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Economic Valuation of Forest Ecosystem Services: Methodology and Monetary Estimates

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Keywords: Forest, Ecosystem Services, Biodiversity, Valuation, Value Transfer

JEL Classification: O13, Q23, Q26, Q51, Q54, Q57

The current research is part of the EU funded project COPI "Cost of Policy Inaction. The case of not meeting the 2010 biodiversity target". The authors thank the whole COPI research team. A special word of thanks goes to Leon Braat (ALTERRA) and Patrick Ten Brink (IEEP) for their valuable comments and suggestions.

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Economic Valuation of Forest Ecosystem Services: Methodology and Monetary Estimates

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Abstract

By using *ad hoc* value transfer protocols, this paper offers a methodological contribution and provides accurate per hectare estimates of the economic value of some selected ecosystem services for all forest biomes in the world, identified following the Millennium Ecosystem Assessment taxonomy MEA. The research also estimates potential total economic losses from policy inaction in year 2050. Final results show that total losses are significant. The total figure is €78 billion, the greatest losses coming from North America and Mexico, followed by Africa, Russia and some Asiatic countries. Most of this loss is attributable to provisioning services and carbon sequestration, while only a minor part is due to loss of cultural services. In terms of biomes the greatest losses are from boreal and warm mixed forests, followed by tropical forests. These results may be surprising to some who argue that it is the loss of tropical forests, particularly the Amazon that is the most significant. A detailed analysis, shows, however, that this is not the case. The best estimates point to greater losses in areas where use and non-use values are highest, which includes North America.

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1 Introduction

In recent years we have been witnessing a major debate on the potential effects of biodiversity loss. The central question being: as biodiversity decreases, what are we losing in terms of goods and services to humans? Far from being a mere accountability issue, this question is about the impact on the welfare and wellbeing of current and future population and societies, as well as about wider ethical questions on the role humans in the stewardship of the planet's natural resources. So far, this has triggered many studies trying to provide economic estimates of the costs and benefits of land conversion and human activities inducing biodiversity losses (e.g. see Costanza et al. 1997). Still, the coverage of the available economic estimates of the costs of biodiversity loss is partial, and the required research effort massive.

By using *ad hoc* value transfer protocols, this paper offers a methodological contribution and provides accurate per hectare estimates of the economic value of a set of forest ecosystem services (ESs) for all forest biomes in the world. The research also estimates potential total economic losses from inaction in year 2050, by using data on forest areas and land use changes from 2000 to 2050 as provided by the EU-funded COPI project "Cost of Policy Inaction: the case of not meeting the 2010 biodiversity target" (see Braat et al., 2008).

The analysis is focused on a selected set of relevant forest ecosystem services identified following the Millennium Ecosystem Assessment taxonomy (MEA, 2005). The estimation of such services, although not covering the full range of forest instrumental values, contribute to the quantification of those values which are expected to be relevant to contexts where it is necessary to make decisions and trade one value against the other. The assessment provided is anthropocentric, as non-anthropocentric values, such as moral and spiritual values, which should be taken into account in decision-making, do not lend themselves to this kind of quantification.

The reminder of the paper is organized as follows. Section 2 provides a brief review of the valuation of forest services and discusses current challenges. Section 3 illustrates the methodological approach employed to estimate forest services worldwide. Section 4 presents and discusses results, while Section 5 offers some conclusive remarks, while discussing future challenges.

2 Valuing forest ecosystem services: where do we stand

Forests are critically important habitats in terms of the biological diversity they contain and in terms of the ecological functions they supply (e.g., Miller et al., 1991; Mendelshon and Balick, 1995; Pearce, 1996, 1998, 1999). Similarly, the ecological and anthropocentric services of forest are many and, although the area-species and the species-services relationships are still debated (e.g. Pimm and Raven, 2000), the loss of forest ecosystem services driven by deforestation is expected to be serious if the rate of deforestation is maintained at the current alarming level of approximately 13 million hectares per year (FAO, 2007). The value that forests provide therefore arises from the estimated rates of loss of forest areas and, hence, in terms of the services they provide humans. Forests not only provide timber but regulate local and global climate, enhance soil retention and water quality, ameliorate water events, facilitate pollination, improve landscape aesthetics and provide habitats for a vast store of species, and genetic information yet to be uncovered.

The forest evaluation challenge has gradually reached the international policy agenda. Forest conservation or prevention of deforestation in order to stabilize Green House Gas (GHG) emissions – questions not originally included in the Kyoto Protocol – have been officially recognized in COP13 in Bali on December 2007 as important issues. Countries rich of forested areas, such as Brazil, are asking for compensation for the environmental services that they give to the planet by helping future conservation of millions of hectares of native woodland in the tropics. Besides, as deforestation is mainly due to conversion of forests to agricultural land in South America and Asia (FAO, 2005), paying farmers for the environmental services they may conserve or provide is generating growing interest worldwide from policy makers to non-governmental and private decision-makers (see FAO, 2007). As such policy initiatives are currently being debated, the availability of reliable and accurate estimates of forest values is becoming pivotal. Although it is not yet clear what will be the policy framework on deforestation in the near future, shading light on this issue from a scientific perspective will facilitate and accelerate the policy process.

