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Creating social and economic drivers of forest conservation through the capitalization of biodiversity services: Methodological framework

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FOREWORD

This document was developed within the framework of the project "Conservation and sustainable capitalization of biodiversity in forested areas - BIOPROSPECT'' (BMP1/2.1/2336/2017) implemented under Interreg V-B "Balkan-Mediterranean 2014-2020" Transnational Cooperation Programme. The document is the Deliverable 3.1.1 of WP3 and provides the identification and classification framework of direct and indirect drivers affecting forest change and promoting conservation forest conservation through the capitalization of biodiversity services.

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EXECUTIVE SUMMARY

Aim of Deliverable 3.1.1 is to provide the identification and classification framework of direct and indirect drivers affecting forest change and promoting conservation forest conservation through the capitalization of biodiversity services.

The first chapter provides a global overview regarding the main change drivers of forest biodiversity in relation to ecosystem services. Conversion of forests into agricultural lands, overexploitation, climate change, and invasive species, all cause great stress on forest ecosystems. Conscious of the negative effects of human activities, society has responded by increasing the area of forest being protected and well-managed, and by incorporating management of trees and forest patches into management of agricultural landscapes. Still, most of natural forests and agricultural landscapes are not well-managed and their existence continues to be threatened by the same drivers. The lack of reduction in the threats to biological diversity is, among other things, due to lack of addressing the subjacent causes of the threats. These are very much linked to level and form of economic development, and are often found outside the forest and environmental sectors.

The second chapter analyzes the EU perspective of forest ecosystem services as natural capital. While Europe has undoubtedly made progress in preserving and enhancing its natural capital in certain areas, overall degradation of ecosystems persists. In addition, abiotic resources and ecosystem capital are under significant pressure across the world and demographic and economic projections suggest that these pressures are likely to grow.

The third chapter is dedicated to the identification and classification framework of the direct and indirect drivers. A direct driver unequivocally influences forest ecosystem processes while indirect drivers operate more diffusely since they alter one or more direct drivers. The main categories of global driving forces are sociopolitical, demographic, economic, scientific-technological, cultural-religious as well as physical and biological. Drivers in all categories other than physical and biological are considered indirect. Important direct, i.e. physical and biological, drivers include changes in climate, land conversion, plant nutrient use, invasive species and diseases.

The fourth chapter identifies the main challenges and opportunities in forest management in relation to the identified drivers. These include: (a) Institutional challenges, (b) natural capital accounting, and (c) policy and management. Based on the drivers of change, the valuation of forest ecosystem services is of primary importance to policymakers, businesses and environmental organizations in that, by quantifying and making explicit the value of the environment in currently existing language: it helps to raise awareness of the benefits; it can target resources for forest ecosystem protection; and can rationalise the decision-making process.

1 THE CHANGE DRIVERS OF FOREST BIODIVERSITY IN RELATION TO ECOSYSTEM SERVICES: A GLOBAL OVERVIEW

Forests are among the most important repositories of terrestrial biological diversity at global level. Biodiversity encompasses a variety of differences in species genetics, composition and their functional roles within ecosystems. According to the Convention on Biological Diversity (CBD), the biological diversity can be defined as "the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part. This includes diversity within species, between species, and of ecosystems" (CBD 1992).

The biological diversity can be considered as the basis for a wide array of goods and services provided by forests. The Millennium Ecosystem Assessment (MEA) defines Ecosystem Services as the benefits that people obtain from ecosystems (MEA 2005) and proposes 4 groups of ecosystem services: provisioning, supporting, regulating, and cultural (Diaz et al. 2005, MEA 2005) which are related to biodiversity either directly or indirectly. According to Kremen (2005) the relationship between the biological diversity and the ecosystem services is rather complex and often poorly understood. In some cases the biological diversity itself is considered to be a service (for example under Costa Rica's 1996 forest law). However, following a more scientific approach, biodiversity can be considered as a mechanism through which services are provided (CBD 2008). Thus changes in forest ecosystem biodiversity, such as richness, abundance, and composition of species, may lead to parallel changes in the amount or quality of services provided by that ecosystem as for example in carbon sequestration, pollination, or pest control (Bunker et al. 2005, Phillpott et al. 2009, Ricketts 2004), indicating that the relationship between biodiversity and ecosystem services is linear (Schwartz et al. 2000).

Biodiversity may also be divided into functional components in which species are classified according to:

- their contribution to ecosystem services (e.g., nitrogen fixing) or by
- their functional response to ecosystem change (e.g., drought tolerance).

According to Flynn et al. (2009) several plant and animal populations and communities have shown functional complementarity or redundancy, causing ecosystem functionality to rapidly decline if species numbers drop below a certain level. A meta-analysis of 446 measures of biodiversity effects on temperate non-forested ecosystems, conducted by Balvanera et al. (2006), revealed that there was a critical number of species (10 to 20). Beyond these numbers the effects of diversity on ecosystem services decreases significantly.

The relationship between forest biodiversity and ecosystem services is not always direct or clear. However, especially in species-poor ecosystems, there is a strong and well documented link between the adaptive capacity of ecosystems to changes or disturbances

(Diaz et al. 2005). According to Balvanera et al. (2006) for example, the resistance to invasion is increased with greater species richness while resistance to drought, windfall, and other disturbances did not. Acosta et al. (2001) also found that although the hurricane Mitch had the same effect on both un-managed and managed stands of tropical broadleaf forests, the former showed greater diversity and recovery in the following years after the event. The fact is that biological diversity has been continuously changing on Earth as a response to both anthropogenic and natural changes in the environment (MEA 2005).

1.1 Biodiversity – Forest Ecosystem Services and Drivers of Change

Drivers of change in forest biodiversity may be distinguished to natural or human-related. The main human-induced drivers iclude the degradation and loss of forest ecosystems due to changes in land use, disturbance of the biogeochemical cycles, invasive species, and unsustainable management or even over-exploitation of resources (Diaz et al. 2005, Fischlin et al. 2009, Kanninen et al. 2007).

Human interventions in forest ecosystems usually trigger multilevel and multiple losses of biodiversity. Under these conditions it is more difficult for ecosystems to recover from the impacts. The recovery from such human-induced changes is usually slow and costly, while in some cases it is even impossible (Ellatifi 2005). The main focus of this work is on human-induced changes on forest biomes. The services provided by forest ecosystems may vary according to biome, socio-economic and cultural context as well as the geographic location. Fischlin et al. (2009) provide several relevant examples, while in this work some clear examples are provided with particular reference to North & South America and in the Mediterranean Basin.

1.1.1 Converting natural forests to other land covers

According to FAO (2009), in the period between 2000 and 2005 the annual loss of natural forests was about 7.3 million ha while before 2000 the annual loss exceeded 13 million ha/year (FAO 2006). Agriculture is considered as the largest direct human-induced driver of biodiversity degradation (Ellatifi 2004). Many additional direct drivers of biodiversity loss (Kanninen et al. 2007) are related to people's livelihoods, which consider more attractive to convert a natural forest into agricultural land than to manage it. These factors include, among others the following (FAO 2009, Geist and Lambin 2002, Kanninen et al. 2007):

- Difficult and slow administrative procedures to obtain permits for forest management,
- Subsidies for agricultural products,
- Policies which consider deforestation as land improvement.

In emerging and under development countries especially, these factors are exacerbated by additional factors such as (FAO 2006, FAO 2009, MEA 2005):

- Increasing population growth,
- Increasing demand for agricultural products as well as biofuels,
- The governance limitations including deficient normative frameworks, lack of transparency in decision-making, etc.

In addition, there are also clear differences in deforestation rates both between forest biomes and within the forest types of each biome. Such a characteristic example is the dry forests in Central America which have been more heavily deforested and degraded than humid forests (Finegan and Bouroncle 2008). Direct effects of such conversions are the loss of biodiversity and changes in structure and functioning of the forest ecosystem. An additional change is the modification of the proportion of forest edge habitat compared to forest interior habitat that is essential to forest dependent species. Critical factors to these effects are (Finegan and Bouroncle 2008):

- The level of fragmentation of the remaining forests,
- The size and shape of fragments, and
- The types of other land uses in the surrounding area.

The deforestation results in loss of biological diversity with a subsequent reduction or loss of ecosystem services (Diaz et al. 2005, Flynn et al 2009, Laliberti et al. 2010, Metzger et al. 2006). However, according to Diaz et al. (2005) ecosystem services are more influenced by the species composition rather than by the number of species. Thus ecosystem services can be restored, at least partially, by appropriate land use management practices focused on the conservation of specific functional groups and communities, rather than by increasing species richness (Balvanera et al. 2006, Kremen 2005). Soil quality, carbon storage, and provision of habitats are some of the ecosystem services reported from forest and agroforest systems that provide regulating and pollination services for agricultural crops, regulation of water quality and runoff (Agbenyega et al. 2009, Diaz et al. 2005, Kremen 2005). Agbenyega et al. (2009) as well as other authors, argue that the same measures that increase non-agricultural crop vegetation may also provide ecosystem services, such as competition for resources and habitat for crop pests.

The effect of native forests versus exotic plantations on recreational fishing (Lara et al. 2009), can be considered as a good example of such trade-offs. In Chile for example, the increasing secondary growth in buffer zones along rivers was associated with the increased abundance of exotic trout species, at the cost of native fish species diversity and abundance. Biological diversity is directly related to the capacity-resilience of ecosystems to adjust to changes (DeClerck et al. 2005, Diaz et al. 2005, Loreau et al. 2002, Naeem and Li 1997). Especially in species poor ecosystems, an increase in species number may increase productivity and resilience of the entire ecosystem (Diaz et al. 2005, Thompson et al. 2009). In the light of projected climate change scenarios, the loss of biodiversity through forest conversion will decrease the potential for adaptation and maintenance of ecosystem services (Flynn et al. 2009, Innes et al. 2009). A particularly compelling example is provided by Laliberti et al. (2010) that includes more than 3000 species from forest ecosystems in Europe, Australia, North America and China. Their study documents that with deforestation and agricultural intensification resulted in the loss of functional diversity. In this perspective the loss of species belonging to different functional response groups, reduces the capacity of these forest ecosystems to recover and/or adapt to short and long term changes.

Big leaf mahogany (*Swietenia macrophylla*) in Peru. (James Frankham / WWF)

(Source: http://wwf.panda.org/knowledge_hub/endangered_species/bigleaf_mahogany/)

1.1.2 Over-exploitation

Overexploitation refers to one of the main activities threatening biodiversity. In case of over-exploitation the number of individuals that are removed from a population exceeds the natural annual increment of that population. While over-exploitation affects many renewable natural resources it has been severe in tropical grasslands, in marine ecosystems, in tropical forests and coastal areas (MEA 2005). Over-exploitation may result in degradation of ecosystems, loss of genetic diversity and even the extinction of some species. The species in Morocco's forests are threatened by the overexploitation of fuel wood (three times the forest production) and fodder (three times the forest-grazing possibility) (Ellatifi 2004, Ellatifi 2005, Ellatifi 2008, Karmouni 2006). In countries where firewood is still the main energy source (e.g. Guatemala, Honduras, Nicaragua), firewood harvests occur both within and outside forests. In such cases the use of wood for energy (FAO 2010), may considerably exceed the production capacity of the forests and is often associated with the use of the former forest area for agricultural activities.

On the other hand, when over-exploitation in forests is related to reasons other than fuel and fodder, it may affect only a few species. Ter Steege et al. (2002) found that 75 years of greenheart (Chlorocardium rodiei) harvesting in Guyana had little effect on overall tree species diversity, while Rice et al. (2001) revealed that over-exploitation of mahogany (Swietenia macrophylla) in Latin America causes only minor changes to species diversity as long as this is not followed by uncontrolled exploitation of other species or the change in land use.

It is underlined that the over-exploitation of a single species, may become more harmful in areas with a low tree diversity, or in cases when harvests move from species to species. In the Mediterranean Basin, as well as in other areas, the over-exploitation is often linked to illegal activities, for the change of land use with subsequent effects on biodiversity. Nasi et al. (2008) suggested that "empty forest syndrome" was becoming common in many tropical regions by documenting numerous changes in populations of wild species hunted for bushmeat. Very important for biodiversity, is the over-exploitation of animals and plants that are related with key ecological processes (eg seed-dispersers, pollinators), or food sources in harsh periods of the year.

1.1.3 Changes in biogeochemical cycles

Biogeochemical cycles are considered as pathways by which chemical substances move through biotic and abiotic compartments of Earth. Well-known cycles are those of water, carbon, nitrogen, oxygen, phosphorus, and sulphur. Timber harvesting is related to different nutrient cycles. Current forest management practices, as long as they are sustainable, allow for their recovery within reasonable periods of time (Poels 1987). Several studies indicate the importance of new vegetation in abandoned agricultural areas for the recovery of soil nutrients (e.g. Cole 1995, Gerding 2009, Gonzalez 2009).

Plant litter production and decomposition are two important processes in forest ecosystems, providing the main organic matter input to soil and regulate nutrient cycling. The use of fossil fuels moves large stocks of carbon that were stored in the ground into the atmosphere. This translocation of carbon may affect regional climate regimes and thus modify terrestrial ecosystem functions and services.

The review of scientific literature concerning climate change, by the Intergovernmental Panel on Climate Change (IPCC), reveals that since the Industrial Revolution, carbon (mostly as CO2 and CH4) and nitrates have accumulated in the atmosphere. This increase was attributed in average global temperature and beyond that caused by natural phenomena detected for the same period (Le Treut et al. 2007). Even there is still some uncertainty on the effects of further increases in greenhouse gas (GHG) emissions on the climate, several scientists are able to project future climate changes under different emission scenarios use based on a relationship between GHG emissions and climate t (e.g. Meehl et al. 2007).

The increased concentration of CO2 in the atmosphere had a fertilization effect on many plant species (in particular in areas where other growth factors such as moisture and nitrogen, are not limiting). An increase in atmospheric CO2 and temperatures for example, according to Phillips et al. (2008), was found to be responsible for the biomass growth and changes in forest composition of the Amazon. Fischlin et al. (2007) revealed that climate change may have a great effect over current, local biological diversity, by increasing species extinctions. In this perspective climate change is also expected to decrease cover and changing forest type in temperate regions, increase forest cover in alpine and boreal regions, and decrease forest and woodland cover in the tropics (Fischlin et al. 2007).

The expected effects of climate change on ecosystem services differ among forest types as well as biomes. In general, the frequency and intensity of disturbances are expected to increase, with extreme temperature and precipitation events, which are likely to be enhanced by increased intensity and occurrence of pests and diseases, fires, and extreme weather events (Fischlin et al. 2009). The phenology of many plant species may be also affected by climate change, altering flowering and fruiting periods, and reproduction processes (McMullen and Jabbour 2009). The prediction of the actual levels and locations of future changes in biodiversity is considered as difficult and challenging task sine there is a great uncertainty about which of the different emission scenarios may be realized, and the resolution of most climate change models is rather low.

The burning fossil fuels releases, in addition to carbon, significant amount of sulphur. The latter, which may also emitted during volcanic eruptions, reacts with the atmospheric water and oxygen releasing sulphuric acid and causing acid rain with negative impacts on plants, animals (e.g. Dirnbϕck et al. 2007), and even infrastructure. Such effects may also be caused by the. In most cases forests need several years to recover from these effects, even once sulphur emissions have been curbed (Dirnbϕck et al. 2007).

The human activities also affect the nitrogen cycle, with the potential to contribute to acid rain, as well as to ecosystems eutrophication. Both phenomena affect the species composition, by driving local species extinctions in grasslands (e.g. Tilman et al. 2002) and the favouring of species with increased tolerance in acid environments (e.g. slight changes in alpine areas in Austria, Dirnbφck et al. 2007). On the other hand, there are also positive fertilisation effects of nutrient-rich rains which increase the on productivity in some systems, especially in Europe (Fischlin et al. 2007).

1.1.4 Invasive species

A species that is not native to a specific location and that has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health can be defined as invasive species. These species successfully invades to forest ecosystems where it was previously unknown, causing biological change and/or ecological or economic harm in this ecosystem (Levine et al. 2002). According to Norton (2009) the invasive species that originate from outside the ecosystem are a major cause of species extinction. This has been particularly studied on islands and in Mediterranean areas owing to the high numbers of invasive species in these ecosystems (Blackburn et al. 2004). The capacity of alien species to invade is affected by various factors, both extrinsic and intrinsic to an ecosystem, including availability of niches, system degradation, and fragmentation. Most introductions are the result of human actions. Although many introduced species fail to increase in numbers, there are also cases that become successful often cause disproportionate damage (Mack et al. 2000). Main mechanisms by which invasive species cause local ecosystem change include: alteration of ecosystem functioning, competition/predation, and even genetic modifications (e.g. Shea and Chesson 2002). The invasions may result in altered community structure, biodiversity, homogenization of flora and/or fauna, and finally reduced ecosystem services (Chapin et al. 2000). The invasive species, after their establishment, they may decrease the resilience of the systems and create an alternative stable state that is exceedingly difficult to eradicate (Hooper et al. 2005, Thompson et al. 2009).

Climate change has been recently reported to increase the success of invasive species by changing the conditions to favor invaders over local species. The success of invasive species is often linked to the synergistic effect of multiple factors favorable to invasion, including habitat alteration and degradation, community structure alteration, and over-exploitation (Diamond 1989).

Following species invasions several ecosystem changes are observed including the loss of native flora and fauna on many islands. The case of Guam provides a characteristic example. The accidental introduction of brown tree snake (*Boiga irregularis*) in the 1950s led to the decimation of most of the island's bird, lizard, and mammal populations (e.g. Mortensen et al. 2008). As a domino effect, loss of biodiversity usually results in reduced capacity of a system to resist invasion while diverse systems are more able to resist invasion (Balvanera et al. 2006). After all it is well documented that diversity enhances the stability of ecosystem processes and the flow of goods and services (DeClerck et al 2005, Hooper et al. 2005, Laliberti et al. 2010).

The invasive brown tree snake (Boiga irregularis), brought to Guam by the U.S. military after World War II. GORDON RODDA / U.S. FISH AND WILDLIFE SERVICE.

(Source: https://www.theatlantic.com/science/archive/2017/08/guam-military-wildlife/536622/)

Many forest ecosystems are not especially resistant to invasion. A number of examples are available of introduced trees invading temperate forest ecosystems (e.g. Richardson 1998) and many invading species are superior competitors to many local species and/or that forest plant communities are not saturated. Furthermore, disturbed systems are more prone to invasion than undisturbed systems, while diverse tropical ecosystems are less prone to invasion (e.g. Sax 2001, Simberloff et al. 2002, Fridley et al. 2007). Lack of resistance to invasion in temperate forests, may be a long-term result of a reduced number of endemic species and the existence of vacant niches due to natural or human disturbances (Simberloff et al. 2002). The number of native plant species in a system to the number of introduced plant species is used as indicator of the invasibility of an ecosystem in several scientific studies (e.g. Keeley et al. 2003, Macdonald et al. 1989). However, the effects of invasion are also affected by the level of disturbance, the extent of the undisturbed area owing to edge effects, and the scale of measurement.

