what will be the impact of increasing marketing of forest products and services on both forests and society, and how can we further reconcile commercial, ecological and social concerns in a harmonious way?**

Breakthrough

Forest conservation and management has increasingly converged with commercial interests during the last decades, and scholars have warned about the possible negative aspects of this trend.

During the 1990s, interest in the commercialisation of non-timber forest products (NTFP) was growing all over the world [110]. Furthermore, forests became valued as laboratories for scientific research and the pharmaceutical and cosmetic industry, as well as locations for spiritual renewal, (eco)tourism, and outdoor recreation [111, 112]. Especially in developing countries, ecotourism has become a local poverty reduction strategy which simultaneously aims at enhancing the conservation of the natural environment and the development of the local communities, who are depending on these forests for their subsistence [113, 114]. Currently, in the era of climate mitigation, forests are becoming key assets as carbon-sinks in the Kyoto Protocol and beyond, while the chemical industry aspires to replace petrol by forest products as a base material for the production of polymers, pharmaceuticals and fine chemicals.

However, in the domain of provisioning services, large challenges are to be met concerning the sustainable yield from forests (see further in section 2.2.2) and the optimal cascade use of wood products, it means that wood is reused several times along a cascade of decreasing versatility in use, until only energetic recovery remains, to minimize environmental impacts (see life cycle approach 2.4). In the domain of cultural services, the impact of ecotourism, for instance, has been put through the mill by scientists both on an ecological and social level [115]. It is not sure whether the marketing of forests through ecotourism actually conserves the forests and improves the well-being of local people [115]. Furthermore, the inclusion of forests to formal markets may erode the ability of governments to enforce environmental protection [116].

Knowledge gap

In general, it is not sure whether the marketing of forests actually conserves the forests and improves the well-being of local people [117, 118]. This knowledge gap about the commodification of forests is two-fold. First of all, as it is only since the late 1990s that the commodification of forests has been booming and forests are increasingly dedicated to income-generation and capital markets, the impact of this trend could not be monitored sufficiently. Secondly, there is a gap of knowledge about successful ways in which commercial, ecological and social concerns may be combined in forest management because of the limited cross-border collaboration between forest conservation and management scholars, anthropologists and practitioners. Peterson et al. [118], for instance, give some recommendations to enhance the transdisciplinary dialogue and practice through reflexive questioning and the adoption of disciplinary humility, in order to guarantee the well-being of both forests and people at the same time.

Policy recommendation

The increased recognition of the value of forests for providing provisioning, regulating and cultural services is an opportunity for forest conservation and management. But forest managers need to stay alert that the tightening bond between forest protection and market expansion is not at the detriment of forests ecosystems and their supporting services, or of societal well-being over the long term. **Forest commodification needs to be monitored and wisely guided in an interdisciplinary effort between forest ecologists and anthropologists.**

2.2.2 FOREST BIOMASS: WHAT'S THE ALLOWABLE CUT?

Policy targets on renewable energy put increasingly high pressure on woody biomass provision from forests. **What is the biomass potential from forest ecosystems without compromising supporting**

ecosystem services?

Breakthrough

Increased harvesting pressure on forest ecosystems might harm future productivity.
Wood and wood waste consumption for bio-energy in the EU-27 increased by 80% since 1990, amounting to about half of the total renewable energy consumption in 2008 [119]. Under the renewable energy targets for the EU-27 the woody biomass need is projected to more than double by 2030, next to a parallel 40% increase in wood provision for material use, and the demand might exceed the supply by as early as 2015 [120]. Already today this results in increased pressure on forest ecosystems, reflected in a trend towards higher removal of woody biomass for bio-energy (e.g. crown wood, first thinning products, bark and even litter). Although it may have a positive influence on forest revenues and profitability [121], this trend may seriously harm the nutrient balance [122-124] This compromises the long-term productive potential and stability of forests, especially in nutrient-poor ecosystems and in a context of increasing environmental pressure on forests throughout Europe [125]. Effects on biodiversity are more inconclusive as increased harvesting might as well counteract the biodiversity loss through darkening in overstocked forests. In conclusion, current European policy on renewable energy may be inconsistent with sustainable forest management.

