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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 goal of the **Forests2011 Position Paper** is to increase awareness of the importance of forests for ecosystem services worldwide, and to make an up-to-date scientific contribution to future forest policies. 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 currently seen as an increasingly significant motivation for protecting forests. The ecosystem services (ES) framework is an interesting basis upon which to develop concepts of protection and sustainable use of forest resources, in part because the ES framework unifies and extends existing concepts of sustainability and multifunctionality. Although forest management and forest policy may benefit a great deal from adopting the ecosystem services framework, ecosystem services need to be fully quantified and trade-offs between ecosystem services better understood before it can be fully translated into practice. National 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 also be established.

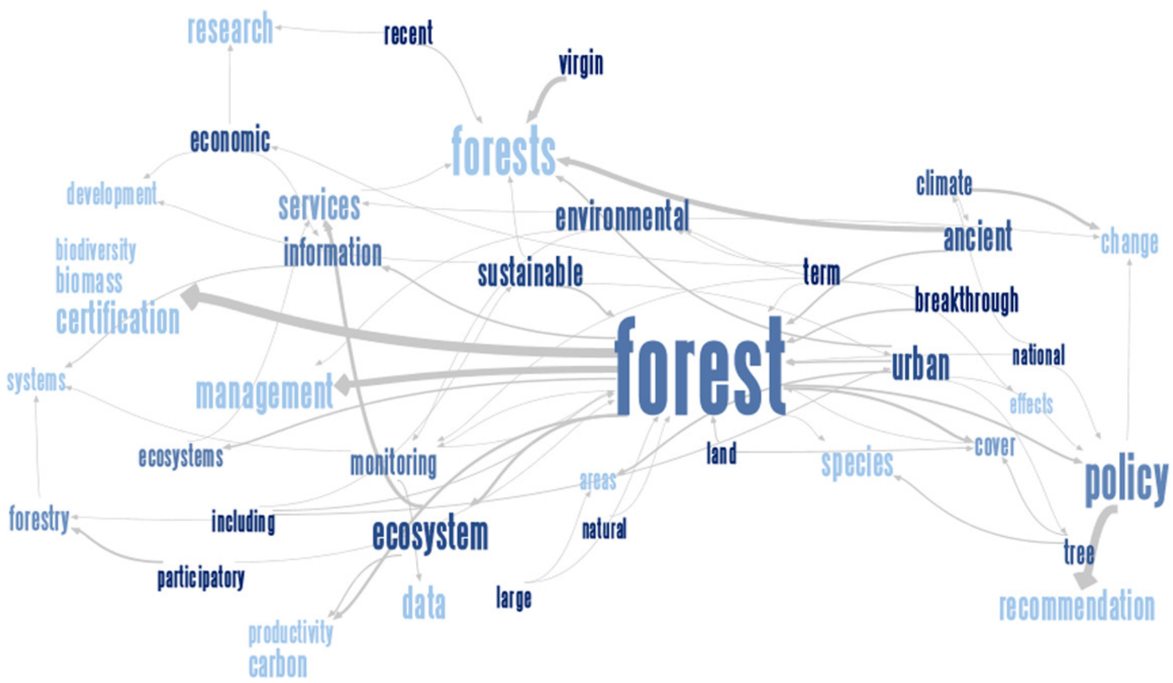

Figure 1 The relationship between the most widely used words (42 of 1136 terms) in the Forests2011 Position Paper, with larger arrows highlighting concepts such as ‘forest management’, ‘forest certification’, ‘forest biodiversity’, ‘forest biomass’ and ‘forest ecosystem services’.

There is accumulating evidence that **forest biodiversity** has functional significance for the 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-scale research facilities. In the meantime, attention should be given to creating awareness and capacity in relation to 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, deforestation, and subtle land cover changes such as forest degradation and spontaneous tree cover restoration are **forest transitions** the causes of which need to be described and understood. Forest transition models reveal the drivers of deforestation and allow for the development of 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 sub-national level is a first step towards deforestation avoidance. In areas like Europe, where forest restoration has taken place in the last decades, there is a need to increase awareness and provide state-of-the-art tools to detect and remedy postmodern forest degradation due to ongoing urbanization and advancing unsustainable biomass use.

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

Surviving **virgin forests** are a unique source of information on 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 Sites.

Ancient forests – under forest cover since time immemorial but not necessarily virgin – offer a unique source for studying ecological processes, including the way species disperse and recruit, or how fragmentation affects their colonisation capacity. Although their importance for forest conservation has been widely accepted , 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 final frontier in forest sustainability assessment is the monitoring of biodiversity and its inclusion in impact assessment and forest valuation to create a sensitive instrument for comparing 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. 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 concerning 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 the 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 into being a workable tool.