1.2 Forest Biodiversity Management in relation to Drivers of Change

Biological diversity promotes the capacity of an ecosystem to resist/adapt to changes (Balvanera et al. 2006, Fischlin et al. 2009). However, diversity in order to provide goods and services (Diaz et al. 2005) needs to balance both the right mix of species and the appropriate structure since most direct links between diversity and services is established between growth rates and species carbon content. In this perspective, fast-growing tree species increases carbon storage (e.g. Bunker et al. 2005), but it seems to be linked mainly with ecosystem stability rather than with the carbon sequestration level (Bunker et al. 2005, DeClerck et al. 2005, DeClerck et al. 2006). In any case there is considerable evidence that ecosystems with numerous species are more productive than simple monoculture plantations (Thompson et al. 2009).

The conservation of biological diversity needs to go far beyond relying only on protected areas. Many decision-makers are aware of this need and that is the reason behind, for example, the establishment of Biosphere Reserves. Areas for the conservation of biological diversity have different levels of management (core area, zones of different use, and buffer areas) and use biological corridors for improving the connectivity between protected areas, often by promoting sustainable land use management on private parcels within agricultural areas. Therefore, three broad settings for biodiversity management can be identified:

(1) Management of protected areas,

(2) Management of forest reserves for timber and non-timber production, and

(3) Management of biodiversity in agricultural landscapes.

1.2.1 Management of protected areas

The best way to ensure the maintenance of biological diversity is the effective and efficient management of protected areas. Recent scientific studies within 198 protected areas in tropical forests of different continents (DeFries et al. 2005), for example, revealed that the habitat destruction, within the same biomes, was lower in protected areas than in peripheral buffer zones or outside the protected areas. In Latin America for example, this has resulted in an increase of the negative effects of surrounding land uses on the diversity inside protected areas (Finegan and Bouroncle 2008). On the other hand, the wise forests management for timber and non-timber products in Mexico and Guatemala (by local communities) may have more positive effects on forest ecosystems conservation than poorly managed protected areas (e.g. Carrera and Prins 2002, Bray et al. 2008).

Given the new global realities, such as including climate change and an ever-expanding human population that continues to erode natural capital, the protected area networks must be managed and extended to provide adequate protection of biodiversity. According to Sanchez Azofeifa et al. (2003) the sustainable management of a park in Costa Rica had a positive effect on surrounding areas with more forest patches on private lands near the parks than away from these parks. This however, may be also the result of appropriate government policies through prioritization of Payment for Ecosystem Services (PES) to land owners within biological corridors linking such protected areas. In addition, the location of protected areas in respect to large population centres and main highways, may also influence the degree to which protected areas contributed to avoiding deforestation.

In Costa Rican regions with high rates of deforestation, the establishment of parks has had the effect of reducing this rate of deforestation. Unlucky, the establishment of parks in areas with poor accessibility and low potential for other land uses had a minimum effect on reducing the already low threat of deforestation (Pfaff et al. 2009). In all of these cases, participation of local land owners plays a key role towards the achievement of conservation goals within protected areas as well as on the neighboring private lands.

In Canada, protected areas are being seen as one way to help natural systems towards climate change adaptation and the reduction of human-caused stresses on landscape. For this purpose over 11 400 000 ha of new protected areas have been established, doubling the amount of land protected over the past 20 years and reaching 10% of the Canadian land.

While in Canada climate change and ecosystem integrity are the drivers behind the establishment of many new parks, in Latin America the major goals for the establishment of protected areas are the prevention of deforestation and forest degradation by over-exploitation.

Furthermore, many older protected areas in Canada and elsewhere were established with the specific objectives of protection of landscapes and/or discrete ecosystems and particularly wildlife, while providing areas of public recreation.

The uncertain climate change projections are a challenge towards the sustainable management of protected areas since adaptation requires careful landscape management of the areas surrounding protected areas, particularly for maintaining / enhancing the connectivity between them (e.g. Rayfield et al. 2008). Climate change has prompted authorities in Costa Rica to consider the connectivity between protected areas, promoting for example the establishment of biological corridors on private lands (Canet Desanti 2007).

An alternative solution to the problems associated with climate change uncertainty, is the expansion in existing protected areas. In any case, improved climate change models and landscape planning are required in order protected areas to be able to address climate change challenges (Scott and Lemieux 2005). Wiersma and Nudds (2009) suggest that a substantial increase in protected areas will still be required if adaptation to climate change is an objective.

Today only 11.5% of the world's natural vegetation is currently protected in such areas (Rodrigues et al. 2004). Even worst, in Latin America and other developing regions, many of these areas lack of adequate management resources and protection measures. Protected area networks, according to Rodrigues et al. (2004), may not provide the degree of protection needed to conserve habitats having an abundance of particularly sensitive endemic species that have narrow geographic ranges (for example, Meso-America, north of Colombia, and Atlantic forests of Brazil). While in some cases, increasing the coverage of protected areas may provide a valid solution, in others, such as in areas where forests are used by local communities, other forms of management of biodiversity are necessary.

1.2.2 Forest management

Forest management can be considered as the process of planning and implementing practices for the stewardship and use of forests and other wooded land to meet specific environmental, cultural, social and economic objectives. In Latin America, about 250 million ha almost 25% of the natural forests have been assigned to local communities (Sunderlin et al. 2008), while 200 million ha privately held are under legal protection (mainly in Amazon). About 3–4% of these natural forests are managed according to the standards of responsible forest management, evaluated by auditors of the Forest Stewardship Council (FSC) forest certification scheme. In addition to these certified natural forests, about 4 million ha of plantations have been certified in community forests (e.g., in Mexico, Guatemala, and Brazil), in private forests (e.g., Argentina, Brazil, Chile and Costa Rica), or in concession areas (e.g., Bolivia, Peru, Guatemala). These areas are considered to be good examples of well-managed forests and contribute to the maintenance of ecological functions as well as some ecosystem services. In the Mayan Biosphere Reserve in Guatemala, the logging concessions are presented in Figure 1. In this Reserve the contribution to biological diversity conservation is probably most striking. Satellite images from 2000–2002 reveal that within the community forest concessions the frequency of fires and land use change is lower comparing to the adjacent reserve buffer zones and park areas (Carrera and Prins 2002).

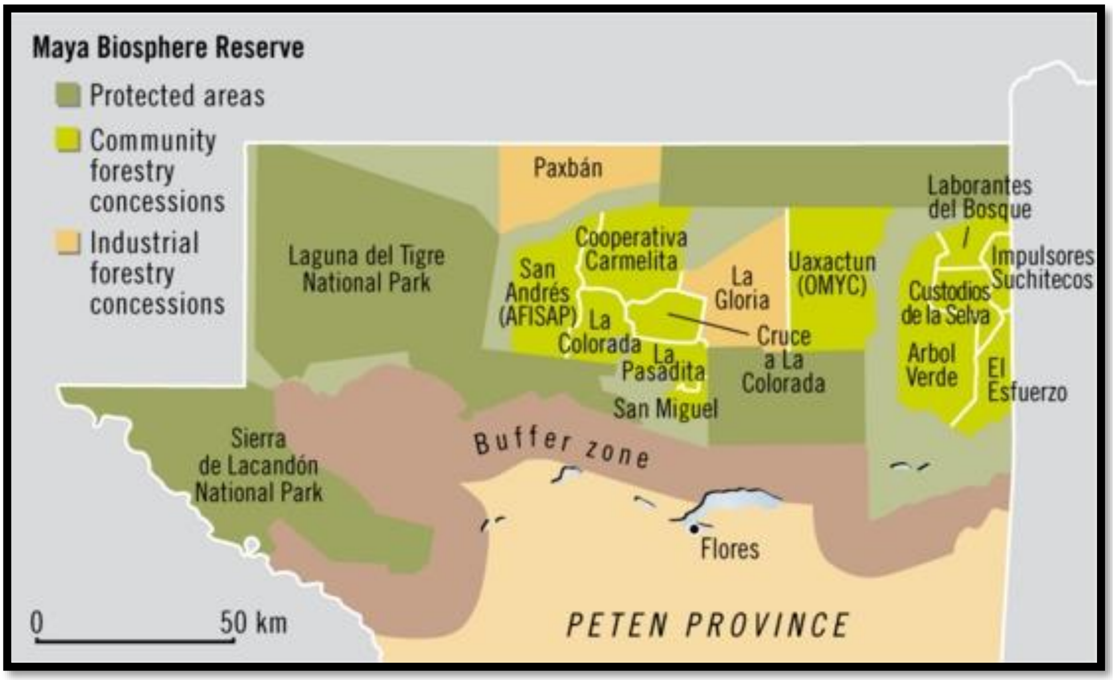


Figure 1. Logging concessions in the Guatemalan Maya Biosphere Reserve
(Source: https://www.grida.no/resources/6741)

In well-managed areas managers know their resources well, perform series of inventories at different scales and of differing designs and objectives, while establishing permanent sample plots to monitor forest dynamics over time, and as a tool for future monitoring. Further more responsible managers plan ahead, apply reduced-impact logging practices, and implement mechanisms to become good neighbours and good employers.

Although these experiences are relatively new, and it is very early to determine their success, it is confirmed that certified Latin American forest managers set aside a considerable part of their management area for conservation purposes. These practices reduced-impact logging activities and appear to reduce direct logging damage to about 50% of that achieved by conventional logging practices (Durrieu de Madron 2009, Johns et al. 1996).

The lack of adoption of forest management practices in Latin America, during the last 10 to 15 years, and in spite of a general improvement of forest policies and legislation, have been the slow administrative procedures, the illegal logging activities, the high cost of management in combination with low timber prices, the high opportunity costs, the uncertainty about future forest use rights, as well as the social conflicts (e.g. Walters et al. 2005, Smith et al. 2006).

1.2.3 Management of biological diversity in dgricultural landscapes

Agricultural expansion is often cited as one of the main driving forces behind deforestation (Kanninen et al. 2007). On the other hand according to Balvanera et al. (2006) the management of biological diversity within agricultural landscapes plays an crucial role in the development of a sustainable agricultural practices. It has been recognized by conservationists that conservation of biodiversity will be impossible without the conservation role of the agricultural landscape. Farmers are also aware of the functional role that biodiversity plays in agricultural production. This perception by stakeholders that traditionally have been considered diametrically opposed to each other sets the stage for landscape-scale management that combines conservation goals with production goals and rural development, which is also the cornerstone for successful establishment and sustainable management of biological corridors.

The landscape classification generally begins with a dichotomy that is the distinction between forest and agricultural land uses, followed by supplementary sub-categories. However, from the ecological point of view, the boundaries between these land uses are not straight forward, since they vary from abrupt to gradual, depending on processes and species. Edge effects occur on the boundaries between ecosystems (e.g. between forest-wetlands-agricultural systems) and encompass a change in structural characteristics and environmental conditions, between them.

In terms of conservation biology, these edges represent the barriers between forest and disturbed habitat that, for some forest-dependent species, essentially acts as an impenetrable wall. Some species prefer edges and their impacts on resource distribution, while others find the edge habitats as suitable blend of nesting habitat (forest) and foraging area (agricultural parcels) and is the source of many of the most valuable ecosystem services for agriculture (e.g pollinators and insect predators) (Balvanera et al. 2006). On the other hand the impacts of this forest habitat can be considered from the opposite point of view. In this perspective the forest serves as a barrier to the movement of agricultural pests or agricultural run-off. The last set of effects may play an important role in understanding the functional role of conserved forests within the agricultural landscape. Three such functions will be reviewed:

1) Forests and species of agricultural importance,
2) Forested areas as Buffers, and
3) Forest patches acting as barriers.

It is underlined that the functional interaction between forest and managed portions of the landscape is not limited to these functions. In Central America, the biological corridors provide an example of the maintenance of forest or tree covers for a combination of functions at a landscape level. For the successful implementation of such an approach, additional factors may be as important as the ecological functions. For example, according to Morse et al. (2009), in Costa Rica the implementation of a payment for environmental services (PES) scheme, the legislative framework that forbids forest conversion, and the social and economic situation of the forest owners are considered as important factors influencing the decision to sustain forest on their agricultural lands.

Forests and Species of Agricultural Importance

Main characteristic of agricultural landscapes is the regular and frequent disturbance as a result of the cultivation practices of annual crops, the application of agrochemicals (fertilizers, pesticides etc) and the pruning practices of perennial crops. The frequent disturbances generally favour species with short life span and/or high dispersal rates, traits that we typically associate with agricultural pests (e.g. insects). Agricultural areas, promote the thriving of agricultural pests and on the other hand inhibit the presence of the natural control agents (e.g. Diaz et al. 2005) since the species that prey on these pests are often associated with longer life spans requiring less frequently disturbed habitats. Studies have shown, however, that reducing the distance between the natural or semi-natural habitats of low disturbance, and the agricultural area, increases the capacity of these natural predators to control pest populations. The semi-natural area serves as habitat where the individuals can breed and survive, whereas the agricultural portion serves as a source of food for the pest-predators. Furthermore pollinators seem to exhibit the same tendencies. Ricketts (2004), counted the richness and abundance of bee species along a gradient from within a forest extending 800 m or so into a coffee plantation. The data analysis revealed that bee richness and abundance dropped dramatically 50 m away from the forest. From 11 bee species that were actively pollinating coffee plants the forest edge, to only 2 species 800 m from the forest edge (one of which was responsible for 98% of the bee pollination at this distance). The reliance on a single species for pollination services compromises the resilience of the pollination service to collapse of the bee populations, a scenario that is not unlikely.

Forested areas as Buffers

Taking into account the predicted increase in natural hazards associated with climate change, the functional role of forests as mitigation agents is becoming increasingly important, and thus further research is needed in order to understand how forest elements can be strategically located within landscapes to effectively serve as buffers. Strategic establishment of forests, beyond creating habitat, it can also play an important role as a buffer, inhibiting the movement of waste products to more sensitive areas and ecosystems (e.g. aquatic systems).

The role of riparian buffers has been well demonstrated in watershed of the Mississippi River in United States (Figure 2). Forest strips along rivers can serve to effectively prevent the movement of agrochemicals and sediments into sensitive water bodies The riparian corridors not only has tremendous potential for increasing the movement of forest-dependent species due to their linear nature, but their filtering ability plays a crucial functional role in maintaining or even improving water quality.

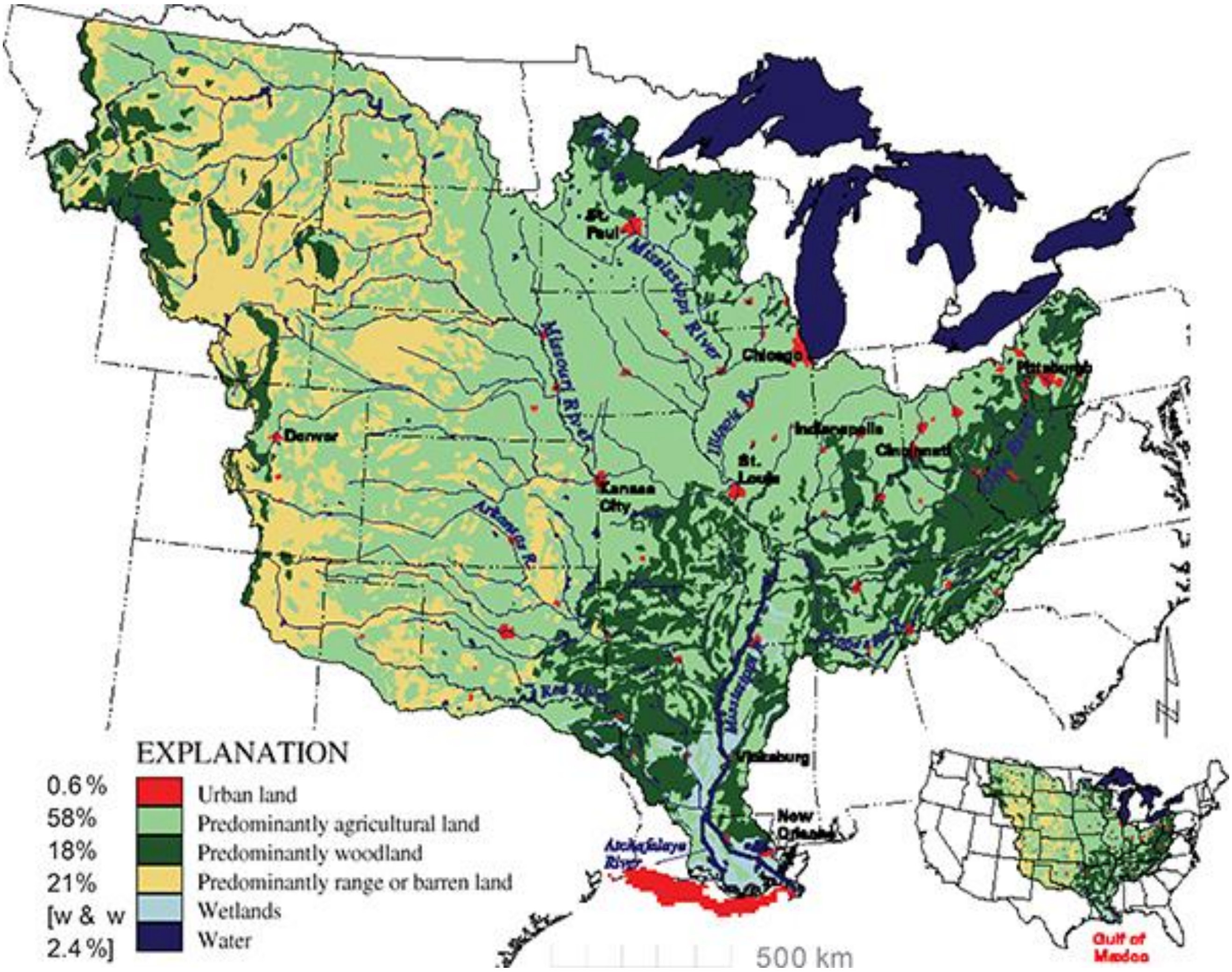


Figure 2. Mississippi River basin, major tributaries, land uses, and typical summertime extent of northern Gulf of Mexico hypoxia (in red)

(Source: National Research Council. 2012. Improving Water Quality in the Mississippi River Basin and Northern Gulf of Mexico: Strategies and Priorities. Washington, DC: The National Academies Press. (https://doi.org/10.17226/13029))

The maintenance of riparian forests is one of the most practical and effective solutions to prevent downstream pollution by agricultural wastes. In the Midwestern US states has been demonstrated that simple 10 m-wide buffers of riparian vegetation can absorb 90% or more of the agricultural run-off before it enters the waterway. In addition the riparian forests are reducing the loss of sediment to erosion, provide corridors for wildlife, and enable recreation opportunities such as hiking, hunting, and fishing (Schultz et al. 2004).

The conservation of forest buffers within the agricultural landscape has impacts that are felt well beyond the boundaries of the area, indeed, extending into adjacent aquatic or marine ecosystems. Kareiva and Marvier (2007) focused on the Mississippi River delta (area devastated by Hurricane Katrina in 2005). The delta area includes a combination of endangered biodiversity, poor communities affected by hurricanes, and low-lying areas with high hazard risk. The mapping of the area permitted a visual overview of priority areas where multiple goals could be met simultaneously. For example, the preservation of natural ecosystems in flood zones adjacent to low-income communities, allow planners to protect endangered biodiversity while protecting human infrastructure and lives.