So far, the estimation of the economic value of forest ecosystem services has been limited by a number of pitfalls. The first point regards the coverage of the economic valuation of forest services. Some recent works, e.g. the CBD report (2001) on the *Value of Forest Ecosystems*, have tried to fill this gap by providing comprehensive literature reviews of the values of a vast array of forest services (from provisioning services to genetic information). The estimations help us to understand the typologies and orders of magnitude of the services involved; however, they cannot be seen as representative of all forest areas. As the current body of knowledge become clearer, we still lack a common and replicable methodological framework to transfer available figures to new, unexplored and heterogeneous, policy contexts, thus allowing a worldwide coverage of the cost estimation to be achieved. A common platform of analysis of forest biodiversity services is needed.

Equally importantly, many studies estimate marginal effects as being equal to the average impact, and do not estimate the former by taking into account statistically significant explanatory factors that may control for heterogeneities across forest areas (and their related socio-economic context). This leads to potential estimation biases. According to a recent review promoted by the European Commission (Markandya et al., 2008), available values tend to be very site and forest specific and transfer to other forests and locations are difficult or often not credible.

Thirdly valuation exercises need to be incremental ones. There is little advantage in knowing the total value of an ecosystem unless there is a threat to eliminate it or a policy to reconstruct it in its entirety, which is rarely the case. Yet many valuation studies provide estimates of the total costs of whole systems and the famous work by Costanza et al. (1997) even estimates the value of the whole world's ecosystems. Performing an incremental analysis (which may entail estimating significant non-marginal changes in ecosystems), however, is not as easy as it might sound, and revealed or stated preferences valuation exercises need to be designed accurately. Besides, many ecosystem services that individuals receive are multidimensional and there is an 'adding up' problem (Markandya et al., 2008). The value attached to one forest area for recreational or other use is not independent of whether another forest nearby is conserved or not. The implication is that studies need to be undertaken allowing for substitution effects, which makes them more specific to a particular application and less capable of being transferred to other applications.

All and all, the question of the extent to which forest values can be transferred from one site to another and from one type of biome to another is a crucial and controversial one. Economists have devoted a great deal of effort to see how far such transfers are possible, given that full valuation studies are expensive and time-consuming to conduct (see, e.g., Brower, 2000; Navrud and Ready, 2007). In principle, the most comprehensive way to carry out transfers is to use a 'meta analysis', which takes all existing studies and figures and statistically estimates a relationship which gives changes in the benefit values as a function of site characteristics, attributes and size of the population affected, type of statistical method used etc. in the sample of existing studies. This is then transferred to the 'policy site' in a procedure referred to as value transfer, which can provide a 'single value' for the policy site or a 'meta-value function', which gives a range of values depending on the characteristics of the object of valuation. Overall, the result of recent discussions on this subject seem to suggest that while value transfer is possible for some ecosystem services it is not appropriate for others (see Braat et al. 2008; Markandya et al., 2008). It should be possible, for example, to derive estimates of some categories of recreational benefits; it is much more difficult to carry out credible benefit transfer for most other categories of value.

Notwithstanding such difficulties, the international community urgently seeks estimates of the foregone forest benefits at the local and global level. Given that there are thousands of forest ecosystems and sites of importance, some kind of value transfer and rules of thumb for acceptable estimates will be essential if the goal of obtaining regional, national and global estimates of the damages from forest loss in the absence of any actions is to be obtained. The present paper presents value transfer protocols for estimating a small but significant array of provisioning, regulating and cultural forest ecosystem services. In this regard, the methodological approach and analyses presented in the following sections can be seen as a pilot case study showing how research synthesis could be used to fill knowledge gaps on biodiversity values.

3 A worldwide assessment of forest ecosystem services: methodological approach

3.1 Introduction: forest ecosystem services, biomes, land use and world regions

The methodological framework applied to derive marginal monetary values and potential total losses of a restricted set of services provided by forest biomes worldwide is illustrated in Figure 1.