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

Increased **harvesting pressure** on forest ecosystems might harm future productivity. There is an 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 thereof is on the increase. Beyond these relatively well accepted benefits, the effects on human health and well-being are less well known and poorly quantified. A systematic collection and organisation of basic data on urban green, including forest and trees, is essential in order 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 for our crowded planet is needed. In view of the current environmental problems of pollution and climatic change, action on behalf of urban forests and trees should become an essential part of sustainable urban development in all urban areas whatever their size and population.

Originating from industry, **life cycle thinking** has successfully established its place and is gaining importance in the forestry sector. No scientific consensus has been found on the inclusion of land use, and the effects of direct and indirect land use change in life cycle assessment. Life cycle approaches must be promoted as the essential tool for analysing the environmental sustainability of new management and production scenarios of the bio-based 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. For many others, however, the extent to which sustainably grown domestic timber will be able to compete with – and substitute – illegally imported timber remains unknown. There is a need for 'full carbon accounting' to avoid leakage and spill-over effects at international level.

In the context of climate change negotiations, a great deal 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 for realizing **mitigation, adaptation and development** objectives are increasingly available and are 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 programmes 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. In the course of 2011, Metaforum Leuven, the interdisciplinary think-tank of the K.U.Leuven together with the university's Forest, Nature and Landscape Division, took the initiative to launch a Metaforum Leuven Working Group on Forests. The objectives of the working group were to increase awareness of the importance of forests for ecosystem services worldwide, and to **make an up-to-date academic contribution 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 theme of the International Year, in a European and global context. The working group was composed of senior academics from the K.U.Leuven with an interest in and experience of forest related research, together with some invited scholars from other institutions. By inviting a number of key stakeholders from the international forest policy scene to the first meetings of the working group, care was taken to ensure that the **issues** discussed were **of high societal relevance**. Our exercise did not intend to be exhaustive, rather it dealt with topics for which our expertise allowed us to tackle problems and issues from a fresh perspective.

This Forests 2011 Position Paper is the outcome of **a genuinely interdisciplinary process, with an active participation from 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 a follow-up to 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 will be 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 arena.

1 FOREST PROTECTION

This chapter takes its point of departure from the concept of forest ecosystem services as the major motivation for protecting the forest (1.1). Secondly, it explains the importance of biodiversity for forest ecosystem services (1.2). Thirdly, it highlights the different aspects of forest protection, namely custody over the forest area, and the maintenance of vitality and quality of the forest resource (1.3). The final two sections explore 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. In recent decades, but especially since the publication of the Millennium 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 added even 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. For forest management and forest policy, ES science likewise 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 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).

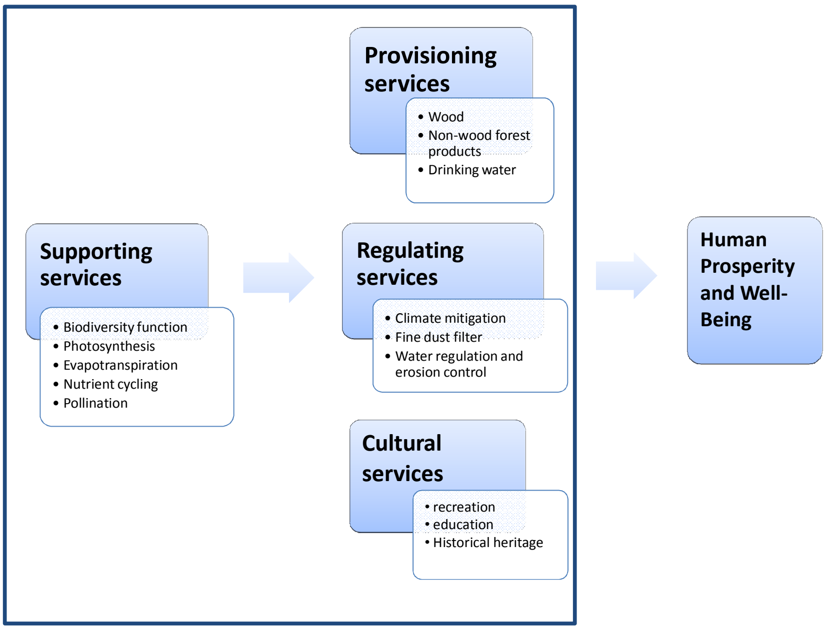

Figure 2: the Ecosystem Services framework according to the Millennium Ecosystem Assessment with examples added of forest ecosystem services.