An additional example may be provided through the Indonesian tsunami (2004). The coastal areas that included forest buffers and mangroves were less affected than areas where such natural barriers had been removed. In terms of forest cover and the damage caused by flooding, Bradshaw et al. (2007) demonstrated that conservation of upstream areas can indeed mitigate the effects of flooding.

Forest Patches acting as Barriers

Spatial heterogeneity of landscapes and their changeability in time must be recognized as fundamental features of a natural situation. Despite natural disturbances, the development of agriculture and man-made processes of land clearing lead to the division of natural, previously large areas of vegetation, like forests, into small discrete patches. Forest are typically considered as corridors, connecting patches on fragmented landscapes and ensuring that species of conservation maintain the ability to move throughout the landscape. Consider for a moment. From the conservation perspective a landscape with 20% forests and 80% agricultural areas, is heavily fragmented and it would be difficult for a forest-dependent species to disperse through the agricultural matrix.

The coffee berry borer (*Hypothenemus hampei*) is the most economically important coffee pest throughout all coffee-producing countries in the world.

(Source: https://www.greenlife.co.ke/coffee-berry-borer/)

However, connectivity is a species-specific phenomenon. From the point of view of an agricultural pest (such as the coffee berry borer) this landscape is not fragmented at all. Studies have shown that the borer considers forest habitat as hostile and for this reason it rarely penetrates more than 10 m into the forest. Thus the increase of forest cover and connectivity in a landscape dominated by agriculture may in some cases effectively decrease the movement of pest species while increasing the movement of species of conservation concern.

Furthermore, mainly in more developed countries, forests have also been used as barriers against pollution and noise. The good understanding of the structural characteristics and interrelationships are critical for the proper functioning of such barriers and the effective selection of their establishment areas.

The inter-patch connectivity can be modified by barrier “filtering” effect. Habitat barriers may act as “filters” which stop some individuals and allow others to pass through, according to their abilities to move. Such “filters” can play an important role in structuring small subpopulations. By “filtering out” different species, habitat barriers can also play an important role in affecting species distribution across fragmented landscapes.

2 EU PERSPECTIVE OF NATURAL CAPITAL AND FOREST ECOSYSTEM SERVICES

The concept of natural capital denotes a rich variety of natural processes, such as forest ecosystems, that produce economically valuable goods and services. Europe's natural capital suffers growing cumulative pressures from intensive and unsustainable agriculture, fisheries and forestry, as well as industrial development and urban sprawl. A substantial volume of relevant EU legislation already exists but lacks adequate integration in sectoral policies. Unsustainable management of natural capital also persists because its full value is not reflected in socio-economic policies and choices despite its fundamental importance for society's welfare. For this purpose sustained efforts are initiated to integrate it into national accounts of EU Member States.

2.1 The Concept of 'Natural Capital'

Natural Capital can be defined as the environmental stock or resources of Earth that provide goods, flows and ecological services required to support life. Natural capital is usually presented as a recent concept, used for the first time in the 1970s, and widely used by ecological economists in the early 1990s. However, the genesis of natural capital as an economic concept, although not in its present-day form, but from its almost unknown, ancient origins in the 1900s–1910s (Missemer 2018). The emergence of the concept of 'natural capital' in recent years reflects a recognition that environmental systems play a fundamental role in determining a country's economic output and social well-being — providing resources and services, and absorbing emissions and wastes. Forest ecosystems and nature in general not only affords human agents passive materials and raw resources to be improved by labor, but endows them with various production processes which generate valuable goods and services in a manner that is detached from human agency (DesRoches 2018).

The nation's wealth is grounded in four core stocks of capital as presented in Figure 3, plus the financial capital. The financial capital plays an important role as a medium of exchange between the four underlying capital stocks and, sometimes, as a source of economic imbalances and instability (World Bank 2006).

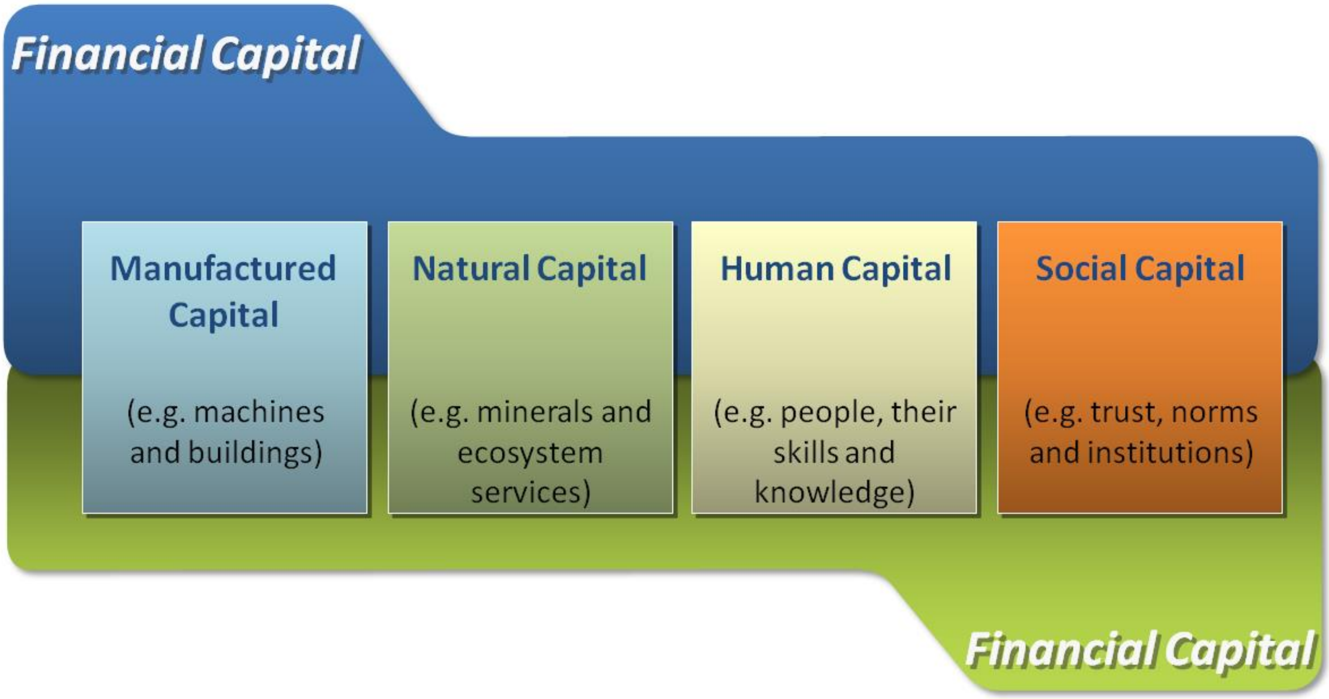


Figure 3. The stocks of Nation's capital

Natural capital is the most fundamental of the forms of capital since it provides the basic conditions for human existence, delivering food, clean water and air, and essential resources. It sets the ecological limits for our socio-economic systems, which require continuous flows of material inputs and ecosystem services (Figure 4). Yet, it is not accounted for in nations' wealth accounting systems.

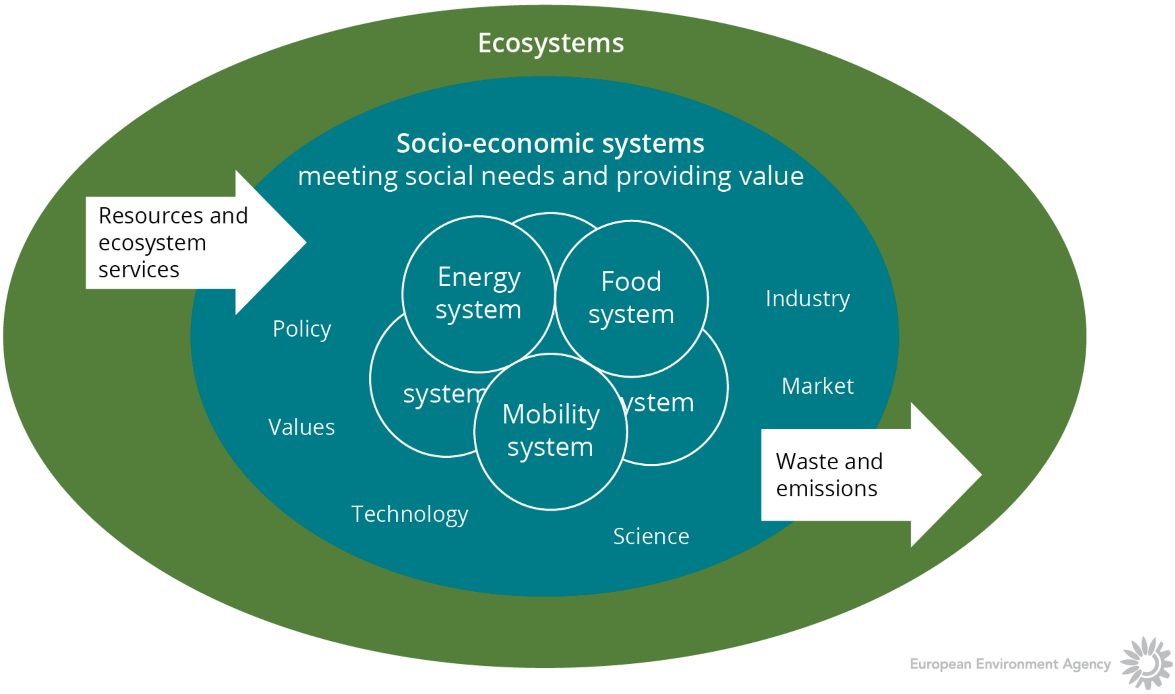
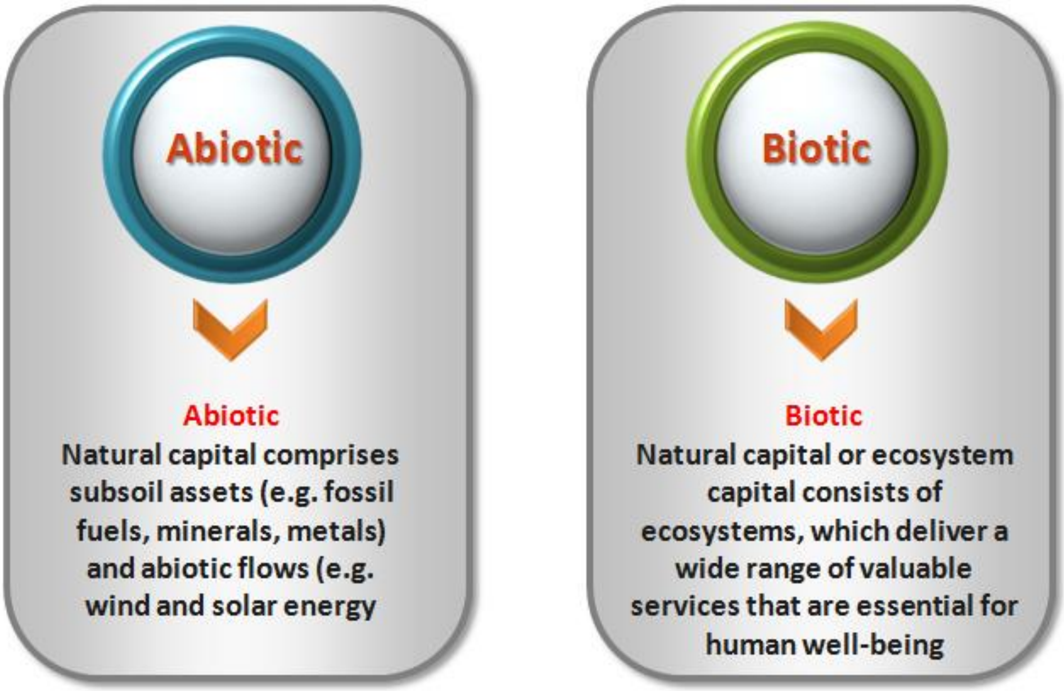


Figure 4. Ecosystems underpin socio-economic systems of production and consumption
(Source: www.eea.europa.eu/soer2015/europe/natural-capital-and-ecosystem-services)

Natural capital comprises two major components:



Ecosystem capital if managed sustainably is normally renewable but on the other hand it can be depleted or degraded in case of mismanaged. In 2013, the Common International

Classification of Ecosystem Services (CICES) has been developed to support environmental accounting (CICES 2013). CICES takes as a starting point the Millennium Ecosystem Assessment classification of ecosystem services (MA 2005) but modifies the approach to reflect more recent research. Furthermore, it does not include supporting services in order to reduce the risk of double-counting of benefits. According to CICES the three main ecosystem service categories include the provisioning services, the regulating and maintenance services and the cultural services.

Replacing natural capital with other forms of capital is often impossible or carries significant risks since natural systems are rather complex and any aspects of natural capital (biodiversity, clean air and water etc) are both limited and vulnerable.

The unsustainable management of natural capital in forested areas can occur in cases when its full value is not reflected in policy trade-offs and economic choices. This problem is reflected at all levels and scales of decision-making, from the macroeconomic (e.g. in excluding environmental values from national accounts and shifting environmental impacts to other countries), up to the microeconomic (e.g. market prices that fail to reflect the full costs and benefits of a product).

The Member States of European Union (EU) and as well as many neighboring countries have introduced a substantial volume of legislation to protect, conserve and restore ecosystems and their services (e.g. Water Framework Directive, Marine Strategy Framework Directive, Air Quality Directive, the Habitats and Birds Directives and the Landscape Convention). A wider range of European policies affect natural capital and ecosystem services including the Common Agricultural Policy, the Common Fisheries Policy, cohesion policy and rural development policies. Furthermore legislative initiatives to tackle climate change, chemicals, industrial emissions and waste also help to ease the pressures on soil, ecosystems, species, and habitats as well as to reduce nutrient releases. Especially in terms of forest, the 2nd European Union Forest Strategy in 2013 responds to new challenges facing both forests and the forest-based sector which highlights the need for a policy framework ensuring coordination and coherence of forest-related policies (Aggestam and Pülzl 2018).

2.2 Key Trends in Ecosystems and their Services

The Assessment of the status and trends of natural capital and in particular of forest ecosystem services is a significant challenge since the scale and diversity of environmental stocks and flows is huge. The EU Biodiversity Strategy to 2020 is an important policy driver of improved knowledge of natural ecosystems and their services. The key actions of this strategy are presented in Figure 5. The vision is by 2050, European Union biodiversity and the ecosystem services it provides – its natural capital – are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human well-being and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided.

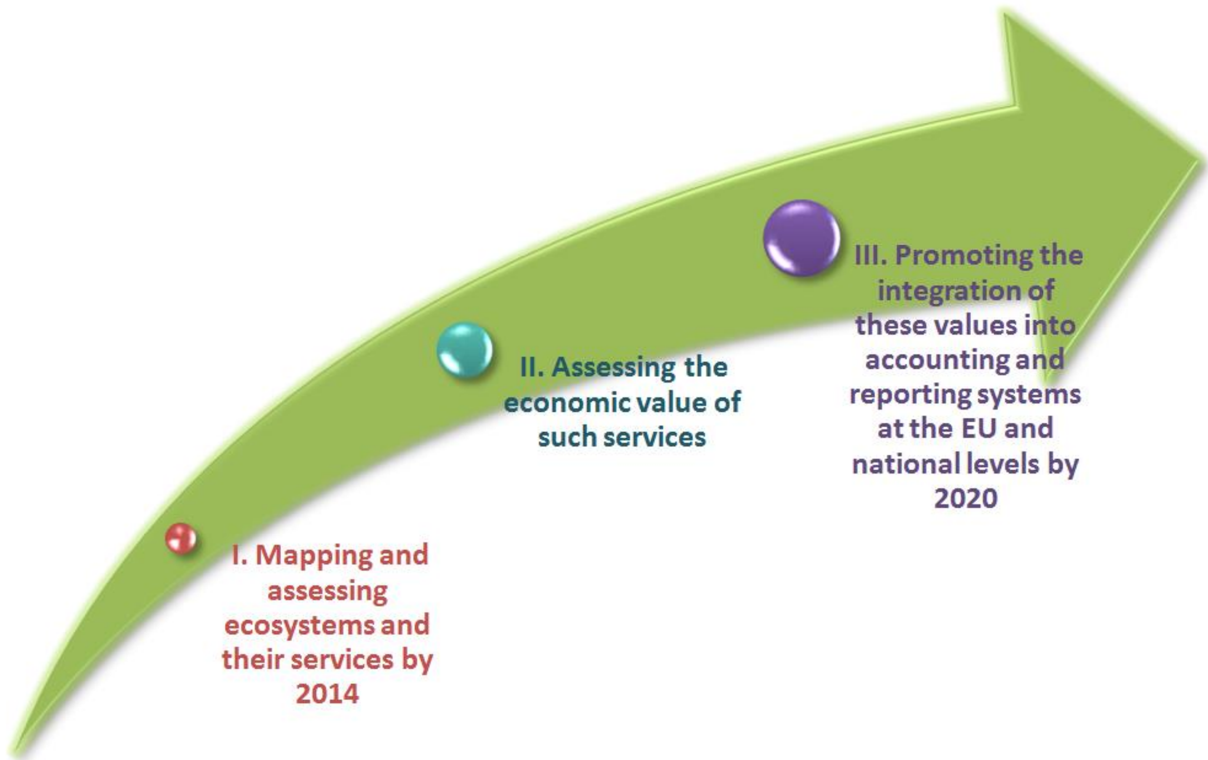


Figure 5. Key actions in EU Biodiversity Strategy to 2020

A comprehensive assessment of the state and trends of Europe's ecosystems and related services has not yet been fully achieved. However significant progress has been achieved. A very important step was the work under the Mapping and Assessment of Ecosystems and their Services (MAES) initiative that will improve the knowledge base on ecosystems and their services across Europe (Figure 6). Information and Key facts (BOX 1) are already available for many ecosystem types and services (Maes et al. 2011, Egoh et al. 2012).