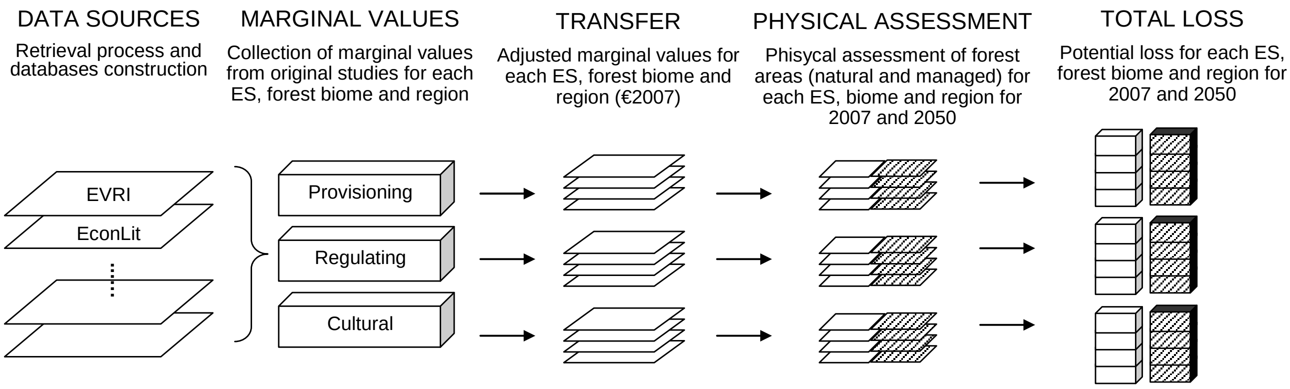

Figure 1: A schematic illustration of the overall methodological approach

The services considered in this study are selected according to data availability and relevance to decision making; this leads to the restricted set presented inv Table 1. As defined by the Millennium Ecosystem Assessment (MEA, 2005), provisioning services are the goods obtained from ecosystems and they include food, fiber, fresh water, and genetic resources. For forestry, we consider in particular wood and non-wood products (both plant and animal) extracted from natural or managed forested areas. Regulating services include benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, pollination and natural hazard regulation. As for regulating services, above all, deforestation is responsible for a huge amount of carbon emissions. We thus include the role of forests in climate regulation as important carbon storage reservoirs. Cultural services are the nonmaterial benefits that people obtain from the ecosystem through aesthetic experience, reflection, recreation and spiritual enrichment. We refer to recreation and ecotourism and passive use of forests, these two dimensions being better covered by the economic valuation literature.

Table 1: List of forest Ecosystem Services addressed for the monetary estimation

MEA category	Ecosystem Services
Provisioning	Food, fiber, fuel: wood and non wood products
Regulating	Climate regulation: carbon storage
Cultural	Recreation and ecotourism
	Passive use

Source: modified from MEA (2005).

For each service under analysis a thorough retrieval process has been performed in order to collect the largest possible set of available data and information that is relevant to estimating marginal values. The literature retrieval process comprised checking several economic and forest databases (among others EconLit, EVRI, FAO), reference chasing, and approaching key scholars in the field. This resulted in three different set of estimates, one for each service category, described in the following sections. Several of these values, however, do not provide usable estimates. Thus, the marginal values actually employed for the transfer exercise represent a sub-sample of the whole body of the literature. Still they are intended to provide the maximum coverage of the variety of forest biomes that populate forest areas worldwide.

Given that there are thousands of different forest ecosystems worldwide – each of which leading, in principle, to different degrees of biodiversity ecosystem services – it is essential that we can capture such variability in the value transfer process. This is done here by using the estimations of the status of biodiversity, for the main forest biomes and world regions, as provided by the EU-funded COPI[1] project "Cost of Policy Inaction. The case of not meeting the 2010 biodiversity target" (see Braat et al. 2008). The classification of forest biomes and world regions – as proposed by the OECD GLOBIO[2] model framework (Alkemade et al., 2006) employed by COPI – distinguishes 6 main different forest biomes distributed across 10 world regions (see Table 2, Table 3 and Figure 2). COPI provides estimates of the spatial coverage and distribution of each forest biomes for different drivers and pressures scenarios. In particular, we consider the forest biomes distribution for 2000 and 2050 as described by the OECD Baseline Scenario (see Bakkes and Bosh, 2008). Changes over time are mainly driven by land use changes (see Table 3). For forestry, among the others, the role of agricultural land-use change (forest areas converted into farmland) and forest management (natural forests versus managed forest) remain the largest of all the pressure factors. In particular, in the reminder of the paper, the term "natural" refers to relatively untouched forest areas, while "managed" refers to forest areas also partially designated to extensive cultivation, wood production or recreational activities. The marginal values of forest ecosystem services estimated in this paper thus refer as much as possible to these forest varieties (biomes and type of management) and world regions.

As shown in Table 3, forest area is expected to decrease by around 76 million hectares by 2050 worldwide. The highest loss in absolute terms is expected for Russia (47 million hectares), followed by Africa (12 million hectares). As regards forest biomes, boreal forests reveal the highest absolute loss, followed by warm mixed forests. It should be noted that, while natural forests decline, managed forests are expected to increase. For some world regions, the increase in managed forest is higher than the expected decrease in natural areas, which results in a total increase in the forest area by 2050 (e.g. Europe). But of course this change in composition has environmental implications. The percent decrease over the period (based on year 2000) is expected to range from 0.5% for North America and Mexico (NAM) to 27% for Eastern Europe and Central Asia (ECA).