Knowledge gap

Although forest management and forest policy may benefit a great deal 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 into ways to deal with spatio-temporal scaling issues are also needed, 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 *versus* synergistic effects). Ecosystem service valuation, and especially turning values into prices, is still very challenging and open to debate (e.g. [4]). Non-use values are particularly difficult to monetarize, but several questions also remain with respect to the quantification of direct and indirect use values. 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 check 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 highlights the unidirectional benefits of ecosystems for society, while focusing less on the distribution of wealth among ecosystem service beneficiaries (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 difficult to substitute. However, a sole focus on profit maximization would imply that the rich can afford a more expensive substitute than the poor. This would cause social inequity. 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 ensure that forest owners and managers are rewarded for the ES they deliver.

Policy recommendation
Awareness of and interest in 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 establish links between its concepts and programmes 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 provide a home to a significant portion of the world's 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.
Since the 19th century, foresters have been asking themselves whether mixed forests might 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 have reported higher productivity in monocultures compared to mixed stands including the same species [7], but a 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 of extracting 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. Over the last two decades, such experiments on grasslands have revealed strong positive diversity/productivity relationships [11, 12] that were at least partly explained by species complementarity in accessing soil resources (e.g. [13-16]). It is only in recent years that 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). In addition to its experimental platform, the FP7 project FunDivEurope (www.fundiveurope.eu) also includes an exploratory platform, in which 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

The results of the new large-scale research facilities that will allow testing diversity/functioning hypotheses in different forest types have yet to be published.

In the coming years, the new research platforms will start to generate huge datasets allowing us 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 of grasslands demonstrates that when considered over time, place, function and environmental change, 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 to create awareness and capacity in relation to the functional aspects of biodiversity and the value of forest biodiversity for human well-being.

Although far from being comprehensively 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 1.1). It should be noted, 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 represent different yet complementary arguments for preserving biodiversity [20].

1.3 THREATS TO FOREST ECOSYSTEM SERVICES

1.3.1 FOREST TRANSITION TRENDS

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

Breakthrough

Forest transition models have revealed the drivers of deforestation and allowed the development of a typology of countries based on forest cover and deforestation rate [21, 22]. A widely accepted framework for the analysis of factors driving 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 for 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]. New concepts related to the forest transition theory have arisen, such as '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 have been established [25, 26].

Knowledge gap

Forest transition not only includes widely lamented deforestation, it also includes more subtle changes like forest degradation and 'agroforestation' (i.e. a trend whereby 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 like deforestation or forest degradation due to indirect land use change are not clearly understood (also see 2.4). **The 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 addition, more socio-economic research is needed, not only into the factors that impede necessary policy change, but also into possible alternatives**. There is a need to better disentangle global from local factors that control forest transition. The various land tenure systems associated with large areas are not only poorly documented, but reliable maps are even more hard to find.

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 a challenge. **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 when it comes to 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 has taken place in recent 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 increasingly unsustainable biomass use.

1.3.2 TRENDS IN FOREST GROWTH AND VITALITY

Forest growth and vitality determine productivity, and are related to many of the forest's supporting, regulating and provisioning services. **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 into forest productivity are being 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 negative effects have also been observed [32, 33]. Furthermore, 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 have often 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 important productivity decreases can also arise for species at the heart of their distribution range, even on the best sites. This is the case, for example, for common beech in Flanders, for which a growth decrease of 15% since the 1960s can be related to decreasing relative air humidity in summer [38]. Other species, such as oaks, may profit from increasing temperature trends in the short to 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 the 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 the Mediterranean and Temperate Continental zones of Europe, but Temperate Oceanic and Boreal regions will probably also 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

The 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 remaining 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 acquire knowledge that 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 great deal of precious ecological data. As self-sustaining ecosystems, these remaining virgin forests represent centuries of forest memory – something 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 to be nature reserves. **A complete inventory of the remaining virgin forests 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 hectares of remaining virgin forests in Romania; 130,000 hectares in Bulgaria and 60,000 hectares in the eastern part of Transcarpathia [41]. There can be little doubt that remnants of virgin forests will also be found in other countries of temperate Europe.