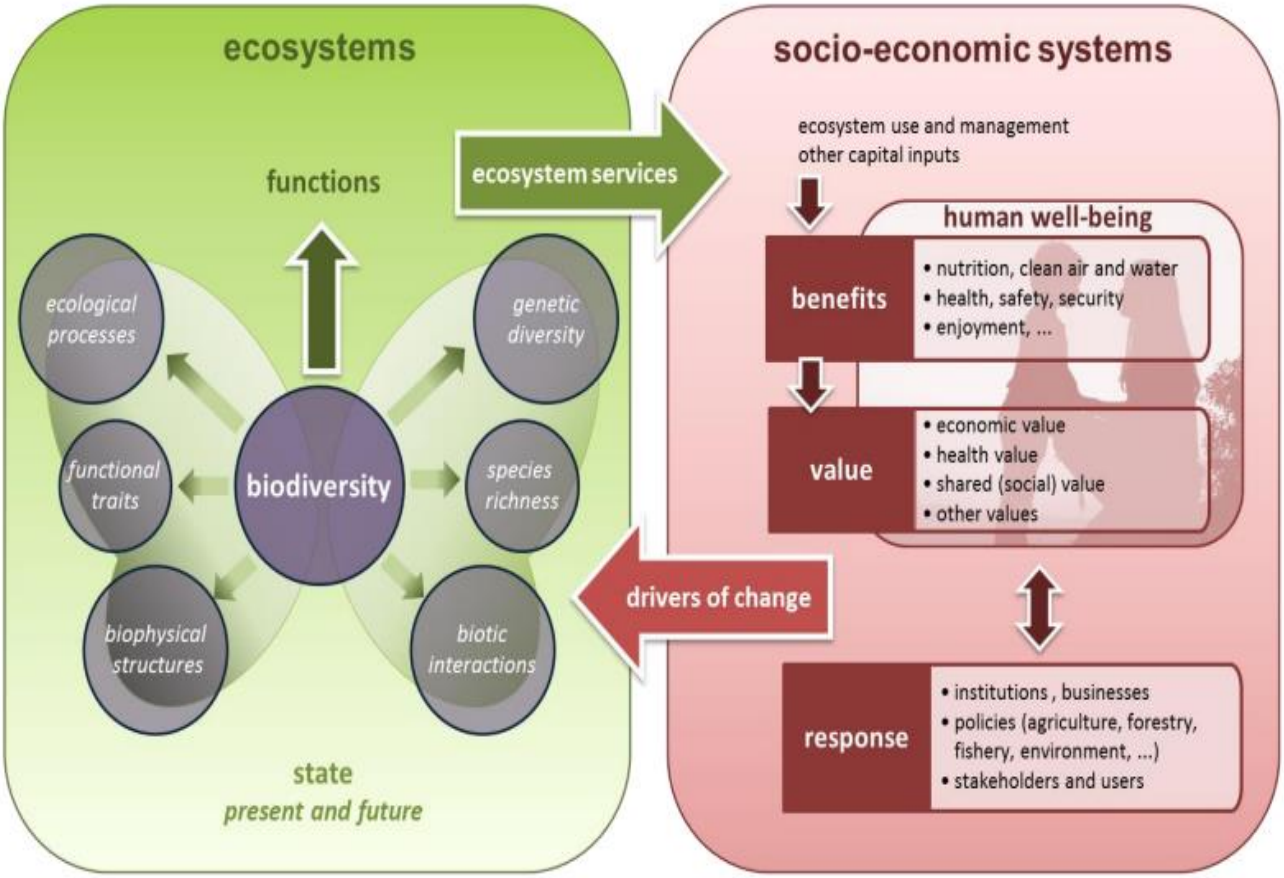
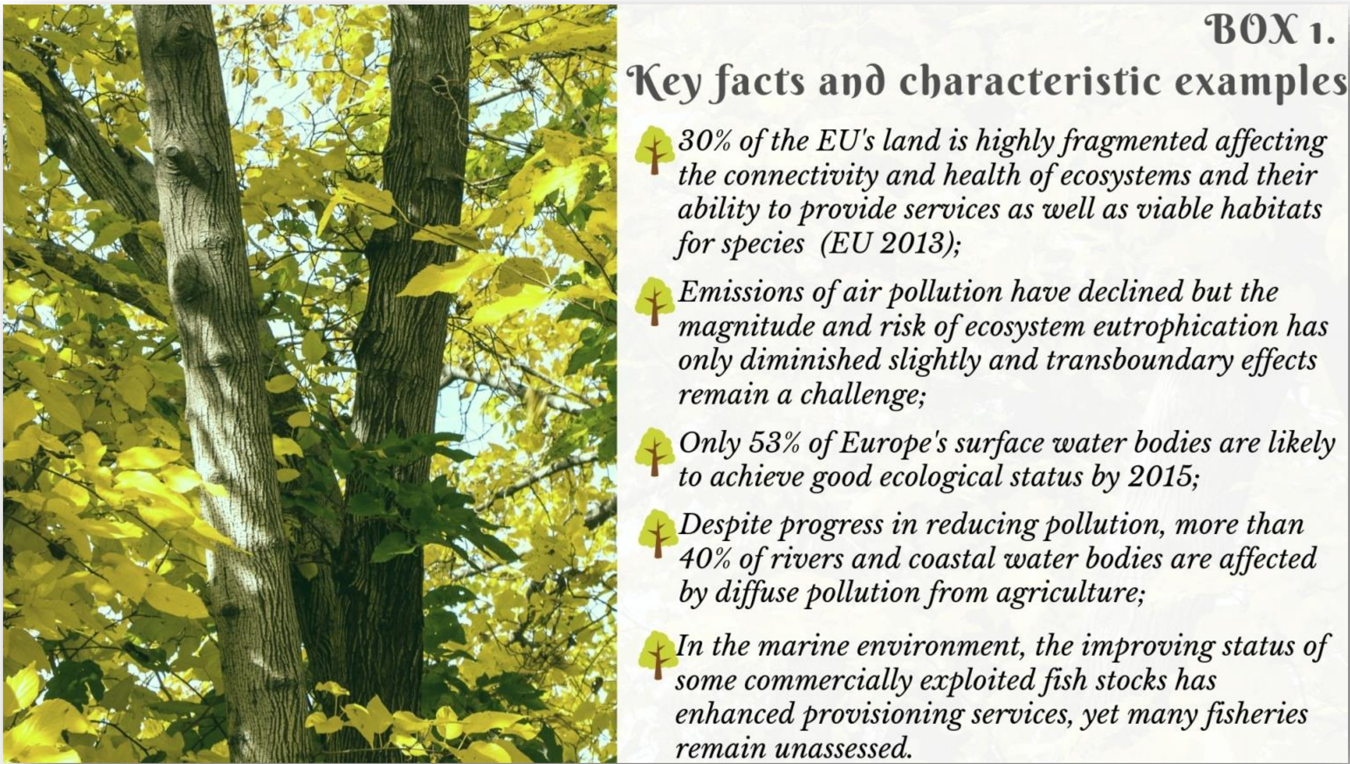


Figure 6. Conceptual framework for ecosystem assessments

(Source: Maes et al., 2013)

Within this framework it is underlined that climate change has already affected ecosystems and their services in Europe (e.g. deterioration of forests, ocean acidification, increasing water temperatures, shifts of biological processes, frequency and intensity of droughts). Ecosystem service flows are mostly projected to decline in response to climate change although this varies by European sub-region.


BOX 1.
Key facts and characteristic examples
30% of the EU's land is highly fragmented affecting the connectivity and health of ecosystems and their ability to provide services as well as viable habitats for species (EU 2013);
Emissions of air pollution have declined but the magnitude and risk of ecosystem eutrophication has only diminished slightly and transboundary effects remain a challenge;
Only 53% of Europe's surface water bodies are likely to achieve good ecological status by 2015;
Despite progress in reducing pollution, more than 40% of rivers and coastal water bodies are affected by diffuse pollution from agriculture;
In the marine environment, the improving status of some commercially exploited fish stocks has enhanced provisioning services, yet many fisheries remain unassessed.

2.3 Integrating Natural Capital and Forest Ecosystem Services into Decision Making

Current development patterns; business practices; exploitation of resources from other countries and government policies are degrading or decreasing stocks of natural capital. This not only has financial implications such as increased market prices due to resource depletion, but also environmental implications as structural forest ecosystem components are damaged and ecosystems are unable to function effectively which in turn, causes flow on effects. For example, as greenhouse gas emissions increase and areas responsible for carbon sequencing such as forests decrease, global temperatures rise, weather patterns change, sea levels increase, terrestrial and aquatic ecosystems re-adjust and land usability patterns change.

Natural income is monetary income derived from natural capital. However, protection and appropriate pricing of forest environmental resources has been largely neglected by economic theories and practices. If economic and societal development is allowed to grow uncheck, stocks of natural capital will continue to decline, resulting in problems for natural life support systems, increased market prices and a decrease in the quality of human life.

Not all forest services or products provided by natural capital can be replaced by technology and some alternatives are either expensive or inefficient. Problems related to the protection of natural capital include the inability of economics to appropriately model and price both market and non-market environmental resources; lack of willingness to pay; lack of knowledge about minimum levels or time spans required for resources to replenish or renew; lack of knowledge regarding the interaction and dependences between resources and their true value, usefulness or necessity; poor management of trans-boundary resources; and inequalities between developed and developing nations. The Natural Capital accounting in forested areas can be considered as a tool for:

- Measuring the changes in the stock of natural capital at a variety of scales.
- Integrating the value of forest ecosystem services into accounting and reporting systems at Union and national level.
- Managing sustainably the Union's natural capital.

This will aim to provide a multi-purpose tool that can be used decision making for a range of policies, at different stages of the policy cycle, and that national authorities and research centres can access. It can enable to explicitly account for the range of ecosystems and their services and demonstrate in monetary terms the benefits of investing in nature and the sustainable management of resources.

The UN System of Environmental Economic Accounting (SEEA) provides an international framework for developing integrated physical and monetary environmental-economic accounts. Within this context, the EU Regulation on European environmental-economic accounts provides a legal basis for harmonised collection of comparable data from countries (TEEB 2010). The Regulation was amended in 2014 and accounting modules now include both physical accounts (addressing air emissions, material flows and physical energy flows) and monetary accounts (addressing environmental taxes, environmental protection expenditure and environmental goods and services sectors). Natural capital accounting, enables ecosystem assets (i.e. the 'stocks') as well as the services (i.e. the 'flows') to be defined in relation to one another as well as to other economic, social or environmental information. . For example, a forest ecosystem (the asset), by way of its trees (the stock) helps provide fresh air and can help defend against flooding, as well as being a source of timber (the services). As long as a forest is sustainably maintained, the supply of fresh air, flood defences and the stock of timber can remain consistent, and the 'balance sheet' remains healthy. If the forest is over-harvested, the 'debits' cover not only loss of the forest itself but all of the other services that the ecosystem provides (Figure 7).

Within this context the EEA is developing Ecosystem Capital Accounts, which are foreseen as the approach to delivering forest ecosystem accounts for Europe. They record changes in the extent and condition of ecosystems and some of the services they provide, as indicated by physical land, biomass carbon and water accounts.

In terms of monetary valuation of ecosystem services and the underlying natural capital stocks, a diverse mixture of techniques exists for estimating values. Approaches are also available to enable values generated in one location to be applied elsewhere or at broader scales (EEA 2010). While there are many uncertainties and difficulties in applying these valuation methods, they can offer insights and play a role in communicating the value of forest ecosystems and in designing environmental policy and tools. The first priority objective of the 7th Environment Action Programme (7th EAP) is to protect, conserve and enhance the Union's natural capital. The 7th EAP highlights the need to integrate economic indicators with environmental and social indicators, including by means of natural capital accounting. The mid-term review of the EU biodiversity strategy adopted on 2 October 2015 also stresses that reaching 2020 objectives will require considering suitable approaches for protecting and enhancing our natural capital throughout the EU.

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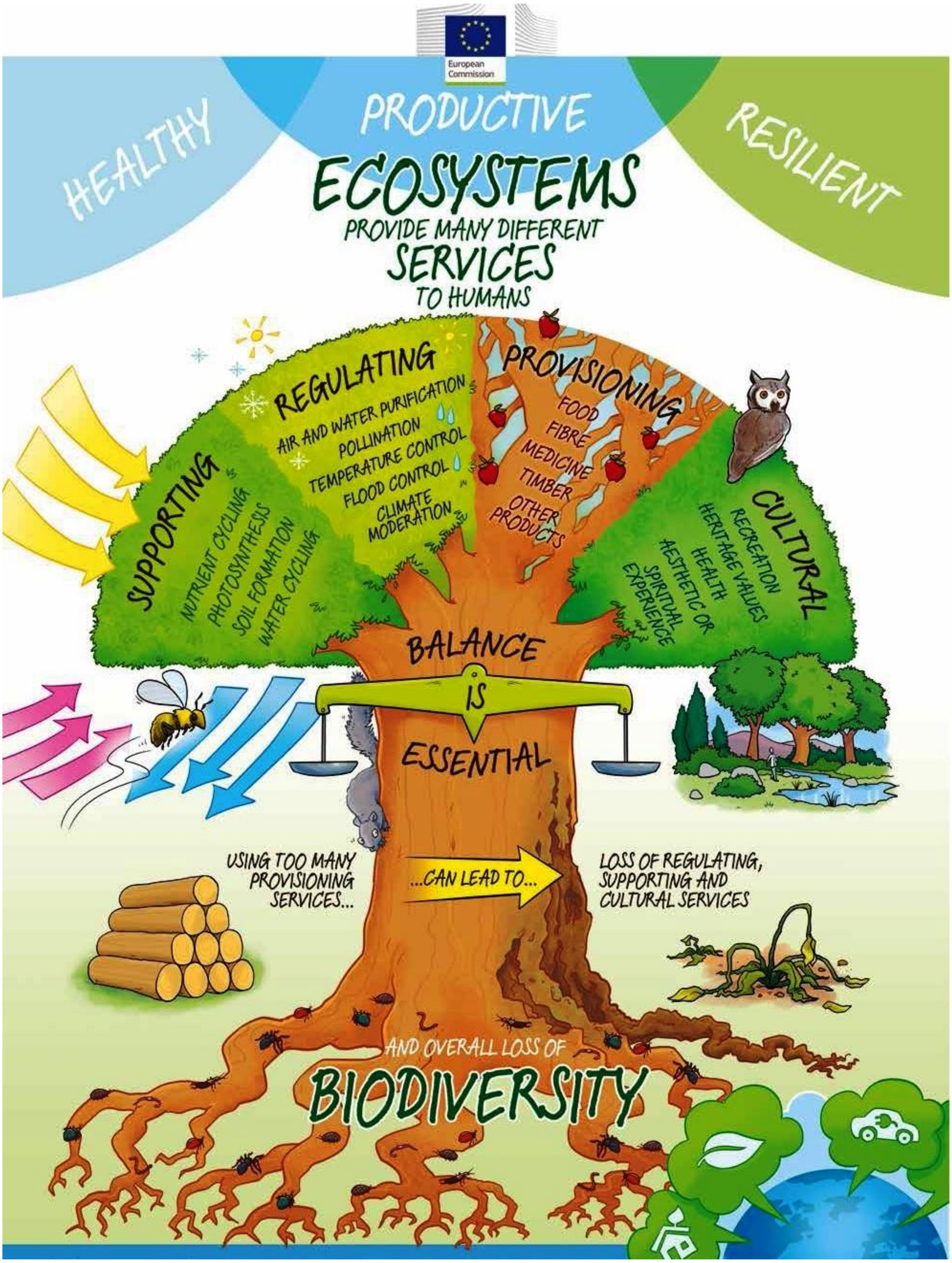

Figure 7. Balancing forest ecosystem assets and services

(Source: Science for Environment Policy (2017) Taking stock: progress in natural capital accounting. In-depth Report 16 produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy)

3 DIRECT AND INDIRECT DRIVERS: IDENTIFICATION AND CLASSIFICATION FRAMEWORK

According to the MA as driver can be considered any natural or human-induced factor that directly or indirectly causes a change in an ecosystem (Carpenter et al. 2006). Changes in forest ecosystem services are usually caused by multiple interacting drivers. These drivers may work over time (e.g., population and economic growth interacting with technological advances leading to climate change), or over levels of organization, e.g., from local laws to international treaties; they can also happen intermittently, e.g., economic crises and wars. Each change that takes place in an ecosystem is the result of several interactions among drivers. Drivers interact across spatial, temporal, and organizational scales (Figure 8). Synergetic factor combinations are the most common, i.e., the combined effects of multiple drivers that are amplified by reciprocal action and feedbacks (Geist and Lambin 2002, 2004).

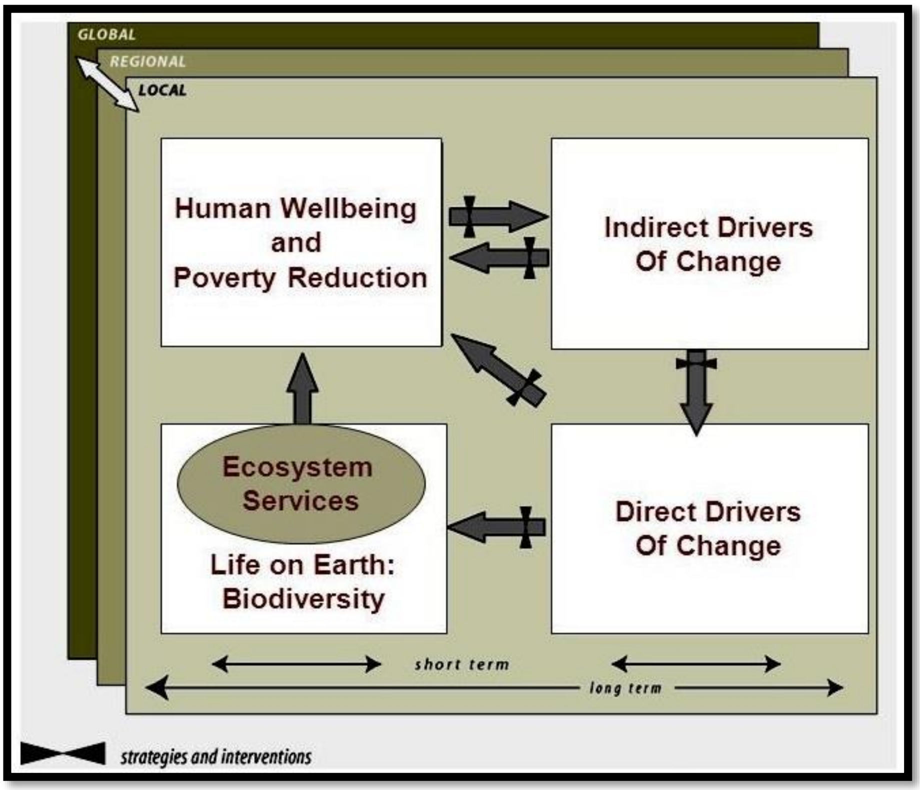

Figure 8. Multilevel interactions of drivers of change on ecosystems and human wellbeing

(Source: Millennium Ecosystem Assessment)

Global trends as for example the climate change or the globalization, may influence regional contexts of forest ecosystem management at local level. But although some drivers are global, each set of interactions is more or less specific to a particular place. For example, although there is an evident link between increasing producer prices and production growth throughout the world, the strength of this effect, however, is depends on site-specific factors such as production conditions, availability of resources and knowledge, and economic status of the farmers (Jones 2002). Thus no single conceptual framework exists that captures the broad range of case study evidence (Lambin et al. 2001). On the other hand the changes in ecosystem services feed back to the drivers of change. Modified ecosystems create new constraints and opportunities on land use, induce institutional changes in response to anticipated and perceived resource shortages and degradation, and give rise to social effects including changes in income inequality since there are winners and losers in every environmental change.

Based on Hauck at al. (2015), the main focus is given on anthropogenic drivers without discussing interactions among them. The main categories include Indirect and Direct drives as discussed in the following sections. A direct driver unequivocally influences forest ecosystem processes. On the other hand indirect drivers operate more diffusely since they alter one or more direct drivers. The main categories of global driving forces are sociopolitical, demographic, economic, scientific-technological, cultural-religious as well as physical and biological. Drivers in all categories other than physical and biological are considered indirect. Important direct, i.e. physical and biological, drivers include changes in climate, land conversion, plant nutrient use, invasive species and diseases.