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[1] In COPI, a model framework and a biodiversity indicator were used for assessment of terrestrial biodiversity dynamics which are able to reflect the impacts of the most important direct and indirect drivers: the extent of biomes and ecosystems, trends in abundance and distribution of species, protected areas, nitrogen deposition, climate change and fragmentation. The biodiversity indicator chosen for use in the COPI study is the Mean Species Abundance (MSA), as used in the GLOBIO model, and the IMAGE framework. The numerical values of the MSA in the COPI study represent the biodiversity impacts of the drivers and pressures in the OECD Baseline Scenario.

[2] The GLOBIO 3 model (Alkemade et al., 2006) contains generalised cause-effect relationships between a selection of pressure factors and the mean species abundance (MSA). The pressures considered in GLOBIO 3 include land-cover change (agriculture, forestry, built up area), land-use intensity, atmospheric nitrogen (N) deposition, infrastructure development, fragmentation and climate change. The current version of the GLOBIO model does not capture that biodiversity is typically lost quickly and regained or restored only slowly. Therefore the overall totals generally underestimate the amount of change.

Table 2: World regions

World regions	Description
NAM	North America
EUR	OECD Europe
JPK	OECD Asia (Japan & Korea)
ANZ	OECD Pacific (Australia & New Zealand)
BRA	Brasil
RUS	Russia & Caucasus
SOA	South Asia (and India)
CHN	China Region
OAS	Other Asia
ECA	Eastern Europe & Central Asia
OLC	Other Latin America & Caribbean
AFR	Africa

Table 3: Area change by forest biome and land use type across world regions 2000-2050 (1000 hectare)

Forest biome and land use type	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR	Total
Boreal	**-4,031**	**1,867**	**27**	**-116**	**0**	**-35,674**	**-760**	**212**	**-1**	**-531**	**-723**	**0**	**-39,731**
Natural	-24,301	-6,425	-590	-125	0	-36,080	-1,400	-4,526	-2	-1,238	-836	0	-75,523
Managed	20,270	8,293	618	8	0	406	639	4,738	0	707	112	0	35,791
Tropical	**219**	**0**	**4**	**-24**	**27**	**0**	**-39**	**19**	**-6,288**	**0**	**392**	**-3,282**	**-8,973**
Natural	-10	0	6	-225	-205	0	-654	-236	-16,503	0	-2,905	-13,824	-34,556
Managed	229	0	-1	201	232	0	615	254	10,215	0	3,296	10,542	25,583
Warm mixed	**17**	**282**	**102**	**-1,270**	**459**	**-1**	**-3,730**	**243**	**-705**	**0**	**-4,194**	**-8,187**	**-16,983**
Natural	-13,248	-1,335	207	-1,935	397	-1	-10,089	-7,811	-2,018	0	-4,745	-10,181	-50,760
Managed	13,265	1,617	-105	665	62	0	6,359	8,053	1,313	0	552	1,994	33,777
Temperate mixed	**303**	**1,870**	**1,666**	**-147**	**0**	**-6,252**	**-427**	**12**	**0**	**-5,584**	**-115**	**0**	**-8,674**
Natural	-14,299	-8,620	-864	-167	0	-6,231	-1,008	-759	0	-5,254	-147	0	-37,347
Managed	14,602	10,489	2,530	20	0	-21	580	771	0	-331	32	0	28,673
Cool coniferous	**-1,252**	**-781**	**57**	**0**	**0**	**-4,621**	**-437**	**-5**	**0**	**-216**	**0**	**0**	**-7,254**
Natural	-5,257	-5,288	-981	0	0	-4,627	-869	-1,078	0	-671	0	0	-18,772
Managed	4,005	4,507	1,038	0	0	7	432	1,073	0	455	0	0	11,517
Temperate deciduous	**200**	**5,673**	**1,366**	**-280**	**0**	**-426**	**-613**	**92**	**-25**	**-423**	**-19**	**-146**	**5,400**
Natural	-8,342	-4,056	2,424	-449	0	-422	-4,092	-5,043	-83	-401	-40	-153	-20,657
Managed	8,542	9,729	-1,058	169	0	-4	3,479	5,135	58	-21	21	6	26,057
Total	**-4,545**	**8,912**	**3,224**	**-1,836**	**486**	**-46,974**	**-6,007**	**572**	**-7,019**	**-6,754**	**-4,659**	**-11,616**	**-76,216**
% Δ (2000 base):total	-0.5%	+3.8%	+7%	-3.3%	+0.3%	-4.2%	-17.3%	+0.2%	-3.4%	-26.6%	-1.6%	-7.1%	-2.2%