Policy recommendation
There are hopeful indications that interest in the remaining virgin forests of Europe is on the increase. In May 2011, the Parties to the Carpathian Convention approved a protocol to protect Carpathian natural forests. However, **a general inventory of the remaining virgin forests in Europe remains urgent.** An appropriate EU programme 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 studied using standardized methods. **Based on the full inventory, a representative selection of virgin forests in temperate Europe should be declared UNESCO Natural Heritage Sites.**

1.4.2 UNDERSTANDING AND CONSERVING ANCIENT FORESTS

Many European forests have been used as agricultural land in the past, but others, even if they are not virgin but managed forests, have not. Ancient forests are defined as forests that have existed for at least a number of centuries, compared to recent forests that are much younger in origin. Most of ancient forests have been traditionally managed and tend to have a specific group of mainly plant species only occurring 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 level of research tradition looking at the impact of former land use on plant species composition and diversity (e.g. [42-45]). Based on 22 studies from 8 European countries, Hermy et al. [42] observed 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, long-term establishment also 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 also indications that 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 circa 23.000 hectares; [49]). **Ancient forests offer a unique source for studying essential processes, including the way species disperse and recruit, or how fragmentation affects their colonisation capacity.**

Knowledge gap
Although ancient forests and their species have received a considerable amount of attention in NW Europe and to some extent also in the northeast of the USA, a great deal remains 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. northeast China, northern Japan, eastern Europe). The full extent and distribution of the ancient forest resource is only known in Great Britain and Flanders [49, 51]. In some countries, studies on the issue of distribution have only recently begun (e.g. France, [52, 53]). Information on whether some animal species or fungi are also confined to ancient forests is extremely limited. Recent studies [47] have shown that the establishment and long term survival of transplanted ancient forest plant species into recent forest is more problematic than was previously believed. 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 forest (plant) species will not be able to migrate. Their migration rates, estimated at about 10-100m per century (e.g. [54]), are thus far too low. This calls for research and procedures concerning assisted migration [55], particularly in view of the vast changes in land use and climate to which extinction-prone ancient forest species are exposed.

Policy recommendation
Ancient forests are threatened by fragmentation and climate change. Given their enormous importance in terms of gene and heritage conservation, there is an urgent need to ascribe ancient forests a significant place in forest policy. Ancient forests are extremely valuable for the conservation of forest species and serve as a reference for comparison with recent afforestations. They also form a valuable field laboratory for studying fundamental ecological processes. Moreover, they often form a last resort for the protection of the archaeological and geomorphological heritage in modern landscapes. **Ancient forests must acquire a more prominent place 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 also needed.

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

In a context of rapid climatic and environmental change, the forecasting of trends in forest vitality, forest production and delivery of forest ecosystems services using conventional model predictions has become illusive and highly uncertain. **How do we deal with the 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 interacting 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 in the system (e.g. tree species, ground vegetation, pollinators, seed dispersers, predators) improves the performance of these entities and strengthens complexity [58]. Complex systems like forests and human society operate far from thermodynamic equilibrium [59, 60], are characterized by synergies and feedback mechanisms, and typically consist of scale-free networks: i.e. networks in which the frequency distribution of the number of links per node follows a power law. Scale-free networks have hubs, crucial but vulnerable network nodes such as 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 that might be very different from the previous one. Such regime shifts are often characterised by hysteresis, which means that they are irreversible unless the stress factor causing the shift decreases to a surprisingly low critical level [62]. Box 1 illustrates some examples of regime shifts in forests.

Box 1 - Regime Shifts in Forests

Holling's adaptive cycle concept is popular in the social sciences (e.g. [63]), although it has its origin in forest succession research [64]. Holling observed that fast growing pioneer forests can gradually develop to old growth forests, which build up such a stable humid microclimate that the probability of burning down is near zero, while the biomass accumulation is so high that in the rare case of extreme drought a tiny spark can be sufficient to create an inextinguishable fire that can destroy the system over a 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 before we have large forest fire events in North-West or Central Europe, where forest fire is still 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 for future catastrophic shifts, although 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 when it comes to forecasting non-linear phenomena. The problem is that most current methods are unable to detect thresholds or tipping-points before they actually occur. Suding & Hobbs [67] claim that since many managed ecosystems are functioning this way, the 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 the monitoring and early detection of change-points. Long-term and large-scale 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 the monitoring and early detection of change, rather than too rigidly based on conventional prediction tools [69]. Use should be made of 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 an inherent part of a modern forest planning process in the course of its design, execution, monitoring and feedback. Evaluating and monitoring forest sustainability is undoubtedly one of the main novelties that have completely changed the face of the forestry sector over 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 a definition of 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 became a pioneer in the development of sustainability standards, based on a hierarchical framework of principles criteria and indicators, often simply called C&I (see e.g. [70, 71] and the criteria of the pan-European Helsinki process). They form the basis for one of the most prominent innovations in environmental management by the private sector, namely forest certification (see section 3.5). 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). Data mining methods for extracting policy-relevant information from monitoring databases have undergone 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 triggered by rapid changes in atmospheric composition, climate, soil, and land use calls for the establishment of 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 end, forest simulator development needs to focus on producing the policy-relevant indicator values of the future, rather than on biophysical variables that are hard to interpret (e.g. water footprint instead of evapotranspiration, carbon sequestration instead of 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 in order to create a sensitive instrument for comparing changes in time and differences in space. Such effort must be based on reproducibility and cost effectiveness, and should facilitate 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 ensure 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. 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 such as proximity and neighbourhood analysis, overlay analysis, cost-distance analysis, interpolation and map algebra are indispensable [75].
One might envisage a single IS exploiting several distributed databases. This is all the more applicable to transboundary issues such as those 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 – e.g. the availability of broadband 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 expression