Knowledge Gap

Urgent need for large-scale quantitative information on sustainable harvest levels in different forest ecosystems. Although potential negative impacts of excessive harvesting levels on forest ecosystems are widely acknowledged, very little quantitative information is available on effects of large-scale biomass removal on (1) biodiversity, (2) nutrient cycling and (3) forest productivity and stability. Therefore, we emphasise the urgent need for investigating these issues in contrasting forest ecosystems, and defining thresholds for allowable biomass cut beyond the concept of sustained yield.

Policy recommendation

Revise European targets for woody biomass production, and stimulate new production potential outside current forests. Because of the potential unsustainability of increased woody biomass harvest from forests and the lack of science-based thresholds for allowable cut, the precautionary principle urges for a review of EU targets for bio-energy from woody biomass. In addition, woody biomass production outside current forests, e.g. from agroforestry or short-rotation coppice on marginal, erosion-prone, or legally conditioned agricultural land, could be stimulated by legal and financial initiatives.

2.3 CITIES UNDER GLOBAL CHANGE: SIGNIFICANCE OF URBAN TREES AND FORESTS

More than half of the world's population is now living in urban areas. Urban activities have now become a threat to the global environment (e.g. [126]). Solving and mitigating problems, including the design of ecologically efficient urban areas is therefore of prime importance. Policy emphasizes the desirability of compact, densified cities [127]. However, this may have profound effects on both ecosystem services and biodiversity conservation [128]. As more people's life's are predominantly urban, opportunities for interaction with the natural world decrease, with potentially serious effects for human health and well-being [129, 130]. Green space, including urban forests and trees are keystone players having a variety of important ecological functions [131, 132]. Yet they are under threat as never before by recent developments in urban areas [131]. **The design of more ecologically efficient urban areas is a prime challenge to create a more sustainable world. What is the role of urban trees and forests in this?**

Breakthrough

Interest in the benefits and costs of urban forests and trees and the quantification of these is growing. Apart from these relatively well accepted benefits, the effects on human health and well-being are less accepted or quantified. The last decades have seen a growing interest in the study of the benefits of urban green in general and urban forest and trees in particular. The U.S. Forest Service developed the Urban Forest Effects (UFORE) model to quantify the functions of urban forest and trees contribute: amount of pollution removed, carbon storage and sequestration, effects of energy use in building and its structural and functional values. Software for cost-benefit analysis of tree species [133], has been implemented. However, the general use of such models is jeopardized by scattered or the lack of knowledge [134].

The extent and nature of effects of urban forest and trees on human health and well-being are much less accepted (including its economic importance [135]). High pressure on urban space and the still unclear benefits of green in living and working environment make that green is not used and often replaced by other land use of which the short term economic return is clearer. This threatens urban forests and trees, also given the fact that most of the benefits are derived from large-stature trees [131, 136].

Knowledge gaps

A systematic collection and organisation of basic data on urban green, including forest and trees is essential to estimate benefits and costs. The effect of green on human health and well-being should be investigated. In general, a more pragmatic ecological science, which delivers solutions to our crowded planet is wanted.

In many cases we do not know how many trees and green spaces are available and how this resource develops. We clearly need more basic data about urban trees and forests, and urban green in general. The implementation and adaptation of existing software to evaluate the urban tree and forest resource to the European situation would be a big step forward. De Vries et al. [135] stress the need for more research on the effect of green on human health and well-being. Wolf & Kruger [137], based on an participatory approach, stress the need to consider social and biophysical interactions of humans with trees in resource planning and management. Valuation research of urban green, including urban forests and trees may help to convince policy and planning.

In general there is a need for a better insight into biodiversity and evolutionary processes in cities for the restoration or increase of ecological services [138]. Solutions designed to moderate the dangerous interactive effects of urbanization, climate, and human health are critical [138]. Palmer et al. (142) further plea for a pragmatic ecological science which delivers solutions to our crowded planet. Ecological efficiency instruments, such as the Biotopenfläche Factor (Berlin: http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/) and the Seattle green factor (http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/), designed to increase the quantity and quality of urban green while allowing flexibility for developers and designers, should be further developed and tested.

Policy recommendation

In view of the current environmental problems of pollution and climatic change, action for urban forest and trees should become an essential part of sustainable urban development of all urban areas whatever their size and population.