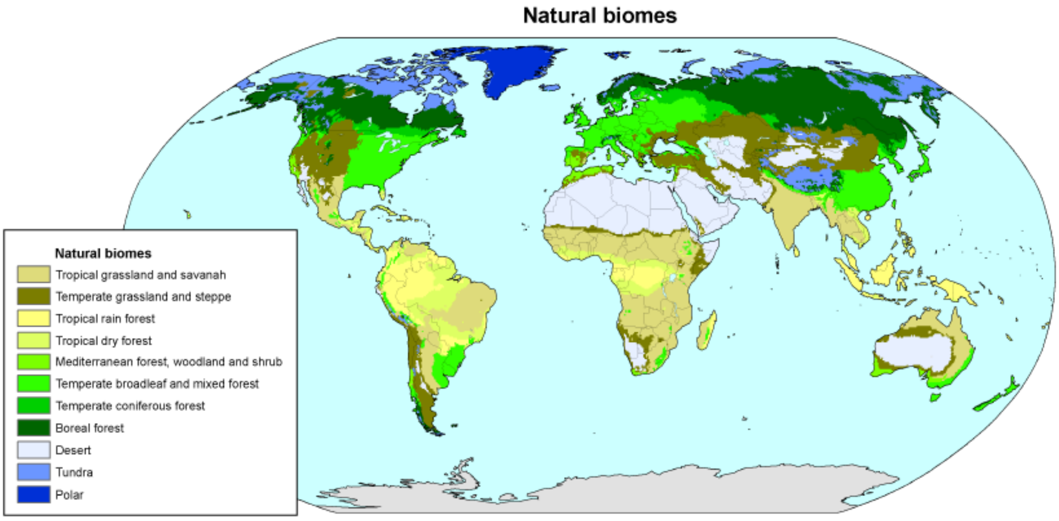

Figure 2: Current geography of the major world biomes, as used in the GLOBIO model framework (source: Braat et al. 2008).

3.2 Valuing forest ecosystem services: from site-specific values to world wide estimates

Several valuation methods can be applied to estimate the monetary value attached to environmental services (ESs) provided by forest biomes. By using the well-known notion of Total Economic Value (TEV), and depending on the nature of the good being valued, we can identify the best available valuation methodology to be employed for the monetary estimation of each ES of concern (see, e.g., Pearce and Moran, 1994). Broadly speaking, depending on the nature of the ecosystem service to be quantified, both market and non-market (revealed and stated preference) valuation techniques have been applied in the literature from which draw suitable marginal values for forest services, to be scaled up at the global level using proper transfer protocols. Given the global perspective of this exercise, it is essential to rely on the full body of knowledge already available in the environmental economics literature in order to gather estimates that cover, for each service to be valued, the highest variability in terms of countries (OECD regions) and forest types (biomes). In this regard, a crucial role is played by the use of research synthesis techniques, such as meta-analysis and value transfer. Thus, for each forest ES, we first performed a meta-analysis whenever possible and, second, applied value transfer protocols to adjust available values to new, unexplored, contexts.

Meta-analyses have been applied to cultural forest ecosystem services, namely recreation and passive use. By means of multivariate meta-regressions, meta-analysis enables us to explain the variance of the available WTPs (Willingness-To-Pay) as a function of few statistically significant explanatory variables. In particular, main explanatory factors for forest recreation and passive use are: i) size of recreational forest sites – and, for passive use, size of forest areas designated to biodiversity conservation – ; and ii) income level in the study area.

As for provisioning and regulating services, the estimation process was based on market data, actual and estimated, respectively. Data on forest products were drawn from the database on forests of the Food and Agriculture Organization (FAO) of the United Nations. Marginal values were estimated with adjustments taking into account: product category or industrial sector; country of origin; forest biome; forest size designated to production; profitability of the forest sector. The estimated prices per ton of carbon sequestered were taken from the EU-funded project CASES "Cost Assessment of Sustainable Energy System", providing price ranges for the baseline year of reference (2007) and few future scenarios (see CASES).

In the following sections we discuss in detail the methodological approach applied for estimating the economic marginal values of each of the four ecosystem services under analysis.

3.3 Provisioning services

Bearing in mind the MEA (i.e. food, fiber, and fuel), we classify the forest provisioning services into two main categories: wood forest products (WFPs) and non-wood forest products (NWFPs). Each of them is further detailed in table 4, according to different industrial sectors in the market, as proposed by the FAO forest database (see FAO/ForestSTAT).

Table 4: The Provisioning Services Provided by Forest Ecosystem

Wood forest products (WFPs)	**Non-wood forest products (NWFPs)**	
	Plant products	**Animal products**
• Industrial Roundwood • Wood pulp • Recovered paper • Sawnwood • Wood-based panels • Paper and paper board • Wood fuel	• Food • Fodder • Raw material for medicine and aromatic products • Raw material for colorants and dyes • Raw material for utensils, crafts & construction • Ornamental plants • Exudates • Other plant products	• Living animals • Hides, skins and trophies • Wild honey and beeswax • Bush meat • Other edible animal products

Sources: FAOSTAT and FAO/FRA 2005.