3.1 Indirect Drivers

3.1.1 Demographic

Identifying the demographic parameters that influence population dynamics may increase conservation effectiveness and enhance ecological understanding. Global population increased by 2 x 10^9 during the last quarter of the 20th century, reaching 6 x 10^9 in 2000. At that time, birth rates fell far more quickly than anticipated, and life expectancies improved steadily. At the beginning of the 21st century, population growth rates were declining nearly everywhere. Despite the declining growth rate, the future global population, as presented in Figure 9, is likely to increase by another 3 x 10^9 by 2050 (Lutz et al. 2001). Recent decades of rapid demographic change have produced unprecedented demographic diversity across regions and countries (Cohen 2003). It is underlined that growth has slowed or even stopped in Europe and East Asia, and rapid aging has become a serious concern (Lutz et al. 2003).

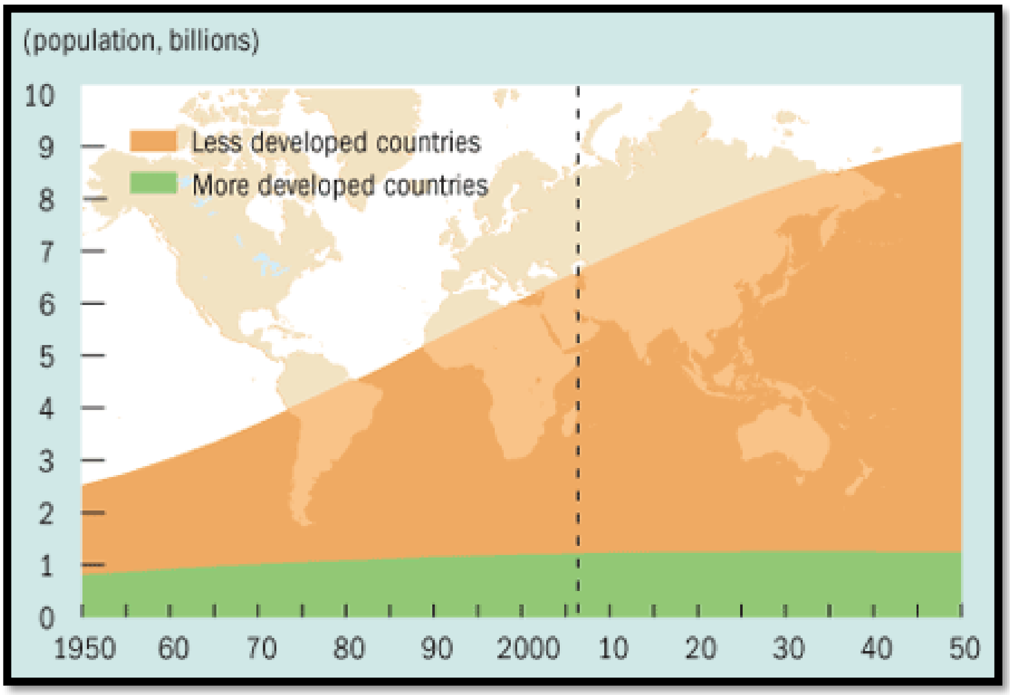

Figure 9. Expected population growth by 2050
(Source: International Monetary Fund (http://www.imf.org))

Today, certain regions are distinguished by their degree of urbanization. Typically, high-income countries have urban populations around 70–80%. Some developing regions, for example in Asia, are still largely rural, while in Latin America, at 75% urban, is indistinguishable from high-income countries in this regard. However the diversity of current conditions means that future demographic change will be highly variable as well. Current age structures are a key determinant of population growth over the next few decades, because of the “momentum” inherent in young populations. In some developing countries, over the next several decades, the population growth is expected to be concentrated in low-income urban communities. However, in a few important developing countries, as China for example, the population growth will cease because of rapid aging of the population and sharp declines in fertility.

The concept of demographic transition is a generalization of the events observed over the past two centuries in those countries with the highest incomes today. These countries shifted from small, slowly growing populations with high mortality and high fertility to large, slowly growing populations with low mortality and low fertility (Knodel and Walle 1979, Lee 2003). Demographic transition has occurred in parallel with social and economic development in the world's most developed countries. Most population projections assume it will occur in many currently developing nations (Figure 10).

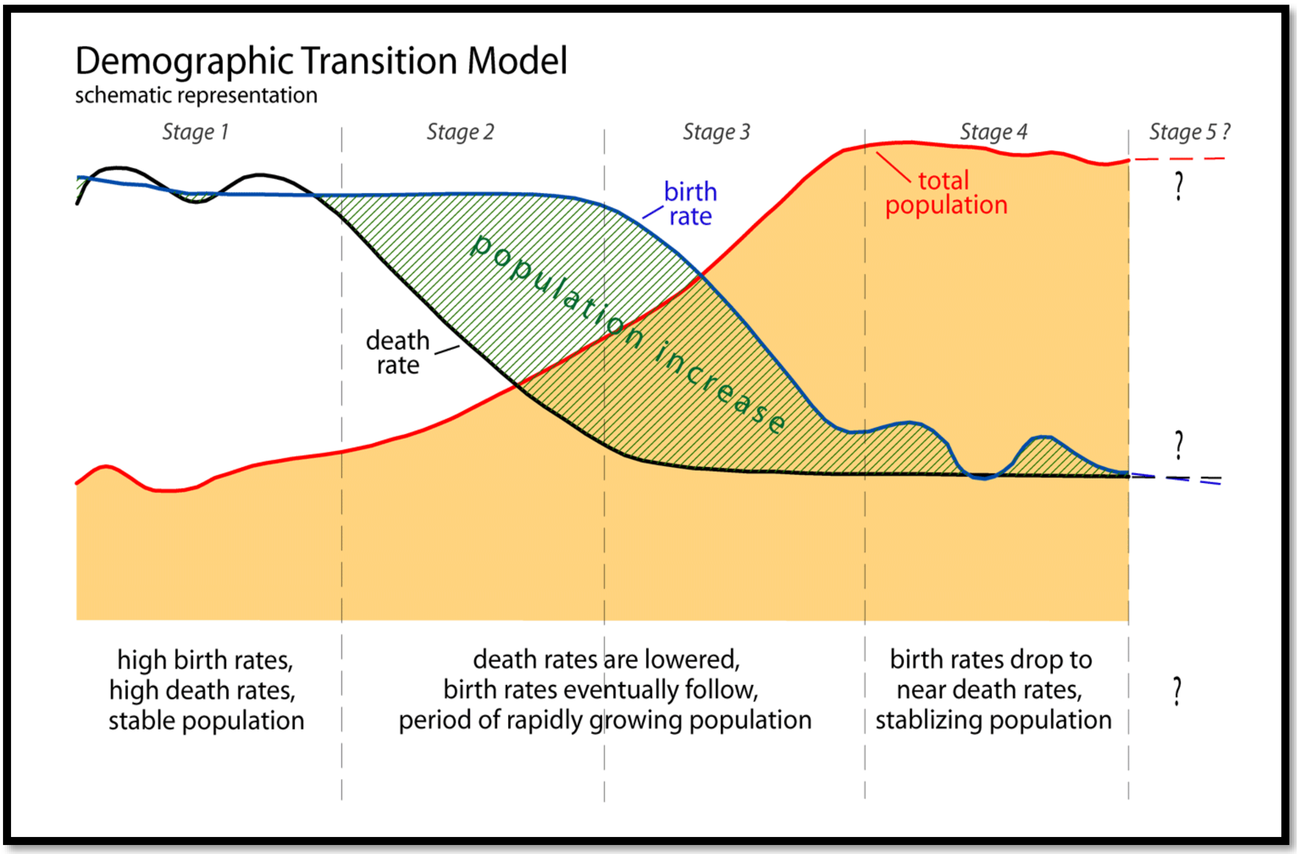

Figure 10. Schematic representation of demographic transition model
(Source: UNEP-GRID Sioux Falls – generalized from multiple sources)

Furthermore, current and future international migration is more difficult to identify and project than fertility or mortality trends. Migration flows often reflect short-term changes in economic, social, or political factors that are difficult to predict. In addition to the above a wide range of factors are affecting the global demographic trends (Figure 11) which in most cases are rather complex and difficult to predict their interactions and long term impacts.

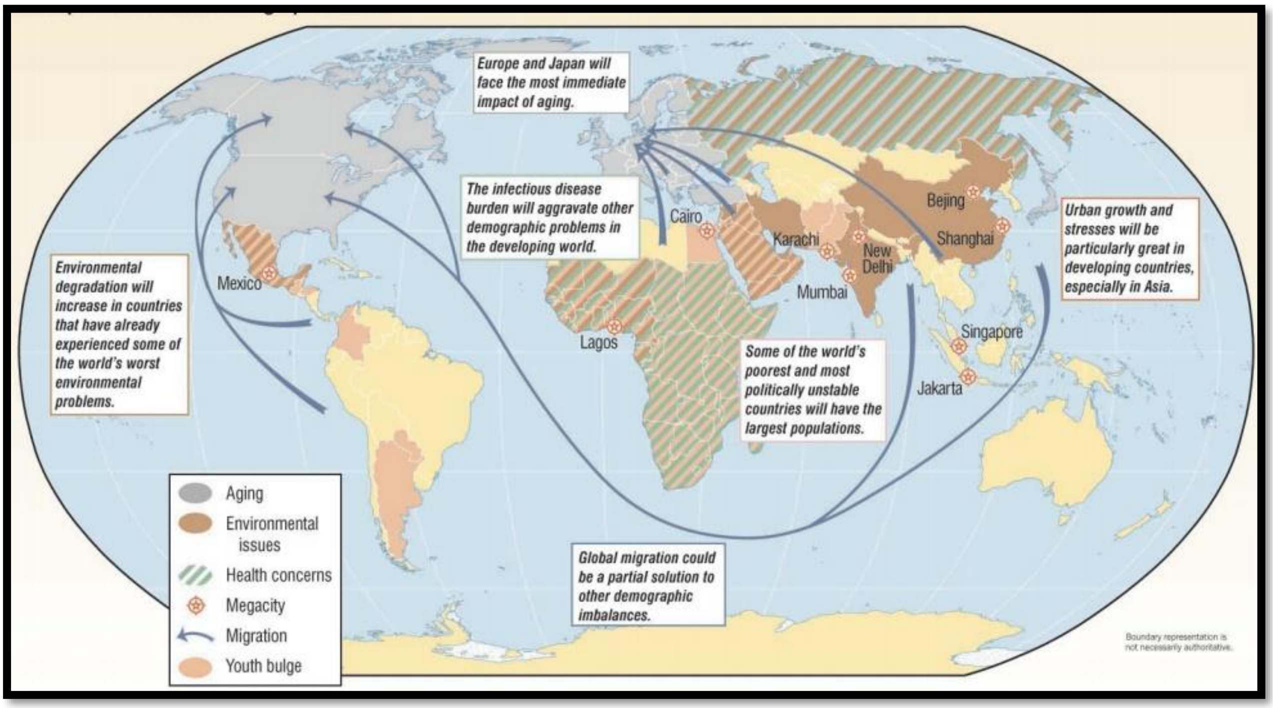

Figure 11. Snapshot of global demographic trends
(Source: https://bulldogclassic.com)

3.1.2 Economic

The links between the economy and the environment are manifold: the environment provides resources to the economy, while acting as a sink for emissions and waste. Natural resources are essential inputs for production and consumption which in turn also lead to pollution and other pressures on the environment (Figure 12). Economic activity is a consequence of humans striving to improve their well-being. The outputs of this activity are determined by natural resource endowments, including forest ecosystem services (natural capital), the number and skills of humans, the stock of built resources, and the nature of human institutions (formal and informal). In addition to the intended outputs, economic activity can also have side effects, called externalities, with usually negative consequences for ecosystems. In this context, environmental policies can curb the negative feedbacks from the economy on the environment (and vice-versa).

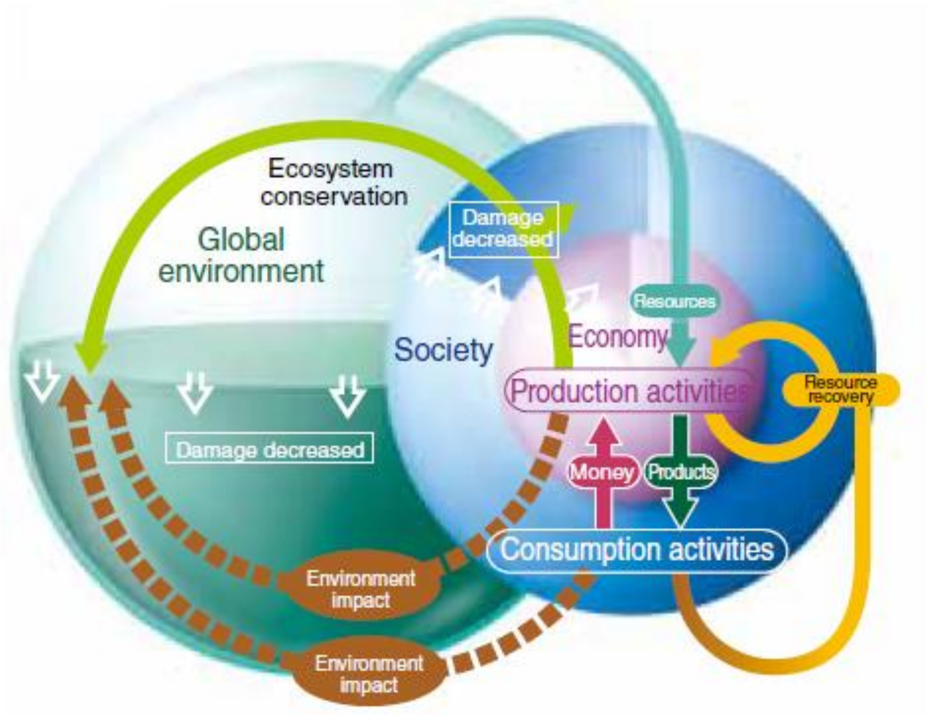

Figure 12. Interactions of economy and environment
(Source: https://www.ricoh.com/environment/management/earth.html)

Human well-being is clearly affected by economic distribution and growth. The level of income received determines the level and nature of consumption. As per capita income grows, the nature of consumption shifts from basic needs to goods and services that improve life quality. This transformation of consumption patterns is a consequence of two related facets of human behavior: the limit to the quantity of food one human can consume and the desire for diversity. As a consequence, with income growth industry's share of output rises initially but then falls while the share of services in economic output rises continuously. In 2000, agriculture accounted for 5% of the world gross domestic product (GDP), industry for 31%, and service industries for 64% (Rosen 2002). The past two centuries has been observed a shift in economic structure from agricultural production to industry and to services for the world's largest economies. In developing regions, the decline in agriculture's share has been accelerated in recent years, and the growth in services' share has been much faster than was the case historically in the now-rich countries.

The effects of economic activity on forest and other natural ecosystems depend on a number of factors, including the location of that activity, resource endowments and ecosystem condition, available technologies, policies, and market reach. According to Maddison (2003) since 1820, the global GDP has increased by a factor of 40, or at a rate of about 2.2%/yr. Between 1950 and 2000, the world GDP grew by 3.85%, resulting in an average per capita income growth rate of 2.09% for that period. In the late 20th century, income was distributed unevenly both within countries and around the world. In Figure 13 the contribution to global growth is presented. Although the level of per capita income was highest in Western Europe, North America, Northeast Asia, and Australasia, growth rates were highest in South Asia, China, and parts of South America. If these trends continue, the within-country disparities might increase but global income disparities will be reduced.

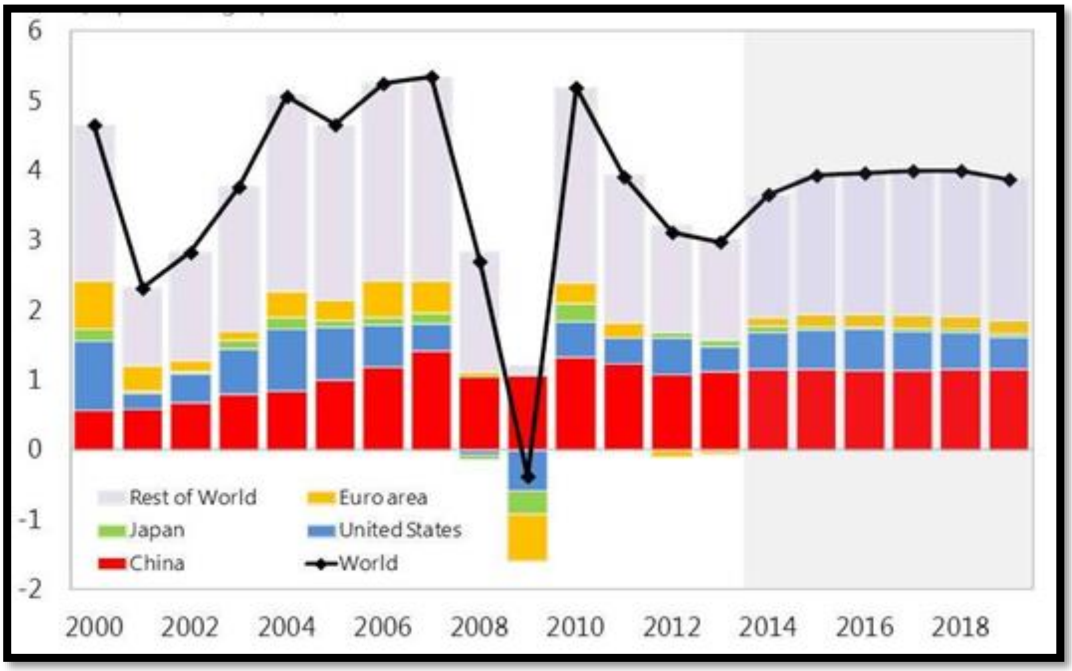

Figure 13. Contribution to global growth (in percentage points)
(Source: International Monetary Fund (https://blogs.imf.org))

Economic growth and development depend on the increasing availability and mobility of resources, the efficiency with which they are used, and the institutional and policy environment. Growth in international trade flows has exceeded growth in global production for several years. In 2001, the growth of trade in manufactured goods has been much more rapid than that of trade in agricultural or mining products, while the international trade in goods was equal to 40% of the gross world product (World Bank 2003). Figure 14 presents a map of the interregional net trade flows of wood raw materials. Intra-regional trade flows are not counted here (i.e. trade between European Union countries). As most often there exists some cross-haulage of the same commodity between two large regions, this is eliminated as well. This means that if there are exports from USA to Europe, and from Europe to USA as well, the smaller flow is deducted from the larger one. The remaining flow represents the inter-regional net trade volume.