Urban ecology research assumes that scientific understanding should inform urban policy and planning. Rather than leaving that to chance, Wolf & Kruger [137] argue for research activities that integrate science and local government action. Indeed, there are innumerable instances where policy and planning decisions appear to disregard or be inconsistent with scientific evidence. Sustainability should be part of every aspect of urban policy. Ecological efficiency instruments should be an integrated part of the evaluation process for spatial planning. For urban forest and trees a great effort is needed to apply scientific knowledge and integrate that into operational planning and decisions. Demonstration projects both in new building and renovation projects should not only advocate the use of purely technological solutions, but also integrate green as far as possible. Urban forests and trees are an essential part of the way to a more sustainable future [131].

2.4 LIFE CYCLE THINKING AND OPTIMIZED FOREST RESOURCE USE IN THE BIOBASED ECONOMY

Life cycle thinking refers to the concept of evaluating impacts of products and services over their complete life cycle, i.e. from extraction of raw materials, transport, processing and assembly till distribution, end use and waste disposal [139]. The life cycle thinking contains methods as life cycle assessment, assessing environmental impact, life cycle costing, assessing economic impact, life cycle management and engineering focussing on product optimization with respect to different sustainability factors [140]. **What is the use of life cycle thinking for forest resource use optimization?**

Breakthrough

Originating from the industrial sectors, life cycle thinking successfully established its place and gains importance in the forestry sector. Life cycle assessment (LCA) was first used in the industry to check the energy requirement of certain products and to identify process steps with a large optimization potential [139, 141]. Since 1997 LCA became an ISO standardized methodology (ISO 14040-14046; 2006). LCA is gaining interest in the forestry sector. Environmental evaluations and optimization exercises are made for construction wood productions, pulp and paper production, forest based bioenergy systems, and many more. Further, LCA derived results, such as carbon footprint, ecological footprint and water footprint rapidly gained a lot of attention based on their characteristics as communication tools [142]. Different from industrial systems, forestry systems could be considered open systems which are often case specific, and for which it is difficult to delineate system boundaries and define by-product use, which may result in incomparability of outcomes.

Knowledge Gap

No scientific consensus is found on the inclusion of land use, and effects of direct and indirect land use change in life cycle assessment. This knowledge gap has two faces. On the one hand there is no consensus on which aspects of land use and land use change should be included. The two main approaches are: (1) single issue methods, where the impact of land use is assessed using one indicator (e.g. soil organic matter [143], biodiversity [144, 145]), which is used as a proxy to assess the impact on the overall land quality; (2) holistic approaches with indicator sets trying to cover different aspects influencing the overall land quality [146]. In this latter, there is discussion which aspects should be assessed with which indicators [146]. On the other hand there is no consensus on how the spatial and temporal dimensions of land use and land use change can be included in the life cycle assessment framework. This discussion also handles about whether to hold land use and land use change as one impact category or to consider them two different impacts.

Policy recommendation

Life cycle approaches must be promoted as the essential tool to analyse the environmental sustainability of new management and production scenarios of the biobased economy. Further

standardization in life cycle analyses is necessary to make results comparable and suitable for trade-off analyses and policy advice. Together with the LCA knowledge and capacity at European level or distributed among different member states, such standardisation (mainly on the definition of system boundaries, impact allocation procedures, etc.) should be transferred to other countries with limited life cycle thinking experience.

3 INTERNATIONAL FOREST POLICY

In this last chapter international forest policy processes are critically analysed. After an introduction on wood fluxes, full attention is given to the role of forests in the international climate debate. Deforestation avoidance is in the centre of climate negotiations, but elementary issues like forest definition and strategies to avoid spill-over are insufficiently addressed to succeed (3.2). We try to open new ways out of this inertia by proposing landscape carbon instead of forest carbon accounting (3.3), integrating mitigation policies with adaptation and development policies altogether (3.4), by developing new views on forest ethics (3.5) and by giving support to improved certification as a unique market instrument (3.6).