The economic value of the provisioning services is a direct use value and is estimated using market valuation methodologies based on quantities and prices available from Food and Agriculture Organization of the United Nations (FAO) database on forests.

The methodological framework to derive the marginal values as presented in Figure 3, involves two main valuation steps. The first calculates total provisioning values for each world region and forest biome. For this purpose, FAO export values at country level by different product categories are adjusted for domestic production quantity and converted into estimates of net income. The second step combines the estimated total values with information about the different forest biomes size, in order to derive the annual marginal values per hectare, by forest biome and world region. For this purpose only the hectares actually designated to production are used (See Braat et. al, 2008 and FAO, 2005). According to this framework, marginal values for forest provisioning services vary in relation to the product category or industrial sector (WFPs and NWFPs), the country of origin, the forest biome, and the forest size designated to production.

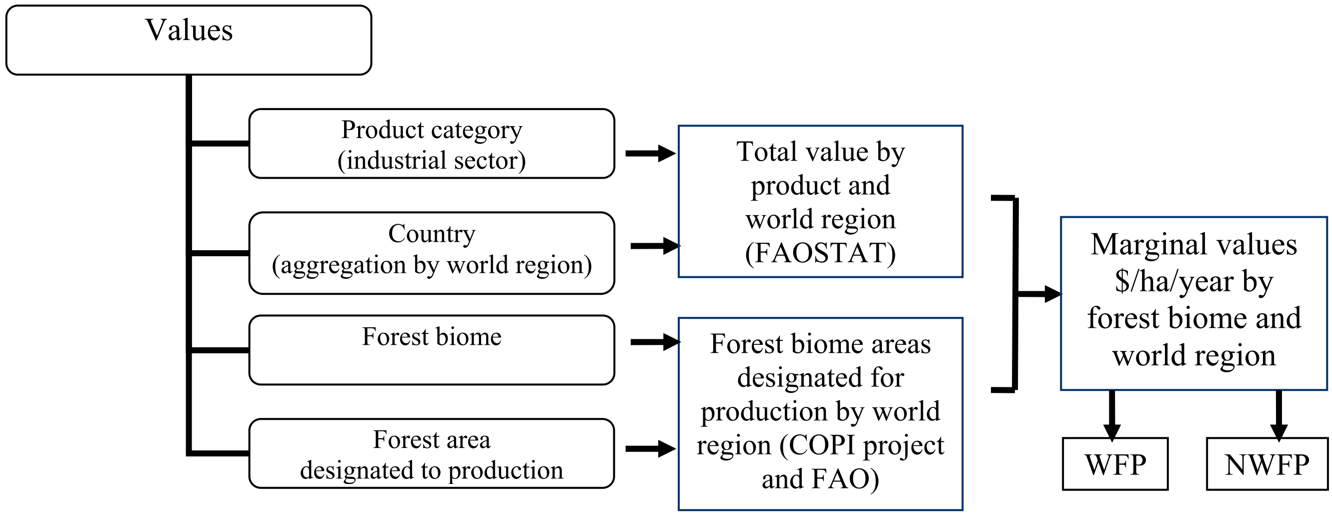

Figure 3: Methodological valuation framework for forest provisioning services

In the first valuation phase, for each forest product, export values at the country level are adjusted for estimating total provisioning values, taking into account domestic production and export quantities (FAOSTAT), as follows:

(1) $$TV_i = EV_i \frac{Pq_i}{Eq_i}$$

Where:
TV_i = annual total forest provisioning value by country *i*
EV_i = annual export value by country *i*
Pq_i = annual domestic production quantity by country *i* (forest products produced within country *i*)
Eq_i = annual export quantity country *i*
i = country

Total values are further corrected for the profitability of the forestry sector, taking into account financial returns from the wood forest production. Returns to the forest owner consist of sales of timber and other wood forest products, increases in the value of the lands, less costs of production and any net payments of taxes. The costs are employment and other purchases costs. For the want of anything more detailed and reliable, the net financial return from forestry is here assumed to be the same for all regions and equal to 8.2 percent per annum in the three-year period 2003-2006 (see UK Forestry Statistics, 2007).

The resulting net values are then summed up across sectors and countries to compute the aggregate benefits deriving from forest provisioning services, for each world region and for each industrial sector:

(2) $$NV_{wr} = \sum_{wr=1}^{n} NV_{i \subset wr}$$

Where:
NV_{wr} = annual forest provisioning net value by world region *wr*, adjusted for profits
NV_i = annual forest provisioning net value by country *i*, adjusted for profits
wr = world region: 1, 2, …, *n*
i = country