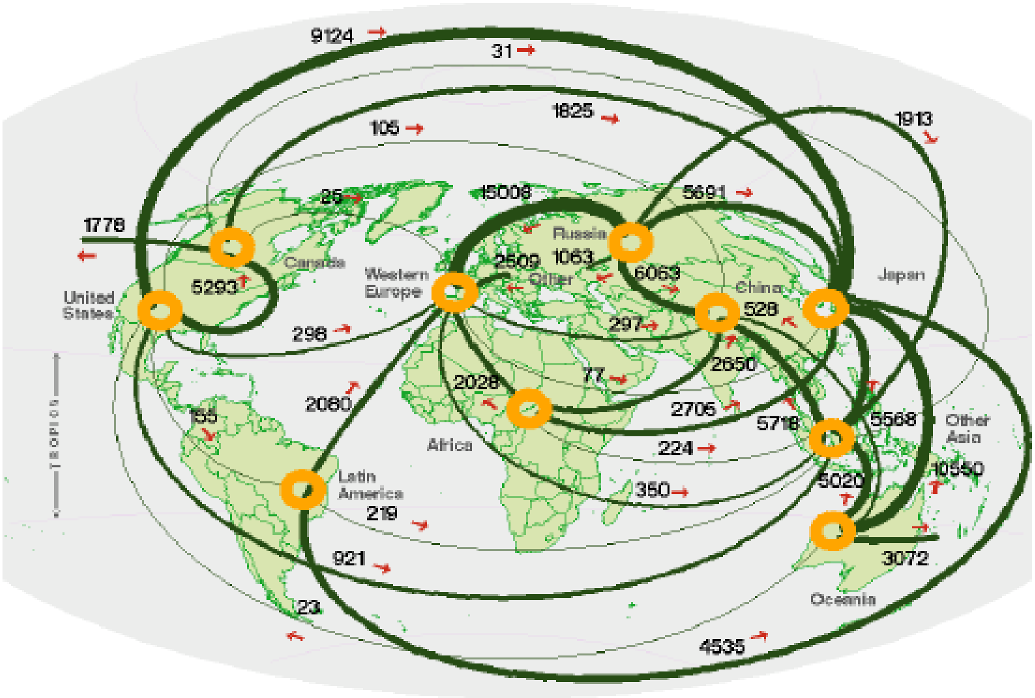

Figure 14. Main net trade flows of wood raw materials in 2000 (in 1000 cum)
(Source: FAOSTAT Trade Flow Data)

International capital flows are crucial to economic growth since they relieve resource constraints and usually facilitate technology transfers that enhance the productivity of available resources. The late 20th-century trend toward more open economies led to greater uniformity in macroeconomic monetary, fiscal, and exchange rate policies across the world and made it easier to move capital across national borders. However, not all developing countries participated equally. For instance, according to World Bank (2002), the vast majority of private-sector capital flows are concentrated in the 10 largest developing countries.

Furthermore, economy activity requires energy and physical inputs, some of which are ecosystem services, to produce goods and services. The rate of conversion of inputs to economically valuable outputs is a determining factor of the impact on ecosystems. With more efficient conversion, fewer inputs are needed, and the potential for by-product effects on ecosystems per unit of economic output is reduced. Low historical rates of energy intensity improvement are representative of the low priority placed on energy efficiency by most producers and users of technology mainly because energy costs have only about a 5% share of the GDP. OECD countries spend some \$82 x 10^9 each year subsidizing energy production, basically through cheap provision of public infrastructure and services, tax breaks, price support and subsidized capital, (OECD 1997). Annual global energy subsidies currently total \$200 x 10^9 (Moor 2002). Globally, more than 80% of these subsidies are for the use of fossil fuels, which are considered as the most polluting energy sources. Besides the fossil energy sources, great breakthroughs have been made in some key technologies and the increasing demand for ecological environmental protection both impel the third time of transformation from oil & gas to new energy sources. Sooner or later, oil, gas, coal and new energy sources will each account for a 25% of global energy consumption in the years to come (Figure 15).

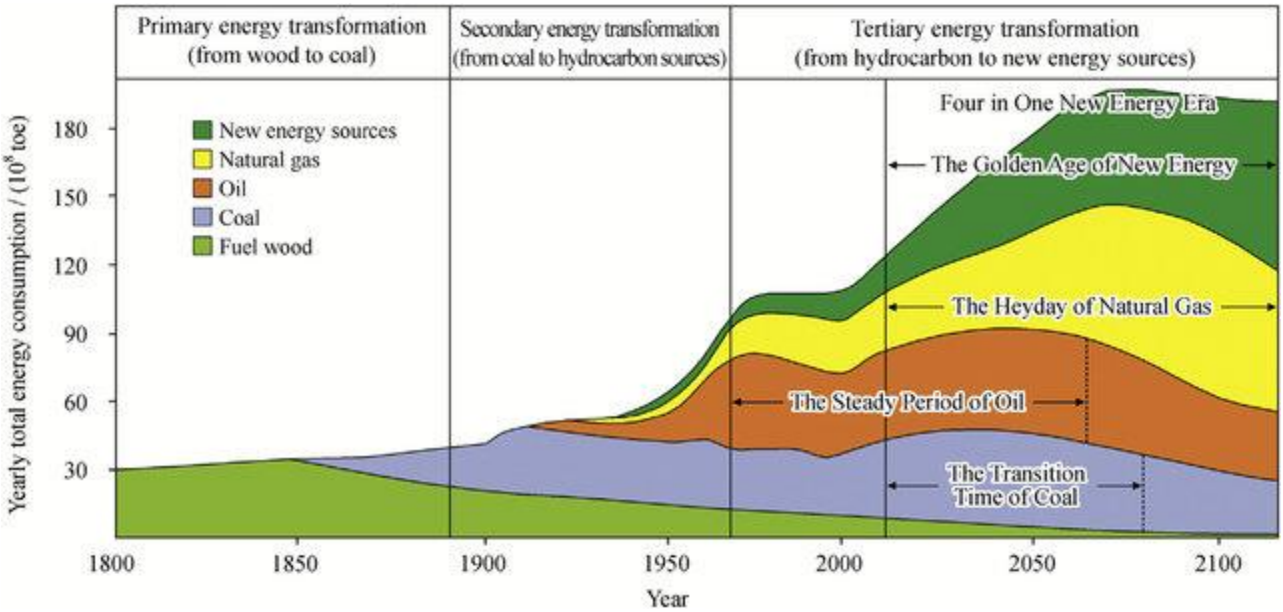

Figure 15. Trends and forecasts of global energy consumption

(Source: Zou, Caineng & Zhao, Qun & Zhang, Guosheng & Xiong, Bo. 2016. Energy revolution: From a fossil energy era to a new energy era. Natural Gas Industry B. 3. 10.1016/j.ngib.2016.02.001)

Government policies may distort market outcomes by reducing or increasing prices and changing consumption and production levels. Unfortunately, the consequences for ecosystems are neither straightforward nor uniform. By some estimates, distortions in agricultural markets are the largest. Total support to agriculture in OECD countries from market-altering government policies averaged more than \$324 x 10^9 annually in 2001–2003. About 75% of this amount was used to support farm income directly, whereas the remainder went into general infrastructure improvements, marketing, research, and so on (OECD 2004).

3.1.3 Sociopolitical

Sociopolitical drivers encompass the forces influencing decision-making and include the quantity of public participation in decision-making, the groups participating in public decision-making, the mechanisms of dispute resolution, the role of the state relative to the private sector, and levels of education and knowledge Sociopolitical drivers may be some of the most fundamental elements of how humans influence the environment. The boundaries among economic, sociopolitical, and cultural categories of drivers are fluid, and they change with time, level of analysis, and observer (Young 2002).

Sociopolitical driving forces have been important in past environmental change (Vries and Goudsblom 2002). One important element of sociopolitical drivers, i.e., human conflicts, acts both as a direct and an indirect driver of change in ecosystem services and human well-being when nature becomes the recipient of “collateral damage.” War-driven environmental degradation can initiate social degradation and protracted cycles of social and environmental decline by creating poverty, overexploitation of marginal resources, underdevelopment, and, in extreme cases, famine and social destruction (Berhe 2000).

The public involvement in environmental assessment and decision making at the local and regional levels generally leads to more sustainable approaches to managing resources (Beierle and Cayford 2002, Dietz et al. 2003). Public participation in environmental decision-making has become an indelible feature of many environmental regulatory systems worldwide over the past few decades. Over the past 50 years there have been significant changes in sociopolitical drivers. There is a declining trend in centralized authoritarian governments and a rise in elected democracies. The role of women is changing in many countries, average levels of formal education are increasing, and there has been a rise in civil society (such as increased involvement of NGOs and grassroots organizations in decision-making processes). Individuals and organizations affected by development approvals, environmental licensing, land use planning and other regulatory processes, have increasingly demanded greater consultation, and more transparent and accountable decisions.

3.1.4 Cultural and religious

Cultural and religious drivers of forest ecosystem change are related to the values, beliefs, and norms that a group of people share affects its perception of the world and decision making about the environment. The word “culture” has many definitions in both the social sciences and ordinary language. In this sense, influences what he or she considers important, and suggests courses of action that are appropriate and inappropriate. Cultural factors, for example, can influence consumption behavior (what and how much people consume) and values related to environmental stewardship, and they may be particularly important drivers of environmental change. However, broad comparisons of whole cultures have not proved useful because they ignore vast internal variations in values, beliefs, and norms. In many circumstances, changing values, beliefs, and norms will have no effect on behavior because individuals face structural constraints to pro-environmental behavior. For example, public education about the problems of using tropical hardwoods will have little impact if people have no way of knowing the origins of the lumber they purchase.

A tradition stretching from Kluckholm (1952) through Rokeach (1968, 1973) to Schwartz (1992) has provided theoretical and empirical arguments to support the idea that values, i.e., the things that people consider important in their lives, are important in shaping behavior and are relatively stable over the life course. In this perspective only when people have achieved a reasonable degree of material security can they assign priority to issues such as the environment. However, there is considerable controversy regarding the empirical support for this argument (Stern et al. 1999, York et al. 2003).

In any case cultural drivers, as aspects of society ranging from knowledge to attitudes and consumption choices, can impact on ecosystems through their links to other drivers such as market forces and legislation.

3.1.5 Scientific and technological

Advances in science and technology result in a greater understanding of how the world functions, and in the development of new products. These advances can interact with other indirect drivers to influence the rise and fall of economic markets, affect the cultural and religious values of society, or lead to changes in demographics.

Debates on how best to promote sustainable and inclusive development are incomplete without a full consideration of issues of science, technology and innovation. Science, technology, and innovation have historically had an immense impact on "solving" the challenges that come with increased modernity and consumption. As globalization "scales up" today's development challenges and official development assistance (ODA) dollars continue to fall, donor governments need to better identify, finance, and scale up science and technology-based approaches to meet these challenges.

The use of the ''Number of scientific and technical journal articles (per billion PPP$ GDP)'' as an indicator provides a good overview of the research efforts throughout the world (Figure 16).

Despite significant investment in innovation inputs, some economies do not generate a corresponding level of innovation outputs and most economies have a linear relationship between innovation inputs and outputs. In this perspective however it has to be mentioned that an alternative frequent policy ambition is to achieve innovation inputs and outputs of high quality. Rather than targeting quantity in terms of university spending, publications, or patents, the focus is on top-ranked universities, much-cited publications, or patents that go international.

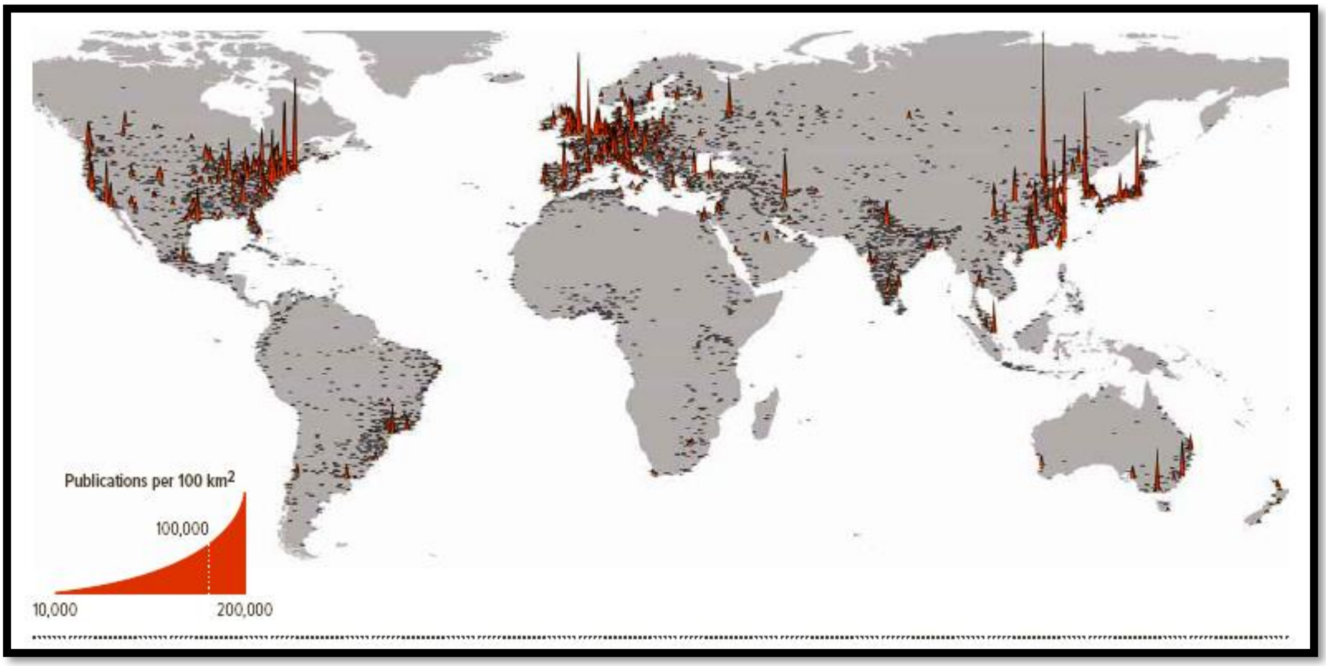

Figure 16. SCIE publication density per 100 square kilometers
SCIE: Scientific and technical publications based on Clarivate Analytics, special tabulations from Thomson Reuters, Web of Science, Science Citation Index and Social Sciences Citation Index (SSCI).
(Source: WIPO IP Statistics Database, March 2018)

The Global Innovation Index (GII) provides a key tool of detailed metrics for 126 economies this year, representing 90.8% of the world's population and 96.3% of the world's GDP (in current US dollars). A look at the 2018 league table of the Global Innovation Index (Figure 17) confirms the surprising presence of a number of countries with small populations, small geographic sizes, or relatively small economies as defined by gross domestic product (GDP). Among the GII top 20, one can find, for example, the Netherlands, the Nordic EU countries, Singapore, Israel, and Luxembourg—in spite of the fact that large economies such as the U.S., Germany, and now China are also part of this top-ranked group. These examples illustrate that, throughout the world there are significant opportunities for successful business, investment, and development, particularly in the science and technology sectors.

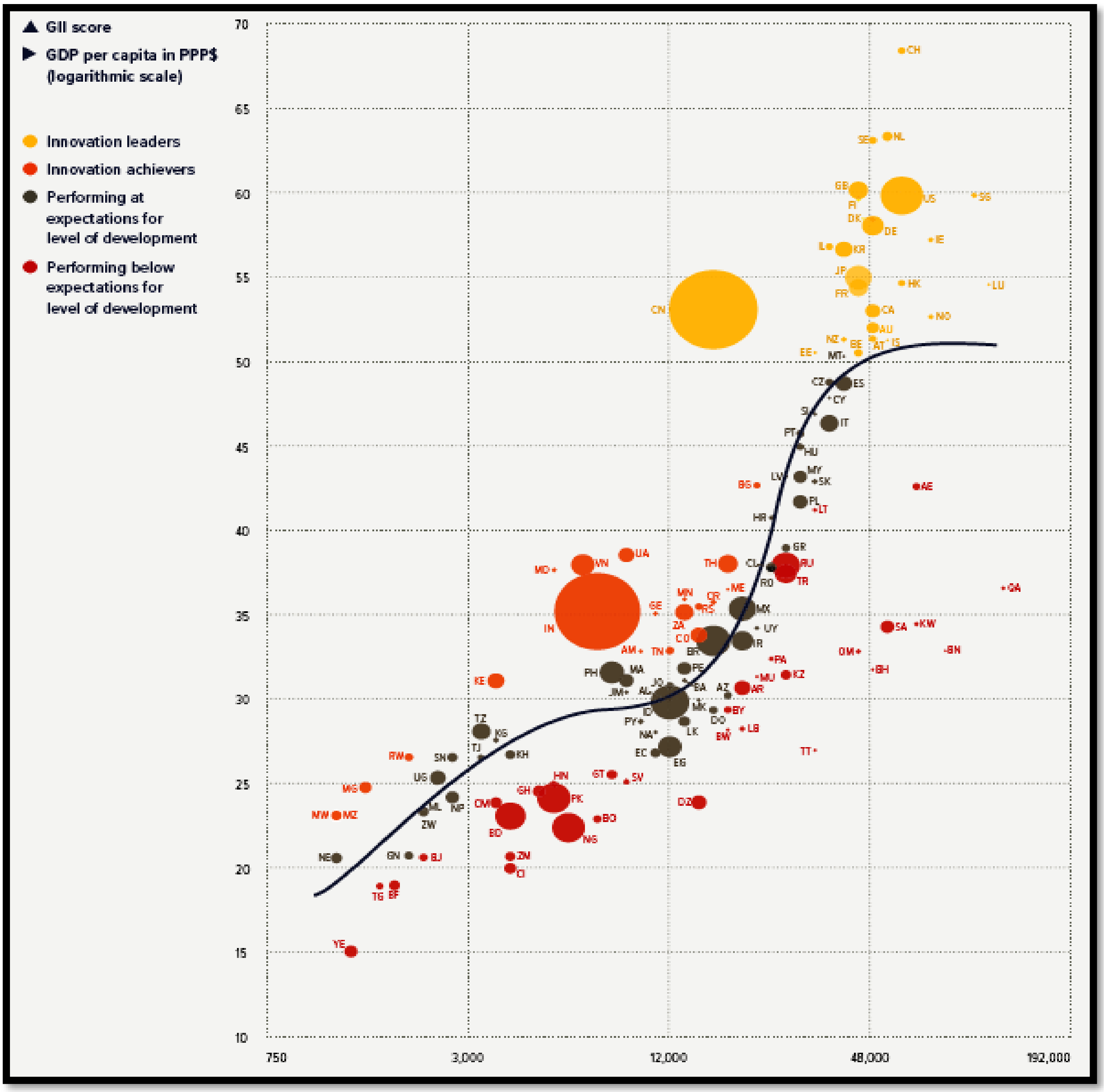

Figure 17. Global Innovation Index 2018
(Source: http://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018.pdf)

Delivering on the full range of amenities which underpin the Millenium Development Goals agenda of United Nations, including, inter alia, environmental protection, the containment of health epidemics, mitigating climate change, requires access to a range of appropriate technologies. Much of the required technology is already available in the public domain but accessing and linking them to the required knowledge and skills within countries is neither automatic nor costless. It calls for investments in dynamic capabilities, particularly those that shape the ability of national stakeholders to uptake and absorb technologies and make improvements in line with local circumstances.