‘Data Infrastructure’, a set of agreements between and within organisations that produce, use or trade data, to facilitate its sharing and reuse [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 provide 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 is increasingly being provided by remote, proximal and *in situ* sensors and by combinations thereof, i.e. by integrated sensing (e.g. [77, 78]). Integrated sensing of forests and corresponding near real-time information systems, however, are in still their infancy. 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

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 that forest-related data infrastructures be built 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 between 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 the first section, therefore, we will explore the state-of-the-art of stakeholder involvement in forest management (2.1). In the second 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 pay 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 ascribe forest management and use more environmental sustainability (2.4).

2.1 ENHANCING PARTICIPATORY FOREST MANAGEMENT

Today, national and international institutions widely accept and promote the idea that common pool forest resources (Box 2) are at best managed by local communities, since 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 e.g. [80, 81]). The shift towards participatory forestry, however, is far from complete. **The question remains as to 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 rightly pointed out to be conditions for improving environmental sustainability. However, participatory approaches frequently evade the issue of bundles of rights and overlapping uses that characterize most tenure systems of common pool resources, such as forests [82, 83]., Like many other natural resources, forests are under the control of established authorities. Moreover, several users hold different rights to the forests and its trees, and all of these tenure relationships 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 served to increase 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 in sustaining their livelihoods [87]. Therefore, learning how to manage common pool resources with multiple and embedded 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 programmes turn out to be difficult to implement, and outcomes turn out to be different than those envisioned [88]. Scientists, therefore, have tended to be critical of the limitation of participation to consultation, without a devolution of rights, benefits and responsibilities, together with the lack of actual participant involvement in the decision-making process [89, 90]. In many cases, citizens have access to involvement in forest management on paper, but not in reality [91]. Furthermore, decentralized forest management faces problems with respect to the 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 3.2), 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 divisions and increased the exclusion of the less powerful in society, such as women and rural populations [96-98]. This is partly 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

The endeavour to address citizens and embrace their stakes takes us into uncharted territory. This has to do with the fact that the complexity of local realities tends to be simplified, and questions such as "who is the community?", "what are people's stakes?" are not uniformly answered. If community is not a good concept for addressing citizens and reaching social equity, one should explore other concepts that might lead to a more sustainable, participatory forest management.

Little is known about the ways in which forest governance may extend 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. This is why, for instance, the International Union of Forest Research Organizations has proposed the establishment of a global platform to steer forest governance at an international level [105]**.** However, this platform also needs to be supported and fed with information at national and local levels.

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 represents a start in the process of enhancing 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 thus need to be monitored and evaluated in order to transform participation from being an empty promise into being a workable tool (see Box 3). New promising tools, such as 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 of Community Participation in Forest Management in South Eastern Tanzania

Angai forest in South-Eastern Tanzania is an example of the successful establishment of a Village Land Forest Reserve, although it did not come about without difficulties. The area consists of woodlands in which hardwood timber (mainly, *Pterocarpus angolensis* and *Dalbergia melanoxylon*) had been overexploited. District authorities therefore decided to establish a district forest reserve, but because they lacked staff and the means to manage the 1400 km² 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. Natural Resource Management committees were created in each of the villages, but these only acquired both internal and external legitimacy once they had also been combined into an inter-village union. The reluctance of some local government officials to devolve authority to villagers on forest management was also a a cause of many delays. The experience demonstrates 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 reveals that this is not always a success story for forests and society. We thus need to better understand **what the impact of increasing marketing of forest products and services will be on both forests and society, and how we can 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) increased globally [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 depend 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, enormous challenges have to be met concerning the sustainable yield from forests (see further in section 2.2.2) and the optimal cascade use of wood products, i.e. the reuse of wood 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 certain 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 in formal markets may erode the ability of governments to enforce environmental protection [116].