In the second valuation phase, by assuming a linear relationship between marginal values and forest biome size, annual forest provisioning net values by world region *wr*, $NV_{wr,b}$, are attributed to each forest biome in proportion to their respective forest area (source: COPI project and FAO 2005):

$$V_{wr,b} = \frac{NV_{wr,b}}{Sp_{wr,b}} \tag{3}$$

Where:
$V_{wr,b}$ = annual value per hectare by world region *wr* and forest biome *b*
$NV_{wr,b}$ = annual total provisioning value per world region *wr* by forest biome *b*
$Sp_{wr,b}$ = forest area size designated to production per world region *wr* by forest biome *b*
wr = world region
b = forest biome

Marginal values are computed in US$ 2005, and then converted into € 2007. To project the future trends of real wood price in 2050, we refer to two studies (Clark, 2001; Hoover, and Preston, 2006) that analyze long-term historical data. Clark (2001) offers a theoretical analysis and an empirical examination of wood prices, based on aggregated global wood market data over the last three decades. Hoover and Preston (2006) analyses trends of Indiana (USA) forest products prices using statistical data from 1957 to 2005. Although different in the spatial scale of the analyses, both papers lead to a similar conclusion: there is no evidence of increase in real prices for wood. We therefore assume that real prices of wood products will remain stable in the future, while allowing different prices to exist across countries and continents.

3.4 Regulating services: carbon sequestration

The methodological framework for valuing carbon sequestration is built on two phases. First, we identify the biomass carbon capacity by forest type and world region (measured as ton of C stocked per hectare, tC/ha). Secondly, we compute annual marginal values of carbon stocked per hectare by using some available estimated market values.

Quantities of carbon stored by forest biome and geographical region (measured in tons of carbon, tC) are drawn from studies by Myneni et al. (2001) and Gibbs (2007). Myneni et al. (2001) provides estimates of carbon stocks for temperate and boreal forest in Canada, Northern America, China, Japan, Russia, Finland, Sweden, Eurasia and South Eastern Asia. Gibbs (2007) provides estimates of carbon stocks for tropical and warm mixed forests in Brazilian Amazon, Latin America, Sub-Saham Africa and Tropical Asia (see Table 5). For world regions not directly covered by these studies, values are transferred from similar geographical regions.

Table 5: Biomass carbon capacity in the world forests (tC/ha)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	37.37*	37.37*	37.37**	37.37**	-	37.37*	59.4**	25.77*	59.4**	37.98*	34**	-
Tropical	92**	-	149**	149**	186*	-	225*	96**	92*	-	149*	200*
Warm mixed	92**	92**	100**	134**	168*	92**	180*	78**	78**	-	134*	168**
Temperate mixed	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	0	59.4*	59.4**	-
Cool coniferous	37.37**	37.37**	37.37**	-	-	37.37**	59.4**	25.77**	0	37.98**	-	-
Temp. deciduous	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	59.4*	59.4*	34.88*	59.4**

Note: (*) Directly reported from the original studies by forest type and geographical region. (**) Transferred from the original studies to similar world regions. Source: R.B. Myneni et al. (2001); H.K. Gibbs (2007).

Carbon stocks vary mainly according to two factors: forest type, tree species having different biomass); and forest area. Following the equation below one can thus estimate annual per hectare values of carbon sequestration:

(4) $$V_{wr,b} = \left(tC / ha_{wr,b}\right) * \$ / ha$$

Where:
$V_{wr,b}$ = annual value per hectare by world region *wr-th* and forest biome *b-th*
$tC/ha_{wr,b}$ = tons of carbon stocked per hectare by world region *wr* and forest biome *b*
$/ha = value per hectare of carbon stocked
wr = world region

Estimated prices per ton of carbon sequestered are taken from the EU-funded project CASES ("Cost Assessment of Sustainable Energy System"), providing price ranges for the baseline year of reference (2007) and for future period scenarios. In particular, lower estimates are based on the Marginal Damage Cost (MDC) approach; while higher estimates are based on the Marginal Avoidance Cost (MAC) approach, assuming the EU target of a 30 percent reduction in 2020 compared to 1990 (for details see CASES). Table 6 reports lower and upper bound monetary values for 2007 and 2050.

Table 6: Monetary values for carbon sequestration (Euro)

Costs [Euro]			
MDC (lower-bound)		MAC (upper-bound)	
Year 2007	Year 2050	Year 2007	Year 2050
6.43	23.11	15.8	179.6

Note: Source http://www.feem-project.net/cases/documents/deliverables/ExternalCosts_per_unit_emission_080313.xls

3.5 Cultural services: recreation and passive use

3.5.1 The economic model

Not being traded in regular markets, recreation and passive use values are usually measured as willingness to pay (WTP) figures using non-market valuation approaches (namely: travel cost method, contingent valuation and choice experiments). According to previous literature reviews on cultural values, a simple expected utility specification can be used to describe how individuals are willing to trade wealth for increases or decreases of forest cultural services, under the assumption that the estimated marginal value of the service decreases with an increase in the size of the forest site, and increases with an increase of the income level of the country where the forest is located (e.g., Hammitt, 2000).