3.2 Direct Drivers

3.2.1 Climate

Climate change affects the living world, including people, through changes in forest ecosystems, biodiversity, and ecosystem services. Earth's climate system has changed since the preindustrial era, in part because of human activities, and this change is projected to continue throughout the 21st century. During the last 100 yr, the mean global surface temperature has increased by about 0.6°C. Precipitation increased by 0.5–1% per decade in the 20th century over most middle and high latitudes of the continents of the Northern Hemisphere but decreased over much of the subtropical land areas at a rate of about 0.3% per decade, although it appeared to recover in the 1990s. Average sea level rose 0.1–0.2 m across the world. There was a widespread retreat of mountain glaciers in non polar regions, with decreases of about 10% in the extent of snow cover since the late 1960s and a reduction of about two weeks in the annual duration of the ice covers of lakes and rivers in the middle and high latitudes of the Northern Hemisphere. Also in the Northern Hemisphere, the extent of the sea ice in the spring and summer has decreased by about 10–15% since the 1950s. Evidence of observed climate change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality.

Greenhouse gases from human activities are the most significant driver of observed climate change since the mid-20th century. Carbon dioxide (CO_2) is the most important greenhouse gas, with methane and nitrous oxides as other contributors. Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years (Figure 18). Worldwide, net emissions of greenhouse gases from human activities increased by 35 percent from 1990 to 2010. Since 1750, the atmospheric concentration of CO_2 has increased by about 32% (Houghton et al. 2001), mainly because of the fossil fuel burning in the last decades and also, at a smaller percentage, due to land-use changes and especially deforestation. Atmospheric concentrations of methane have increased by a factor of 2.5 since 1750 and the atmospheric concentration of nitrous oxide has increased by about 17% since 1750 from about 270 to 315 ppb (Houghton et al. 2001).

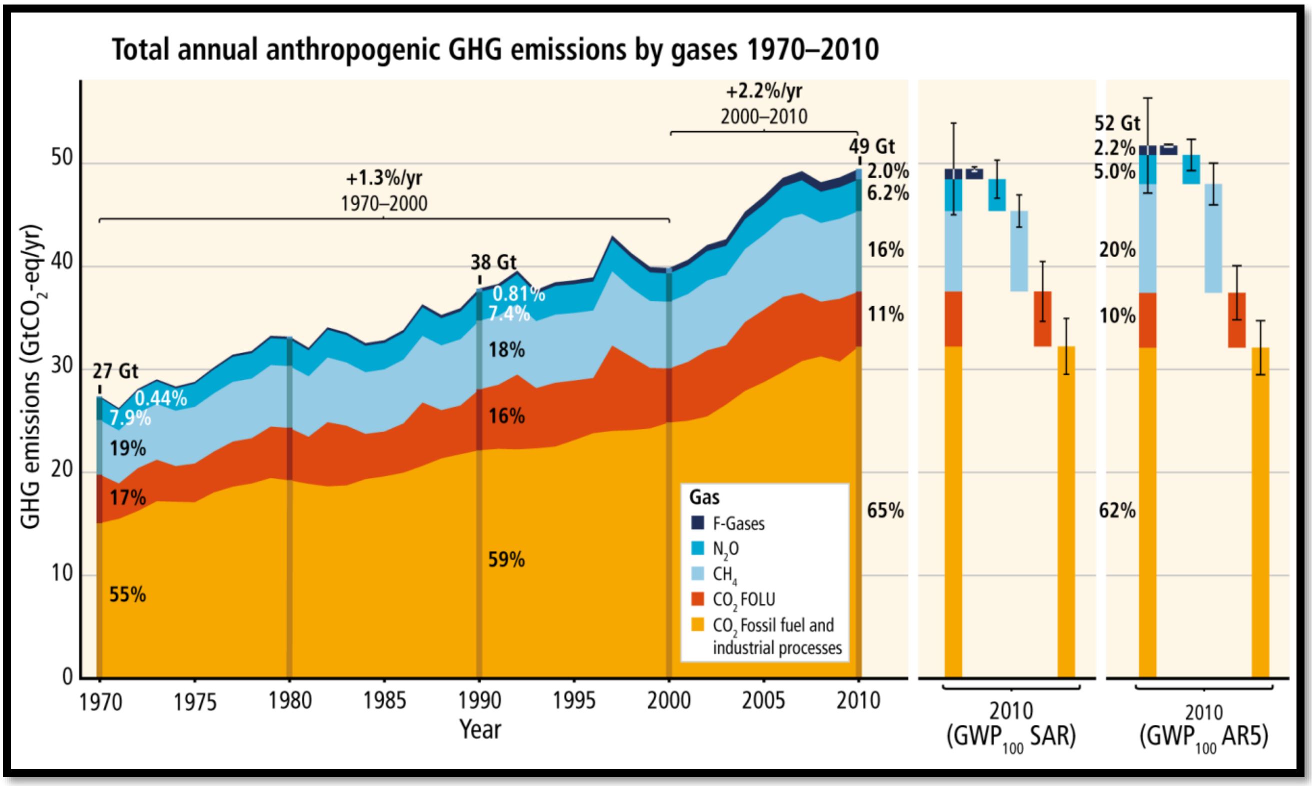

Figure 18. Total annual anthropogenic greenhouse gas (GHG) emissions (gigatone of CO2-equivalent per year, GtCO2-eq/yr) for the period 1970 to 2010

(Source: IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp)

There is a direct influence of global warming on precipitation. Increased heating leads to greater evaporation and thus surface drying, thereby increasing the intensity and duration of drought. Precipitation varies from year to year and over decades, and changes in amount, intensity, frequency, and type (e.g. snow vs rain) affect both society and environment since it is considered as critical factor of forest ecosystem functioning. Evidence is building that human-induced climate change (global warming), is changing precipitation and the hydrological cycle, and especially the extreme events which are typically defined as floods and droughts. In the Northern Hemisphere, a robust pattern of increased precipitation polewards of about 45°N is projected for the 21st century, by the Intergovernmental Panel on Climate Change (2007), due to the increase in water vapor in the atmosphere and the resulting increase in vapor transport from lower latitudes (Figure 19).

It is evident that climate change has large direct impacts on several aspects of the hydrological cycle, increasing extremes events and making the use and management of water resources more challenging. Dealing with drought one year and floods the next (as in

Europe in 2002 and 2003) presents major challenges for water managers concerned with how to save in times of excess for those times when there is too little.

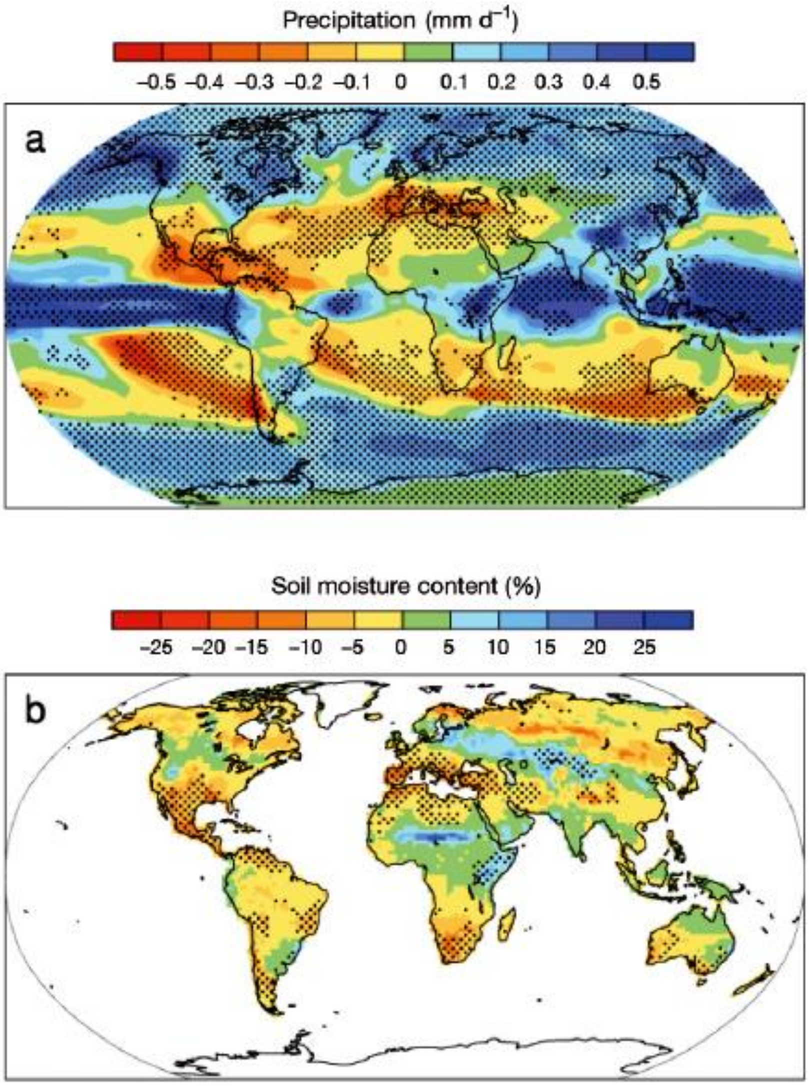

Figure 19. Multi-model mean changes in (a) precipitation and (b) soil moisture content.
To indicate consistency in the sign of change, regions are stippled where at least 80% of models agree on the sign of the mean change. Changes are annual means for the SRES A1B scenario (Special Reports on Emissions Scenarios, IPCC) for the period 2080–2099 relative to 1980–1999. Soil moisture changes are shown at land points with valid data from at least 10 models.
(Source: Intergovernmental Panel on Climate Change (IPCC) 2007)

Temperature projections from the IPCC Third Assessment Report indicate that the mean global surface temperature (Figure 20) is expected to increase 1.4–5.8ºC between 1990 and 2100 (Houghton et al. 2001). Precipitation patterns are projected to change, with most arid and semiarid areas becoming drier and with an increase in heavy precipitation events, leading to an increased incidence in floods and drought.

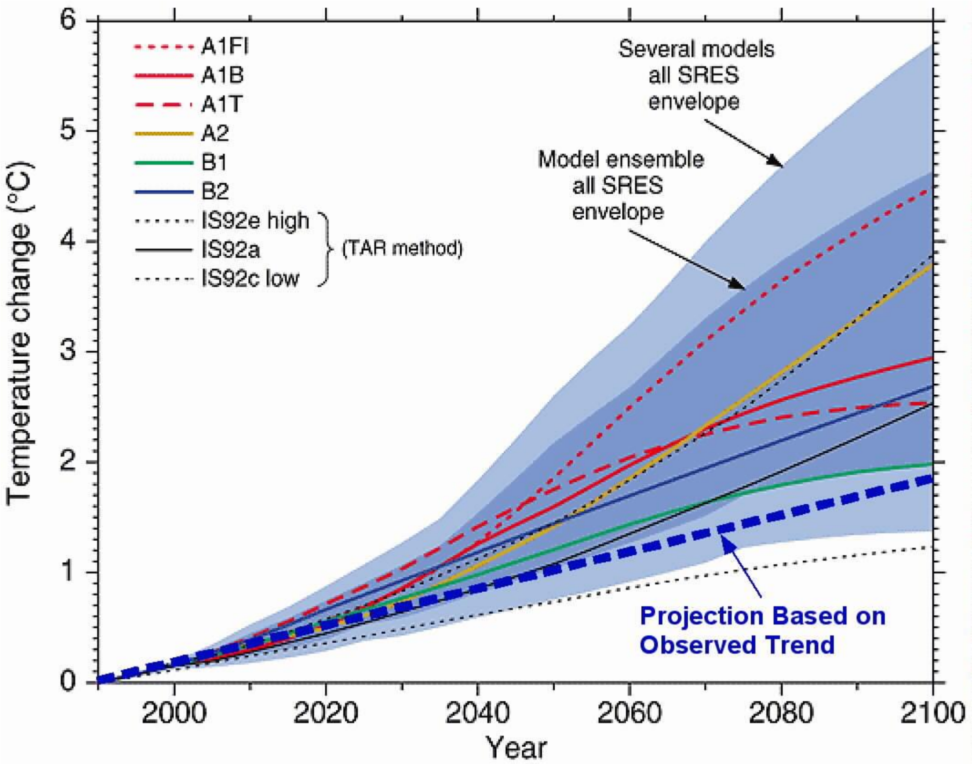

Figure 20. Temperature projections from the IPCC Third Assessment Report for all the scenarios investigated

(Source: http://www.grida.no/climate/ipcc_tar/wg1/fig9-14.htm)

Climate change is a large scale and emerging environmental risk (Pana et al. 2013) which affects the living world, including people, through changes in ecosystems, biodiversity, and ecosystem services. Ecosystems entail all the living things in a particular area as well as the non-living things with which they interact, such as air, soil, water, and sunlight (Chapin et al. 2011). According to Schmitz et al. (2003), in response to global climate change, the composition of key players in ecosystems may remain intact, but the fundamental character and complexion of the ecosystem and its feedbacks may become uniquely transformed. Likewise, the possibility of shifts in forest ecosystem state driven by top predators indicates that higher-order trophic interactions are likely to play an important role in determining ecosystem structure and function.

It is underlined that it is often difficult to quantify human vulnerability that results from shifts in ecosystem processes and services. For example, although it is more straightforward to predict how precipitation will change water flow and availability, it is much harder to pinpoint which sites, cities, and habitats will be at risk of running out of water, how they will respond, and even more difficult to say how people will be affected by the loss or degradation of ecosystem functions and features (e.g. a favorite fishing spot or a wildflower that no longer blooms in a region). A better understanding of how a range of ecosystem responses affects people – from altered water flows to the loss of wildflowers –

will help to inform the management of ecosystems in a way that promotes resilience to climate change.

3.2.2 Agricultural practices

A key component of the technological advances in agriculture has been the rapid growth in the use of fertilizers in the last century. Nitrogen and phosphorus applied on farm fields to help crops grow can be carried beyond the bounds of the field to which they are applied, potentially affecting ecosystems off site. By 1990, the total amount of reactive nitrogen created by human activities was over 150 Tg/yr (Figure 21). This represents a ninefold increase over 1890, compared with a 3.5-fold increase in global population (Galloway and Cowling 2002). Although plant nutrients are essential for food production, current methods of fertilizer use contribute to environmental problems such as greenhouse gas emissions and eutrophication. According to FAO (2017) the demand for N, P_2O_5 , and K_2O is forecast to grow annually on average by 1.5, 2.2, and 2.4 percent respectively from 2015 to 2020. Over the next five years, the global capacity of the production of fertilizers, intermediates and raw materials is also expected to increase.

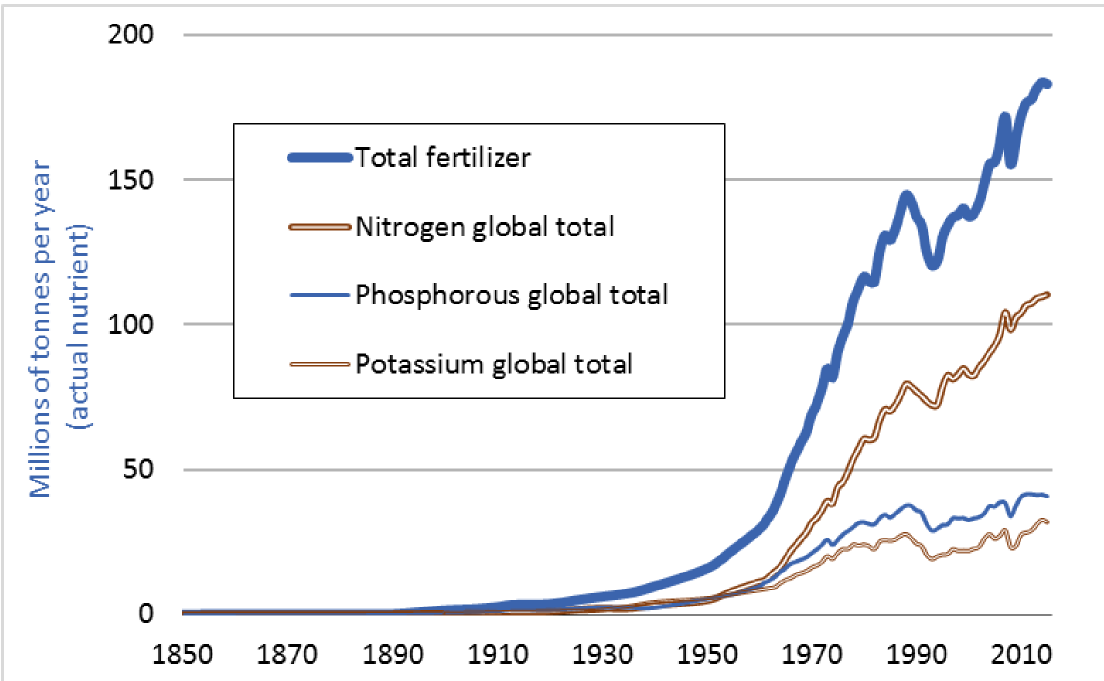

Figure 21. Global consumption of nitrogen fertilizer and other fertilizers, historic, 1850 to 2015
(Source: https://www.darrinqualman.com/historic-nitrogen-fertilizer-consumption/)

A substantial portion of the nitrogen applied is not used by plants and is carried off the field in runoff. Such losses of reactive N can damage environmental services in the receiving ecosystems. On the other hand, phosphorus tends to accumulate in the soil. Hence, the growth in application is accompanied by accumulation in soils, which is an indicator of the eutrophication potential of freshwater lakes and P-sensitive estuaries.

The use of pesticides is another important factor affecting agricultural ecosystem, surrounding ecosystems including forests, and human health. The term refers to insecticides, fungicides, herbicides, disinfectants and any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. Excessive use of pesticides may lead to the destruction of biodiversity. Many birds, aquatic organisms and animals are under the threat of harmful pesticides for their survival. Pesticides are a concern for sustainability of environment and global stability. The worldwide consumption of pesticides in 2014 was about two million tonnes per year – mostly used in China, USA and Argentina (Figure 22), of which 47.5 % is herbicides, 29.5 % is insecticides, 17.5 % is fungicides, and others account for 5.5 %. (De 2014).