Knowledge gap

Broadly speaking, it is not clear whether the marketing of forests actually conserves them and improves the well-being of local people [117, 118]. This knowledge gap in relation to the commodification of forests is two-fold. First of all, given the fact that the commodification of forests and their increasing dedication to income generation and capital markets is a relatively recent phenomenon, only dating back to the late 1990s, the impact of this trend has not yet been sufficiently monitored. Secondly, there is a knowledge gap of concerning the successful ways in which commercial, ecological and social concerns may be combined in forest management due to limited cross-border collaboration between forest conservation and management scholars, anthropologists and practitioners. Peterson *et al.* [118], for instance, offer some recommendations for enhancing 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 to ensure that the tightening bond between forest protection and market expansion does not continue to the detriment of forests ecosystems and their supporting services, or societal well-being over the long term. **Forest commodification needs to be monitored and wisely guided in an interdisciplinary endeavour between forest ecologists and anthropologists.**

2.2.2 FOREST BIOMASS: WHAT IS THE ALLOWABLE CUT?

Policy targets on renewable energy are placing 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 has resulted 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], thus compromising 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 also 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 the potential negative impacts of excessive harvesting levels on forest ecosystems are widely acknowledged, very little quantitative information is available on the 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 calls 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: THE 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 lives 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 unprecedented threat from recent developments in urban areas [131]. **The design of more ecologically efficient urban areas is a prime challenge for the creation of a more sustainable world. What is the role of urban trees and forests in this process?**

Breakthrough

Interest in the benefits and costs of urban forests and trees and the quantification thereof is on the increase. Beyond these relatively well accepted benefits, however, the effects on human health and well-being tend to be less accepted and quantified. Recent 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: amount of pollution removed, carbon storage and sequestration, effects of energy use in building and its structural and functional values. Software for the cost-benefit analysis of tree species [133] has been implemented. However, the general use of such models has been undermined by fragmentary if not lacking knowledge [134].

The extent and nature of the effects of urban forest and trees on human health and well-being are much less accepted (including their economic importance [135]). High pressure on urban space and the still unclear benefits of green in our living and working environment undermines its use and often leads to its replacement 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 in order to estimate benefits and costs. The effect of green on human health and well-being should be investigated. Broadly speaking, a more pragmatic ecological science, which delivers solutions to our crowded planet, is needed.

In many cases we do not know how many trees and green spaces are available and how this resource is developing. 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 major step forward. De Vries *et al.* [135] stress the need for more research on the effect of green on human health and well-being. Based on an participatory approach, Wolf & Kruger [137] 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 makers and planners.

There is a general need for improved insight into biodiversity and evolutionary processes in cities to facilitate 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) call for a pragmatic ecological science that delivers solutions for 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 on behalf of urban forest and trees should become an essential part of the 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 this to chance, Wolf & Kruger [137] argue for research activities that integrate science and local government action. Indeed, there are innumerable instances in which policy and planning decisions appear to disregard or are 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 environmental planning. For urban forest and trees considerable effort is needed to apply scientific knowledge and integrate this 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 to distribution, end use and waste disposal [139]. Life cycle thinking embraces methods such 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 value of life cycle thinking for forest resource use optimization?**

Breakthrough

Originating from the industrial sector, life cycle thinking has successfully established its place and continues to gain importance in the forestry sector. Life cycle assessment (LCA) was first used in industry to check the energy requirements of certain products and to identify process steps with a large optimization potential [139, 141]. LCA became an ISO standardized methodology in 1997 (ISO 14040-14046; 2006). LCA is attracting increasing interest in the forestry sector. Environmental evaluations and optimization exercises are being devised for construction wood productions, pulp and paper production, forest based bioenergy systems, and many more. In addition, LCA derived results, such as carbon footprint, ecological footprint and water footprint, have rapidly acquired a great deal of interest because of their characteristics as communication tools [142]. In contrast to industrial systems, forestry systems might be considered open systems that 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 available on the inclusion of land use, and the 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 endeavouring to cover different aspects influencing the overall land quality [146]. In relation to the latter, there is discussion as to 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 deals with the question whether we should maintain land use and land use change as one impact category or consider them as 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 final chapter, international forest policy processes are critically analysed. Full attention is given to the role of forests in the international climate debate. Deforestation avoidance is at the centre of climate negotiations, but elementary issues such as forest definition and strategies to avoid spill-over are insufficiently addressed to succeed (3.1). We try to open new ways out of this inertia by proposing landscape carbon instead of forest carbon accounting (3.2), integrating mitigation policies with adaptation and development policies altogether (3.3), developing new views on forest ethics (3.4) and giving support to improved certification as a unique market instrument (3.5).