3.1 SPILL-OVERS OF DEFORESTATION AVOIDANCE: UNDERSTANDING THE SOCIO-ECONOMIC DRIVERS OF ILLEGAL TIMBER TRADE AND DEFORESTATION

A limited number of case studies [147] illustrates that forest protection in one country can have a large impact on forest cover in neighbouring countries. **How can these spill-over effects be better quantified and what are options to reduce them?**

Breakthrough
The spill-over effect of deforestation avoidance has been quantified for some countries. The analysis of land use change data using satellite imagery and of a time series of export/import data of wood revealed important negative side effects in Laos and Cambodia of a successful policy reform in Vietnam [147]. State owned land was privatised in patches of on average 12 ha on the condition that forest cover was maintained or increased to 30%. The booming economy of Vietnam made that demand for forest products, especially wood, remained high. Law enforcement and the attractiveness to preserve and manage forests led to an increased import of illegal timber from neighbouring countries like Cambodia and Laos where law enforcement was weaker [147]. This case study revealed the importance of policies and agreements at regional and global level, because the spill-over effect of global trade is very high.

Knowledge Gap
For many countries, it is still unknown to what extent sustainably grown domestic timber will be able to compete with – and substitute – illegally imported timber. For the Vietnam case, it is unclear to what extent this import of illegal timber will remain at a high level, increase, or reduce. Up to now comparable case studies are still limited in number and still incomplete; there is a need for a more detailed quantification at global and national level.

Policy recommendation
There is a need for *'full carbon accounting'* to avoid leakage and spill-over effects at international level. Meyfroidt and Lambin [147] show that this full accounting also needs to be carried out by non-

Annex 1 countries to avoid leakage and spill over effects internationally. Non-annex 1 countries should be helped to establish these carbon balances and improve data quality. There is a need to carry out and fund similar analyses in other parts of the world.

3.2 THE FOREST DEFINITION PITFALL: IS REDUCING EMISSIONS FROM ALL LAND USES (REALU) A VALID ALTERNATIVE TO REDD?

During the climate change negotiations a lot of time has been spent – and will be spent – on establishing a forest definition for REDD. Is it worth all the trouble or is it a pitfall?

Breakthrough

There is probably no single definition of forest that can apply in the continuum of landscapes with trees [148]**.** A very broad definition like currently used in PR China makes the reforestation figures look attractive, but does not say anything about how sustainable or biodiverse these often new forests are [149]. In most countries almost any forest definition would exclude the trees outside the forest (e.g. on farms), trees that make up an increasing share of global forest cover. A recent study in Indonesia [150] shows that if the current REDD policy would be carried out as designed, with a full protection of forest, it would take 6.4 years before the first emission reductions would take place. The amount of trees and forest in Indonesia, not recognized as forest, is so large, that payments for the REDD – mechanism would the first 6.4 years only result in a displacement effect.

The only UNFCCC definition that currently exists is the one that was established for Afforestation/Reforestation under the Clean Development Mechanism (CDM – A/R) with the Marrakesh negotiations in 2001 at the UNFCCC COP-7. Forest was then defined as "a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 % with trees with the potential to reach a minimum height of 2-5 metres at maturity *in situ*." In addition "a clearcut area that is temporarily unstocked, but that is expected to revert to forest" is also considered forest.

REALU (Reducing Emissions from All Land Uses) also known as AFOLU (reducing emissions from Agriculture, Forestry and Other Land Use) makes the unfruitful discussion about forest definitions superfluous [148]. A better option would be to consider 'ecosystem carbon', rather than forest carbon alone [151, 152]. The emphasis should be on monitoring persistent declines and increases of carbon stocks over time, based on the Intergovernmental Panel on Climate Change (IPCC) methodologies.

Knowledge Gap

How can the scope of current REDD preparatory activities be broadened and a cross-sectoral policy reform be realised, with attention for ensuring local land use rights? There is a need to test out these REALU or AFOLU approaches in different contexts and conditions. The effects on carbon mitigation, food security, biodiversity and poverty reduction need to be investigated. In addition the quality of the emission factors of various land use and forest types is still rather low to be applied at a national level. There is need for investment in research for a better parametrisation of emission factors for the various land use types, with the results made available in globally accessible databases.

Policy recommendation

The current focus of the international REDD negotiations and related (sub)national case studies on forest carbon alone needs to be broadened to ecosystem carbon. The current focus on countries with high forest cover or high deforestation is understandable, but increases risks of large-scale leakage. An ecosystem carbon approach through REALU or AFOLU would overcome this leakage problem and also has a large potential for integrated adaptive development. There is a need for more REALU pilot projects in close collaboration with different levels of governance.