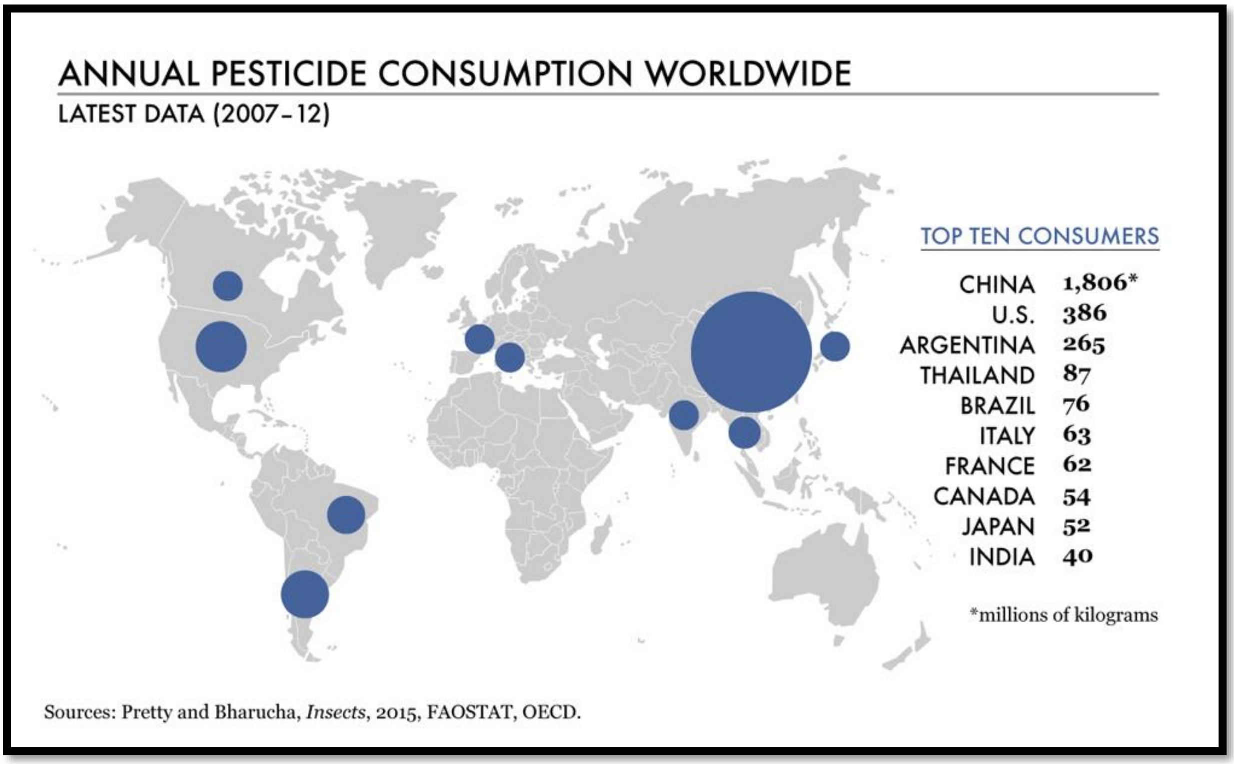

Figure 22. Top consumers of pesticides around the world

3.2.3 Land conversion

The extent and type of land use directly affects GHGs emissions, wildlife habitat, and thereby impacts local and global biodiversity. Humans change land use to alter the mix of ecosystem services provided by that land. In some cases the land conversion effort is intentional (e.g. plowing grassland to grow crops), while in other cases, land conversion is a consequence of other activities (e.g. salinization as consequence of irrigation that does not have adequate drainage). The Millennium Ecosystem Assessment sponsored identifies as major types of land conversion: deforestation, desertification, agricultural expansion and abandonment, and urban expansion, most important of which can be considered the first two.

Forests cover about 30% of the planet, but deforestation is clearing these essential habitats on a massive scale. Deforestation is the single most measured process of land-cover change at a global scale. During the industrial era, global forest area was reduced by 40%, with three quarters of this loss occurring during the last two centuries Forests have completely disappeared in 25 countries, and another 29 have lost more than 90% of their woodlands (Millennium Ecosystem Assessment 2005*a*). Deforestation and forest degradation affect 8.5% of the world's remaining forests, nearly half of which are in South America. Figure 23 presents the annual net change in forest area from 1990 to 2015. Deforestation and forest degradation have been more extensive in the tropics over the past few decades than in the rest of the world.

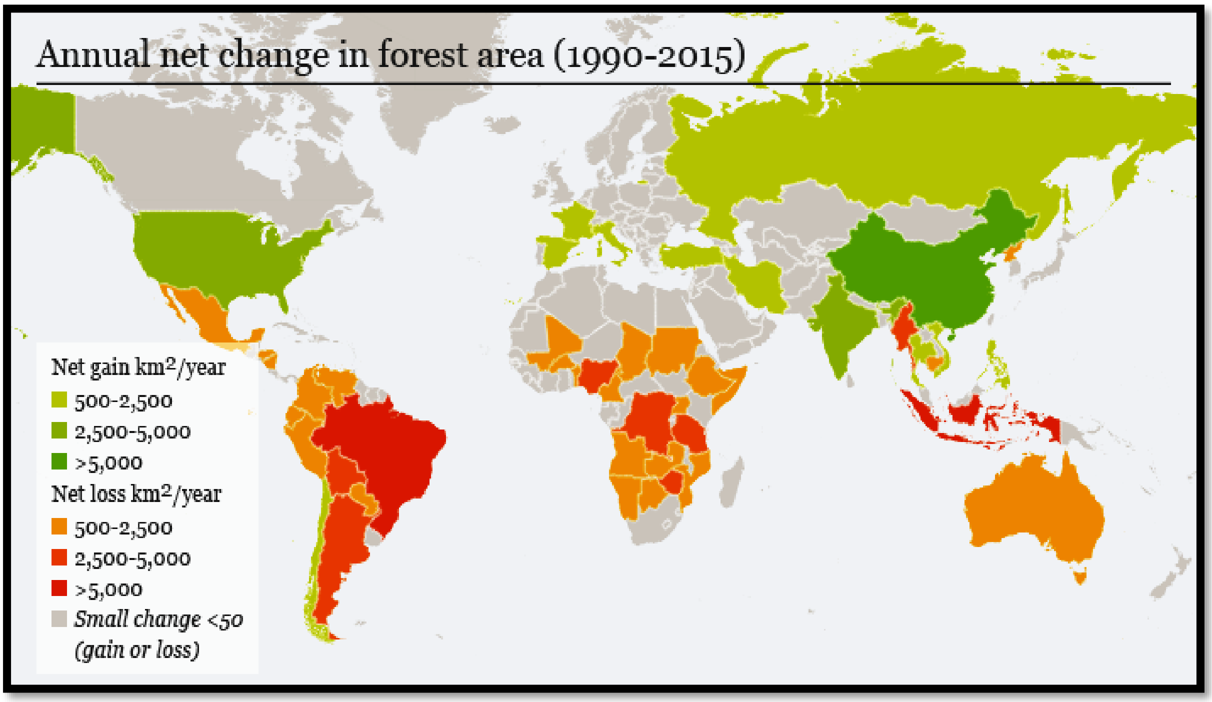

Figure 23. Annual net change in forest area from 1990 to 2015
(Source: FAO 2015. Global Forest Resources Assessment. FAO, Rome)

Desertification or also called dryland degradation, has affected parts of Africa, Asia, and Mediterranean Europe for centuries, parts of America for one or two centuries, and parts of Australia for 100 yr or less (Dregne 2002). Approximately 10-20% of the drylands and hyperarid zones of the world are considered degraded, with the majority of these areas in Asia and Africa (Figure 24). Based on rough estimates, about 1-6% of the dryland people, approximately 20 million-120 million people, live in desertified areas. Desertification is a change in soil properties, vegetation or climate, which results in a persistent loss of ecosystem services that are fundamental to sustaining life.

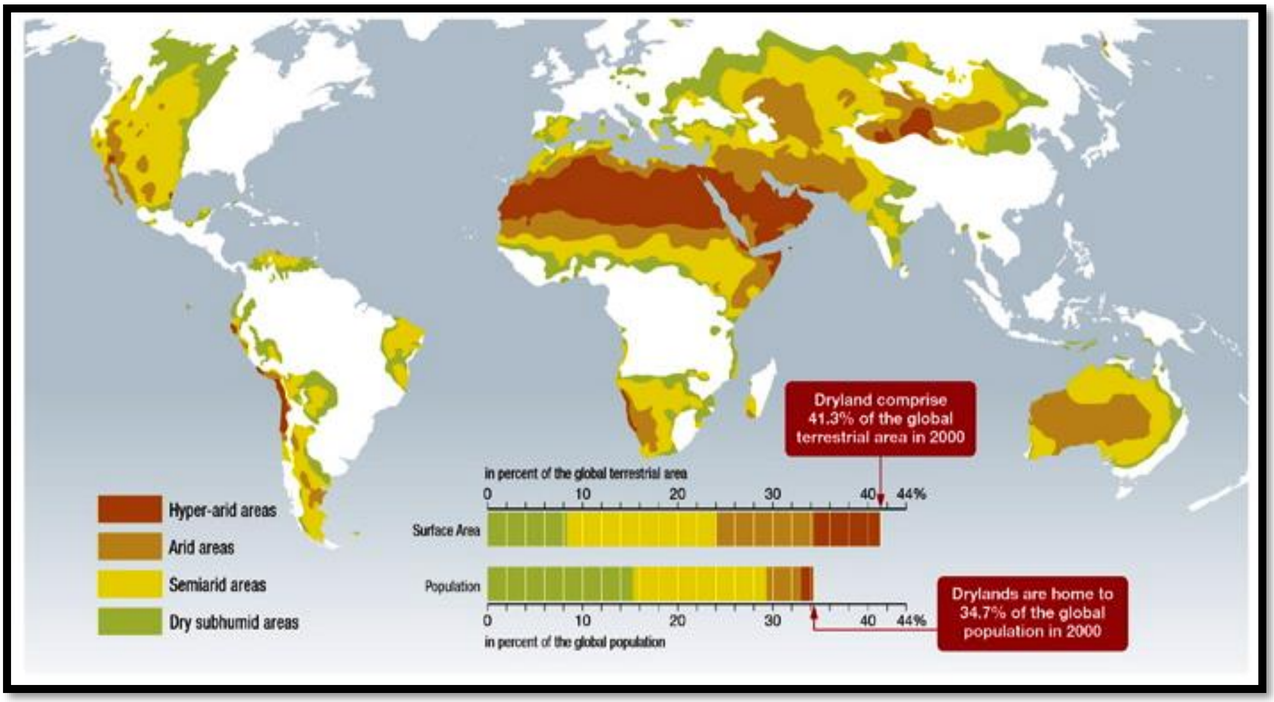

Figure 24. Drylands vulnerable to desertification and their categories
(Source: Millennium Ecosystem Assessment 2000)

3.2.4 Biological invasions and diseases

Biological invasions pose a leading threat to biodiversity world-wide. Through competition, predation, and habitat alteration, invaders can radically change both the species composition and functioning of native ecosystems. Biological invasions are a global phenomenon affecting ecosystems in most biomes (Mack et al. 2000). Deliberate or accidental movement of organisms, has caused a massive alteration of species ranges, overwhelming the changes that occurred after the retreat of the last Ice Age (Semken 1983).

The threats that biological invasions pose to biodiversity and to ecosystem-level processes translate directly into economic consequences such as losses in crops, fisheries, forestry, and grazing capacity (Mack et al. 2000). The economic costs of such phenomena are estimated at over 100 billion US dollars per year in the United States alone.

On the other hand introductions of alien species can be beneficial in terms of human population. For example 98% of the U.S.A. food supply comes from introduced species including corn, wheat, rice, cattle, poultry etc (Pimentel 2002).

Invasive and native parasites and pathogens possess a considerable potential to significantly modify ecosystem function due to their diversity and ability to multiply very rapidly. Future insights on biological invasions will likely emerge from the current focus of the ecological community on the impacts of climate change. Worldwide, numerous studies are manipulating environmental factors such as temperature and precipitation to better understand how ecosystems will respond to forecasted changes in these variables. The growing field of invasion science, poised at a crossroads where ecology, social sciences, resource management, and public perception meet, is increasingly exposed to critical scrutiny from several perspectives.

4 CHALLENGES AND OPPORTUNITIES IN FOREST MANAGEMENT

Loss of biodiversity and economic development cannot be seen as separate processes, although their relationship may differ according to geographic, cultural, socio-economic, and political context. Reducing biodiversity loss, therefore, has to deal with the complex issues of development. If biodiversity is not conserved along the way, the new forests may never come near to recovering the diversity nor the functions (and, therefore, the ecosystem services) of the old forests because the forest resilience has been lost. Towards this direction the main challenges for addressing the drivers of change, and relevant opportunities, can be distinguished in four main categories including the institutional framework, the accounting of natural capital the management and policy issues.

4.1 Institutional Challenges

The drivers are directly and strongly related to factors of economic development, and economic development is influenced by institutions at different levels, thus biodiversity conservation needs to be mainstreamed at these same levels. Towards this direction institutional interventions are necessary in order to successfully counteract the main anthropogenic drivers.

Most progress can be seen at the international level such as the 1992 Earth-Summit in Rio de Janeiro which gave rise to a number of international agreements and conventions for the development of policies and strategies that balance between social, economic, and environmental costs and benefits.

However the different international agreements and conventions show much overlap but have failed to integrate their actions, often with duplication of efforts and even with competing interests. Furthermore efforts at national and local level aiming to improve forest management and protection or to reduce deforestation through legislation and policies, have concentrated on regulating activities within the forest sector, while many of the problems arise from pressures outside that sector.

This challenge, among others, lies in creating platforms at different levels (international, national and local) where different actors are able to discuss natural resource management openly, where all stakeholder groups are well represented, and that will have the capacity to address the most pressing issues at the corresponding level. The FAO (Food and Agriculture Organisation of the United Nations) -supported national forest programs have been designed to do just that, but in Latin America, few governments have the experience, skill, and willingness to apply them as designed.

Forest ecosystem service knowledge had particularly little bearing in those planning and policy-making situations where it challenged established interests and the current distribution of benefits from ecosystems and their services. One of the greatest challenges will be to increase knowledge on the effects of biological diversity on the desired forest ecosystem services and to valuate them properly. Although current efforts to conserve biological diversity within and outside forests show interesting experiences, it remains difficult to establish quantitative links between specific biodiversity and a specific level of environmental services, making it difficult to incorporate biodiversity into payments for environmental services or market schemes. An additional challenge will be to make sure that such schemes are accessible to those people most in need of the additional income, and not, as in many cases, to those that do not depend on the forest or forest land to make a living.

Furthermore the concept of forest ecosystem services is not yet integrated into national level regulatory frameworks and hence the knowledge can be considered as useful but voluntary add-ons lacking policy driven substance and momentum. One critical factor, which prevents knowledge uptake, can be considered the established professional norms, competencies and codes of conduct, which made practitioners to rely on traditional solutions. These posses an additional challenge, to communicate the information to the stakeholders in such a way that they can use it for individual and group decision-making. This may require decision-making tools, such as multi-criteria analysis tools, or tools that allow them to make simple cost-benefit analyses.

4.2 Policy and Management

In recent years, EU environmental policies such as the 7th Environment Action Programme (7th EAP) and the Biodiversity Strategy to 2020 have shifted towards a more systemic perspective on the managing the environment, explicitly addressing natural capital. For example, a priority objective of the 7th EAP is 'to protect, conserve and enhance the Union's natural capital'. There are many synergies and co-benefits to a more integrated management approach. Implementation of ecosystem-based management approaches that consider the entire ecosystem, including humans, offers much potential. Adopting this approach in the management of human activities in the aquatic environment and in developing green infrastructure development will provide important evidence and learning.

Local successes have been (or can be) achieved in reducing pressure on forests. Successful approaches were different depending on the circumstances (e.g studies for the Mayan Biosphere Reserve in Guatemala, highlands of Costa Rica and the eastern lowlands of Bolivia). The results of these studies suggest that the research should not only focus on the drivers of deforestation (a negative effect) but also on the drivers of conservation (a positive effect). Activities that reduce land use change and over-exploitation also contribute to a reduction in carbon emissions. Reduced impact logging practices, usually an integral part of good forest management, also contribute to reduced emissions in comparison with conventional logging due to a reduction of 50% in road areas and damaged remnant trees. Unfortunately, these practices are not widespread. The experience in forest conservation and management over the last decades in Latin America, however, indicates that this may be more expensive than estimated by economists such as Stern (2006), may need more than a mere transfer of money from the developed to the developing countries, and may not be determined by economic factors alone.

Strategic placement of forests in agricultural landscapes presents multiple opportunities where conservation, production, and livelihood needs are simultaneously promoted. The science of landscape ecology, particularly of strategic arrangements of forest cover within the agricultural matrix, is nascent; however, it shows tremendous potential for increasing the multifunctionality of agricultural landscapes, including built-in adaptability to climate change, hazard risk reduction, and the provisioning of agro-ecosystem functions. An interesting example of this is the promotion of biological corridors in Costa Rica, involving private land owners in enhancing biodiversity and increasing the provision of ecosystem services within their agricultural fields.

4.3 Natural Capital Accounting

The 7th EAP states that 'further efforts to measure the value of ecosystems and the cost of their depletion, together with corresponding incentives, will be needed to inform policy and investment decisions. Work to develop a system of environmental accounts, including physical and monetary accounts for natural capital and ecosystem services, will need to be stepped up. This supports the outcome of Rio+20, which recognises the need for broader measures of progress to measure well-being and sustainability to complement GDP.

EU bodies, Member States and researchers are responding to this challenge and developing more comprehensive environmental accounting systems, including approaches for measuring the condition of forest ecosystems and their services. This supports the EU's current efforts to develop new more inclusive indicators of social, economic and environment progress via the 'Beyond GDP' initiative (EC 2014).

Recently, a Knowledge Innovation Project (KIP) on Integrated Systems for Natural Capital Accounting (INCA) in the EU was initiated in 2015 to strengthen the knowledge base that will feed into national capital accounts. In developing an integrated system (INCA), data will be brought together from a variety of existing data collections, structured in terms of the Mapping and Assessment of Ecosystems and their Services (MAES) framework (see Box 3), and related in a nested structure. The KIP-INCA project is clear: data sets will be integrated by EU-level bodies, at no extra work or cost for Member States, but Member States will be able to ‘plug in’ their national accounting systems to KIP-INCA. The Directorate-General for Environment, which is a main project partner — along with Eurostat, the European Environment Agency, DG JRC and DG RTD — states that biophysical and economic data to the extent and condition of ecosystems should be integrated in a systematic way, so that they can be aggregated and disaggregated at the required scale to complement figures of economic performance (EC, 2016). To date, work has started on developing basic extent accounts in the EU, and a selection of specific ecosystem services such as pollination and water-related services. Work has also aimed to integrate policy applications with the development of accounts. The design of an integrated geographically referenced knowledge platform has also started, that will be able to integrate data form a range of sources such as data reported under EU Directives, CORINE land cover, COPERNICUS (satellite observation land monitoring) data and LUCAS (ground observation) data, and others (EC, 2017).

5 CONCLUDING REMARKS

Conversion of forests into agricultural lands, overexploitation, climate change, and invasive species, all cause great stress on forest ecosystems. Conscious of the negative effects of human activities, society has responded by increasing the area of forest being protected and well-managed, and by incorporating management of trees and forest patches into management of agricultural landscapes. Still, most of natural forests and agricultural landscapes are not well-managed and their existence continues to be threatened by the same drivers. The lack of reduction in the threats to biological diversity is, among other things, due to lack of addressing the subjacent causes of the threats. These are very much linked to level and form of economic development, and are often found outside the forest and environmental sectors.

While Europe has undoubtedly made progress in preserving and enhancing its natural capital in certain areas, overall degradation of ecosystems persists. In addition, abiotic resources and ecosystem capital are under significant pressure across the world and demographic and economic projections suggest that these pressures are likely to grow (EEA 2014). Changes in ecosystem services are almost always caused by multiple interacting drivers. The direct and indirect drivers can work over time, e.g., population and income growth interacting with technological advances that lead to climate change, or over levels of organization, e.g., from local zoning laws to international environmental treaties. Based on the drivers of change, the valuation of ecosystem services is of primary importance to policymakers, businesses and environmental organisations in that, by quantifying and making explicit the value of the environment in currently existing language: it helps to raise awareness of the benefits; it can target resources for ecosystem protection; and can rationalise the decision-making process.

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