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 options are available 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%. Vietnam's booming economy ensured that the demand for forest products, especially wood, remained high. Law enforcement and the attractiveness of preserving and managing 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, the extent to which sustainably grown domestic timber will be able to compete with – and substitute – illegally imported timber remains unknown**.** In 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 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?

Climate change negotiations have dedicated – and will dedicate – a great deal of time to the establilshment of 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 such as that currently used in the People's Republic of 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] reveals that if the current REDD policy were to be carried out as designed, with full forest protection , 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 only result in a displacement effect in the first 6.4 years.
The only UNFCCC definition that currently exists is that established for Afforestation/Reforestation under the Clean Development Mechanism (CDM – A/R) at 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 of 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 while paying attention to ensuring local land use rights? There is a need to test out these REALU or AFOLU approaches in different contexts and conditions. 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 too 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 have considerable 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 RECONCILE 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 historical carbon debt has been generated for the most part by the industrialized world. Their focus rather is on economic development and adaptation to climate change. **Which policies can help realise the triple objective of mitigation, adaptation and development?**

Breakthrough

Integrated policy approaches and tools are increasingly available and are 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 programmes on their merits regarding climate change mitigation, adaptation and overall sustainable development [154].

The 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 programme 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 and protect the coastline, they have also triggered development.

Forests store large amounts of carbon and provide livelihoods for many rural poor, but can generally only sustain a low population density. Increasing the tree cover of the agricultural landscape using agroforestry practices (e.g. using nitrogen fixing trees or exclosures for small-scale forest rehabilitation), has the potential to increase and stabilize harvests, and deliver the ecosystem services farmers really need, while also offering opportunities to store carbon for the global community. Land use practices that increase soil organic carbon not only store carbon, they 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 in which trade-offs seem to exist. There is more research needed to explore possible direct and indirect side effects of policy measures and to what extent they affect countries, regions and their populations, including smallholders.

Policy recommendation

Development, mitigation and adaptation projects and programmes should not be conceived on a separate sectoral basis, but jointly. A sectoral government architecture is not conducive to responding 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 in addition to resource use, not only humans but also global ecosystems benefit from the natural functioning of forests. **But how do we 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 to advocate direct ethical responsibility to the non-human world. His ideas put an end to the understanding of natural environments as amenities and commodities, instrumental 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]. In addition to their resource use, both the human population and the ecosystem benefit from the natural functions and environmental profits provided by forests from the local to the global level. However, such forest supporting services tend not to be very visible and are generally not well-known or properly assessed. Recent research has provided a large amount 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 can 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 has to account for biomass functions (carbon dioxide sequestration and carbon storage, oxygen generation through photosynthesis), environmental benefits (air pollutant absorption and filtration, climate regulation, rainwater retention), wildlife habitats, biodiversity conservation, recreational opportunities and aesthetic enjoyment (e.g. 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 and 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 planet as a whole, require unconventional appraisal to address their non-commercial and non-commodity traits. The international post-Kyoto climate regime development agenda focuses on the theme of reducing emissions from deforestation and forest degradation (REDD), while neglecting other ecosystem services [161, 162]. A great deal of information has been developed using external market techniques to assess their monetary value, but different proposals tend to be characterised by different notions of equity. Providing a workable and more generally acceptable method for valuing these services would help to overcome the impediment of translating all ecosystem services more accurately into economic values, thus facilitating a global forest management beyond carbon credits.

3.5 FOREST CERTIFICATION AS A FOREST GOVERNANCE TOOL

How do we 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 variations in institutional design between the different existing schemes [174-177]. The FSC is generally considered to be the most credible certification system. However, convergence between FSC and PEFC, for example, 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 (Box 4). 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 mostly being 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 for a variety of 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 the 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]. Broadly speaking, significant variation in forest management standards has been observed [70].

Box 4 – What is Forest Certification?

Forest certification is becoming an increasingly important instrument in promoting 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." According to Meidinger [172], Forest certification "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. Firstly, forest management (FM) certification provides certification according to a set of principles and standards and governs the supply of certified wood. Secondly, other organisations in the supply-chain that provide certified wood products to customers can be certified with a chain of custody certificate or a CoC.

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 that 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 that 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 should be conducted, preferably through an experimental design. Sufficient time should be allowed to assess the short-term and long-term effects of certification on social, economic and ecological dimensions.

Certify the Certifiers. Forest certification is increasingly being seen 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 the sale 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 for achieving sustainable forest management. In order to increase and maintain the overall adoption, additional financial and technical resources will be necessary. Research reveals that the cost of getting certified and regaining 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 could be funded, for example, by a special tax on forest derived products or by donations.