3.3 NEW WAYS TO RECONCILIATE MITIGATION AND ADAPTATION BY LINKING ENVIRONMENTAL AND DEVELOPMENT POLICIES

Few developing countries (generally called non-Annex 1 countries in a UNFCCC context) feel compelled to invest in climate change mitigation, as the historical carbon debt was generated largely by the industrialized world. Their focus is rather on economic development and adaptation to climate change. **Which policies are beneficial to realise the triple objective of mitigation, adaptation and development?**

Breakthrough
Integrated policy approaches and tools are increasingly available and being promoted [153-155]**.** Climate change is not only an environmental issue, but a crosscutting theme involving many sectors. A long term vision, participation and a fair distribution of benefits are key. A toolkit has now been developed by the interuniversity KLIMOS research consortium to screen planned development projects and programs on their merits regarding climate change mitigation, adaptation and overall sustainable development [154].
Rehabilitation of mangroves reduces coastal erosion and stores carbon. In the north of Vietnam mangrove forests were planted without respect for traditional land rights [155]. Land conflicts followed. In the south of Vietnam a similar program was directly embedded in poverty reduction. Farmers and fishermen received training, schools were built, areas to be rehabilitated were delineated with local communities, according to processes described in section 2.1. The new mangrove forests in the South of Vietnam not only store carbon, protect the coastline, but have also triggered development.
Forests store large amounts of carbon, provide livelihoods for many rural poor, but can generally only sustain a low population density. But an increased tree cover of the agricultural landscape using agroforestry practices (using e.g. nitrogen fixing trees or exclosures for small-scale forest rehabilitation) have the potential to increase and stabilize harvests, and deliver the ecosystem services farmers really need, while offering also opportunities to store carbon for the global community . Land use practices that increase soil organic carbon not only store carbon, but are also beneficial from a soil fertility perspective [156].

Knowledge Gap
Reconciliation between mitigation, adaptation and development can be easy in the case of clear win-win situations, but more action research is needed to find opportunities in those cases where trade-offs seem to exist. There is more research needed to explore possible direct and indirect side effects of policy measures and to what they affect countries, regions and their populations, including smallholders.

Policy recommendation
Development, mitigation and adaptation projects and programs should not be conceived on a separate sectoral basis, but jointly. A sectoral government architecture is not conducive to respond to the new climate objectives in connection to older development challenges. More pilot studies need to be carried out to test transversal and participative ways of governance.

3.4 FOREST ETHICS

The old dilemma "forests have to be managed wisely for human economic benefit versus they should be protected from such development for aesthetic and moral reasons" is no longer valid. There is consensus that next to resource use, not only humans but also global ecosystems benefit from the natural functioning of forests. **But how to assess this higher value of forests?**

Breakthrough

Forester Aldo Leopold made it possible to overcome the either-or debate between conservationists and preservationists (whether priority should be given to nature protection or to human welfare). In his essay *A Sound County Almanac* he wrote: "Quit thinking about decent land-use as solely an economic problem. Examine each question in terms of what is ethically and aesthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise." [157] Leopold was the first advocate to promote direct ethical responsibility to the nonhuman world. His ideas make an end to the understanding of natural environments as amenities and commodities, instrumentally to human societies by fulfilling direct human needs (lumber, paper, cellophane, turpentine, firewood). Forestry's traditional concept of conservation is not superseded by Leopold's respect for the larger biological community but it is included within it. Any kind of anthropocentric resource use that ignores its relationship with the larger biotic community, not only degrades the biotic but ultimately also the human community.

Knowledge Gap

Since not only people but also global ecosystems benefit from sustainable forests, all ecosystem services need to be quantified. Forests are impure public goods, having both public and private characteristics [158]. Next to the resource use, both human population and the ecosystem benefits from the natural functions and environmental profits provided by forests from the local to the global level. However, such supporting services of forests are not very visible and generally not well known or estimated. Recent research has provided a lot of scientific data on the range of their benefits. A more accessible interpretation of these benefits would promote their preservation and enhancement. A useful approach is to quantify the ecosystem services and to value these non-commodity and non-market goods. If the outcome could be turned into the common language of monetary units, it would facilitate decision-making on dilemmas between efficient production of commodities and distribution of ecosystem services (see also section 1.1). Quantifying ecosystem services generated by forests, have to take into account biomass functions (carbon dioxide sequestration and carbon storage, oxygen generation through photosynthesis), environmental benefits (air pollutants absorption and filtration, climate regulation, rainwater retention), wildlife habitats, biodiversity conservation, recreational opportunities and aesthetic enjoyment (f.i. the landscape beauty of urban forests) [159, 160].

Policy recommendation

Providing an acceptable method for valuing ecosystem services of forests would facilitate a global forest policy beyond carbon calculation. Traditional forest products, such as timber, firewood, food, are traded in conventional commodity markets, making use of traditional economic valuing instruments. Forest ecosystem services, considered as public goods with positive externalities for both human beings and the global planet earth, require unconventional appraisal to address their non-commercial and non-commodity traits. The international post-Kyoto climate regime development agenda is focusing on the theme of reducing emissions from deforestation and forest degradation (REDD), while neglecting other ecosystem services [161, 162]. A lot of information on external market techniques for their monetary valuation have been developed yet but various proposals are characterised by different notions of equity. Providing a workable and more generally acceptable method for valuing those services would help to overcome the impediment of translating all ecosystem services more accurately into economic values, facilitating a global forest management beyond carbon credits.

3.5 FOREST CERTIFICATION AS A FOREST GOVERNANCE TOOL

How to advance forest certification (Box 4) as a global forest governance tool?

Breakthrough

Forest certification is an important non-state market regulatory governance tool [163-167]. Significant research has focused on explaining the emergence of forest certification schemes [168-173] and the variation in institutional design between the different existing schemes [174-177]. The FSC is generally considered as the most credible certification system. However, convergence between for example FSC and PEFC has been observed mainly due to a ratcheting up of the PEFC system [178, 179]. Other studies have focused on the adoption of forest certification, both CoC and FM. A strong growth of adoption has been documented [163, 180, 181] driven by several factors including government support through public procurement [182]. However, growth has not been distributed evenly across the world. Some authors [181, 183-185] stress the important North South divide with certification being mostly adopted in the North leaving forests in developing countries only marginally involved in forest certification processes.

Knowledge Gap

An important scientific gap concerns the assessment of the effectiveness of forest certification. Effectiveness can be operationalised in several interrelated dimensions. For some dimensions, it is too early to make an assessment. For others, such as problem solving effectiveness, studies are available, but the overall results remain highly inconclusive due to several reasons [186]. First, several studies, although excellent in their own right, rely only on a few or one case study [187-189] and hence are prone to case selection bias. Secondly, some studies only rely on indirect measurement of effects and do not use longitudinal observational studies or experimental research designs to assess effects [190]. Thirdly, some studies raise doubts about the impact of certification. A study conducted in Cameroon concluded that due to the stipulation and application of weak standards certified forests might not be managed sustainably [191]. More in general significant variation in forest management standards has been observed [70].

Box 4 – What is Forest Certification?

Forest certification is increasingly becoming an important instrument to promote sustainable forest management (SFM). Cashore et al. [171] argue that forest certification is “one of the most innovative and startling institutional [governance] designs of the past 50 years.” Forest certification, according to Meidinger [172], “is a process through which transnational networks of diverse actors set and enforce standards for the management of forests around the world” [172]. In forest certification, two types of certificates are of importance. First of all, there is forest management (FM) certification. In this case the forests are certified according to a set of principles and standards. They provide the supply of certified wood. Secondly, other organisations in the supply-chain which provide certified wood products to customers can be certified with a chain of custody (CoC) certificate.

Currently several systems of forest certification exist, including the Forest Stewardship Council (FSC), the US Sustainable Forest Initiative (SFI), the Lembaga Ekolabel Indonesia (LEI), the Programme for the Endorsement of

Forest Certification Schemes (PEFC), the Malaysian Timber Certification Council (MTCC), the Certificación Florestal (CerFlor Brazil), the Canadian Standard Association (CSA) and American Tree Farm System (ATFS). Most initiatives are characterized by an organisation that defines social and ecological standards and provides verification procedures to ensure that products or production processes conform to these standards (i.e. conformity assessment). When products or production processes comply with the defined standards, a certificate is awarded which may or may not be used for external communication (label).