4 RECOMMENDATIONS

1. One third of European and global land is covered with forests, and although society generally regards these forests very highly, the ecosystem services they provide are undervalued, and appropriate forest policies are lacking to enhance their benefits, optimize their trade-offs, and reward their managers.

2. Biodiversity is declining in European forests. The forest sector needs to urgently recognise and address the fact that forest management does play a role in the loss of forest biodiversity. Especially the conservation of remaining virgin and ancient forests is at stake. More refined indicators for forest biodiversity monitoring are needed as well.

3. In complex systems such as forests, external stress factors can induce abrupt changes that are hard to predict. Climate change is likely to induce unprecedented disturbances, including heavy storms, uncontrollable fires and new pests with significant regional impact. A European risk facility using advanced early warning tools should address this.

4. Environmental stress due to climate change and air pollution may have a severe negative impact on forest productivity in Europe, albeit with much variation between regions. This may jeopardize the provided role of forests in the biobased economy. National and regional action and outreach plans for adaptation are needed.

5. On the one hand, the role of European forests in the green economy is undervalued, in the sense that applications are too focused on merely burning biomass, rather than considering new high value material or chemical applications. On the other hand, the potential of the resource is overestimated, while there are still no methods for sustainable yield assessment in terms of allowable cut and nutrient export in place.

6. The multiple roles that forests play in climate change mitigation through carbon sequestration and material and energy substitution can be greatly enhanced through appropriate policies and measures. Mitigation measures should not be stand-alone but integrated as part of the adaptive management and sustainable development of forests in general.

7. Keeping the forest area intact is crucial to ensuring its multiple ecosystem benefits. Europe can play a key role in facilitating the development of a fair and performing REDD instrument, to help preserve the world's forest resources. In this context we believe that landscape carbon accounting instead of forest carbon accounting can largely resolve present challenges related to forest definition, spill-over and leakage effects.

8. Governance of European and global forests can be improved. First, coordination between different international, European, national, regional and local initiatives should be supported. Second, there is an important role in forest governance for genuine stakeholder participation, and for private governance initiatives such as third party forest certification. Third, the importance of forests remains undervalued. Extensive awareness-raising campaigns could enhance support for forest policies. Fourth, the policy principle of integration should be applied to forest policy. Governance of forests should be integrated in other policy areas (energy,

agriculture, climate, biodiversity, ...). Fifth, data harmonization and integration should be supported.

9. There is a tendency to refocus forest management on biomass production and carbon accounting. The multiple and often non-marketable ecosystem services of forests should not be forgotten, given their high importance in an urbanized society. The fact that forests do not only provide commodities for humans but also serve the global planetary ecosystem is an ethical issue.

10. Forest research is crucial to supporting the major challenges and ambitions that are facing the management of the world's forest resources and the forest-based sector in the context of an emerging bioeconomy. But forest research in Europe is too often fragmented, mono-disciplinary and lacking substantial facilities to efficiently address such challenges. A coherent and ambitious European forest-based research area should be developed based on well coordinated national programmes and increased international and interdisciplinary collaboration as a primary pillar within the framework of the new EU Forestry Strategy.

5 GLOSSARY

Adaptation

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

Afforestation

The establishment of a forest in an area where there was no forest in the past (for 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 programmes 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 N_2O and CH_4 in agriculture and increasing sinks of CO_2 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 for at least a number of centuries, compared to recent forests which are much younger in origin.

Annex-1 countries

41 Annex I countries together with the European Union 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 in which the effects 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 less diverse communities, and they appear to be more stable in the face of perturbations.

Common pool resources

Resources or goods that face problems of overuse or degradation when exploited. Although the term is closely linked to resources that are governed in common property regimes, common pool resources are not governed *per se* according to social arrangements as 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 that 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 non-forest use.

Ecosystem services

All the benefits humans derive from ecosystems.

Facilitation

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

Forest commodification

Transformation of the natural environment into a commodity, i.e. 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 via a single gateway.

Forest productivity

The net primary production (NPP) of a forest is an appropriate 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, behavioural 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. Behavioural effectiveness assesses the degree to which the regime generated differences in behaviour 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 according to 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 such as 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 merely hints at the inclusion of local populations in 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 can be excluded from use. Semi-public or impure public goods combine public and private characteristics.

REALU

Reducing Emissions of All Land Uses.

REDD

Reducing Emissions 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 (such as timber or fish) under management procedures that 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 the tipping point 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 that have not been influenced directly by human beings in their development. Such forests 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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