Policy recommendation

To advance forest certification as a governance tool the effectiveness of forest certification should be assessed, forest certification schemes should be independently certified and adoption be supported. Forest certification is a remarkable governance institution which has received increased attention by policy-makers and stakeholders [163, 164, 192]. In order to operate in a policy context 3 recommendations are formulated.

Assess the impact and effectiveness of forest certification. The current lack of conclusive evidence on the effectiveness and impact of forest certification should be addressed. A comprehensive impact assessment framework should be developed. In addition, data-collection preferably through an experimental design should be conducted. Sufficient time should be allowed to assess short-term and long-term effects of certification on social, economic and ecological dimensions.

Certify the Certifiers. Forest certification is increasingly considered as a legality verification tool in the context of FLEG initiatives (Forest Law Enforcement and Governance initiatives). For example Article 6 of EU Regulation 995/2010 on the prevention of sales of illegal timber and timber products within the EU recognizes forest certification as an assurance of compliance with applicable legislation. This increasing legal anchoring of certification might generate a proliferation of certification initiatives as has happened in the food sector following liability clauses in food regulation [193]. This will increase the need to certify the certifiers in order to distinguish credible from less credible initiatives.

Provide financial and technical support for adoption in developing countries. If certification proves to be effective it could constitute an important policy tool to achieve sustainable forest management. In order to increase and maintain the overall adoption, additional financial and technical resources will be necessary. Research shows that the cost of getting certified and regain certification are substantial [188, 194]. Several donor agencies and technical assistance bodies are already providing financial and technical support. More is necessary. A fund supporting the adoption of certification might be established, especially supporting small forest owners or concession holders to obtain forest certification. This fund could for example be funded by a special tax on forest derived products or by donations.

4 RECOMMENDATIONS

Text

5 GLOSSARY

Adaptation

Adaptation covers measures to reduce the negative impact of climate change.

Afforestation

The establishment of a forest in an area where there was no forest since time immemorial (more than fifty years)

AFOLU

Agriculture, FOrestry and Other Land Uses The UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol requires the Parties (including the European Community, EU-15, and most of new Member States) to regularly report inventories of greenhouse gas (GHG) anthropogenic emissions and removals, as well as to publish and regularly update national programs containing measures to mitigate climate change. In this context, the AFOLU (Agriculture, Forestry and Other Land Uses) sector is considered important because of green house gas such as N2O and CH4 in agriculture and increasing sinks of CO2 in forestry.

Allowable cut

Volume of timber that may be harvested during a given period to maintain sustained production

Ancient forests

Ancient forests are defined as forests that have existed since at least a number of centuries, compared to recent forests which are much younger in origin.

Annex-1 countries

There are 41 Annex I countries and the European Union that signed the Kyoto protocol. These countries are classified as industrialized countries and countries in transition: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America

Anthropocentrism

(synonym: humanocentrism) The tendency to consider reality and nature exclusively from a human interest perspective.

Biodiversity function

The diversity of species in ecosystems affects the functioning of these ecosystems. The two main areas where the effect of biodiversity on ecosystem function have been studied are the relationship between diversity and productivity, and the relationship between diversity and community stability. More biologically diverse communities appear to be more productive (in terms of biomass production) than are less diverse communities, and they appear to be more stable in the face of perturbations.

Common pool resources

Resources or goods which face problems of overuse or degradation when exploited. Although the term is closely linked to resources which are governed in common property regimes, common pool resources are not per se governed according to social arrangements as the common property used to be governed before.

Complexity science

Recent domain in science describing, understanding and modelling the structure and behaviour of complex systems such as ecosystems and human systems

Criteria & Indicators

Criteria and indicators are tools which can be used to conceptualise, evaluate and implement sustainable forest management. Criteria define and characterize the essential elements, as well as a set of conditions or processes, by which sustainable forest management may be assessed. Periodically measured indicators reveal the direction of change with respect to each criterion.

Deforestation

Deforestation is the removal of a forest where the land is thereafter converted to a nonforest use

Ecosystem services

All the benefits humans derive from ecosystems

Facilitation

Ecological facilitation describes how an organism profits from the presence of another. Examples are nurse plants, which provide shade for new seedlings or saplings

Forest commodification

Transformation of the natural environment into a commodity, it is a marketable item produced to satisfy wants or needs

Forest Information System

A collaborative effort aiming to maximize the value of different forest information sources and providers through the sharing of forest-related information through a single gateway.

Forest productivity

The net primary production (NPP) of a forest is a well suited indicator of forest productivity. It consists of the annual accumulation of stem wood in standing trees plus the growth of all the other tissues or components including those that are short- lived and roots.

Forest transition

Refers to a geographic theory describing a reversal or turnaround in land-use trends for a given territory from a period of net forest area loss (i.e., deforestation) to a period of net forest area gain

Governance effectiveness

Effectiveness of an international governance regime can be operationalized on six interrelated dimensions, namely problem solving, goal attainment, behavioral effectiveness, process effectiveness, constitutive and evaluative effectiveness. Problem solving refers to the degree to which the problem, which prompted the establishment of an international governance regime, is solved. Goal attainment refers to the degree to which specific goals, as stated for example in principles and standards, are achieved. Behavioral effectiveness assesses the degree to which the regime generated differences in behavior and practices, such as differences in forest practices. Process effectiveness evaluates the adoption of a new regime in a region or country. Constitutive effectiveness refers to the acceptance of the regime by a large group of stakeholders. Finally evaluative effectiveness assesses the regime on a set of criteria such as efficiency equitability and sustainability.

Hysteresis

The dependence of a complex system not just on its current environment but also on its past. This dependence arises because the system can be in more than one internal state. To predict its future evolution, either its internal state or its history must be known

Land use impact
Land use and land management practices including forestry have a major impact on natural resources including water, soil, nutrients, plants and animals.

Metadata
Data about data. By describing the contents and context of data files, the quality of the original data/files is greatly increased.

Millenium Ecosystem Assessment (MEA)
The MEA was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being (source: www.maweb.org)

Mitigation
Mitigation covers measures to reduce anthropogenic greenhouse gas emissions.

Participatory forestry
Forestry in which partnerships are formed between state forest departments and local communities to jointly manage the forests. Currently, a third partner is sometimes added to manage the forests in a sustainable way, namely private operators. However, participation hints merely at the inclusion of local populations in the management.

Public goods
Goods that are non-rival and non-excludable. Non-rivalry means that consumption of a public good does not reduce availability for others. Non-excludability means that no one could be excluded from use. Semi-public or impure public goods combine public and private characteristics

REALU
Reducing Emissions of All Land Uses

REDD
Reducing Emisisons of Deforestation and forest Degradation

Reforestation
The restocking of existing or recently vanished forests

Regime shift
Rapid shift in an ecosystem from one relatively stable state to another, as a response to physical drivers such as climate, human degradation, etc.

Sustained yield
Production of a biological resource (as timber or fish) under management procedures which ensure replacement of the part harvested by regrowth or reproduction before another harvest occurs

The Economics of Ecosystems and Biodiversity (TEEB)
The TEEB study was launched by Germany and the European Commission in response to a proposal by the G8+5 Environment Ministers (made in Potsdam, Germany in 2007) to develop a global study on the economics of biodiversity loss (source: www.teebweb.org)

Tipping point
In complexity science it is the value of a parameter for which the set of equilibria abruptly changes. Beyond this point the system will abruptly change to another sometimes very different stable state.

UNFCCC
United Nations Framework Convention on Climate Change

Urban forestry
Urban forestry is the careful care and management of urban forests, i.e., tree populations in urban settings for the purpose of improving the urban environment. Urban forestry advocates the role of

trees as a critical part of the urban infrastructure.

Virgin forests

Forests, which have not been influenced directly by man in their development. They are formed by site-indigenous tree species, native to the biogeographical region and phytogeographic zone and form specific forest types with their characteristic species composition, corresponding spatial structures, dynamics and overall diversity, forthcoming from their postglacial history and ecological relations with their abiotic environment. Tree species are present in various stages of their life cycle and as dead wood (standing and lying on the ground) in various stages of decay. Their vertical and horizontal structures may vary from complex to irregular, depending on forest type, disturbance regime and natural development dynamics. A typical structural feature is the presence of very old and very thick trees. The dynamics of virgin forests are connected to ecological properties of dominant tree species, site factors and disturbance regimes.

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