The results of our meta-analyses confirms such expectations both for forest recreation and passive use values: income level and size of forest areas are the main statistically significant factors explaining variation in WTP estimates for changes in forest cultural services (see Tables 13 and 17). The meta-regression function can therefore be written as:

(5) $$V = f\left(S, I\right)$$

Where:
V is the marginal value (willingness to pay, WTP) of a given forest site designated to recreation or conservation of biodiversity (*effect size*).
S is the size of the forest area designated to recreation or conservation [hectares]
I is the income level [measure as PPPGDP]

By running the regression function expressed by equation (5):

(6) $$\log V = \alpha + \beta \log S + \gamma \log I$$

we can therefore obtain an estimate of the marginal effect − on the recreational or passive use value of a given site, V − of: i) the size of the forest site designated to recreation (or conservation), represented by β, and ii) of the income level of the country where the site is located, represented by γ. These coefficients are used for the geographical as well as the inter-temporal value-transfer.

For recreation and passive use services the following operational steps have been applied: (i) creation of a database of all available WTP estimates selected from a worldwide literature review; (ii) estimation of a meta-regression function based on suitable WTP values; and (iii) application of value transfer procedures for spatial and inter-temporal transfer. Firstly, the literature retrieval process has lead to a selection of suitable case studies providing WTP estimations of recreational and passive use values in different unit of measure[3]. Secondly, after conversion of all values in WTP per hectare[4], and following Equations (5-6), the usable WTP estimates have been employed to estimate - for recreational and passive use separately - the income level and forest site's size coefficients (see Tables 13 and 17). Lastly, marginal values have been transferred in space and time following a two-step approach. The following sections illustrate the transfer strategies used for the each of the two cultural services: recreation and passive use.

3.5.2 Value transfer for recreational forest use

Building on the results of the meta-analysis for the recreational values, we can apply a simple value transfer exercise to measure the total annual value of a forest recreational site (the 'policy site') not yet estimated by previously performed original case-studies (the 'study sites'). In doing this, we focus on one single exemplar country, the UK, for which we have a representative and high quality picture of forest recreational sites and their monetary values, and estimate a recreational value for all the existing forest sites in it[5]. For the sake of this exercise, the study-site is the one addressed by Scarpa, et al. (2000); β is the meta-regression size coefficient; H denotes the size of the forest recreational site; and V denotes the marginal (per hectare) value of the site. Results of the meta-regression are provided in section 4.3.

The marginal value of the n-th recreation policy site in the UK, V_n, can thus be estimated with a transfer based on the study-site value, V_s, as:

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[3] Part of the literature review and computations of standardized marginal values per hectare per year in US$2000 has been conducted within Ojea, E., Nunes, P.A.L.D. and M.L.G. Loureiro (2008) "Impacts of Climate Change and Biodiversity Effects: Evidence from a Worldwide Meta-analysis on Forest Ecosystem Values", Mimeo, Fondazione ENI Enrico Mattei, Venice, Italy. Further details are available upon request to the authors.

[4] All the estimates are computed in US$2000 (standardized WTP estimates per hectare per year) and then converted into €2007.

[5] The literature is rich of many studies on the value of forest recreation for UK. In addition, UK has a rich and completed database on protected forest areas, the so called Special Areas of Conservation (SACs). By definition, SACs are strictly protected sites designated under the European Habitats Directive. For the sake of the present study, only the forest related SACs are considered for recreational use. The reasons for this choice are related to the availability of detailed data on recreational forest size and to the notion of accessibility of the site. This latter is a crucial feature in the valuation process, because the use of recreational services and the associated economic value depends strongly on the accessibility of the area. The values for recreational use are higher in accessible systems while they drop significantly in degraded systems.

(7) $$V_n = V_s (H_n / H_s)^{\beta}$$

where *n* denotes the policy sites (with *n* =1,2,.., *N*); and *s* denotes the study site.

From Equation (7) we are now able to derive the marginal annual value of an average recreational forest site in UK, V_{UK}, as:

(8) $$V_{UK} = \sum_{n=1}^{N} V_n \Big/ \sum_{n=1}^{N} H_n$$

V_{UK} can then be transferred to all the other *i-th* geographical regions in the world, by correcting for income differences and population density as illustrated by Equation (9).

(9) $$V_i = V_{uk} \left(\frac{N_i}{N_{uk}} \right) \left(\frac{Sr_{uk}}{Sr_i} \right)^{\beta} \left(\frac{PPPGDP_i}{PPPGDP_{uk}} \right)^{\gamma}$$

Where:
V_i = estimated annual value per hectare for country *i-th*
V_{UK} = estimated annual value per hectare for UK
Sr_i = forest area designated to recreation in country *i-th*
S_{UK} = forest area designated to recreation in UK
N_i = number of households in country *i-th*
N_{UK}= number of households in UK
$PPPGDP_i$ = GDP adjusted for PPP (purchasing power parity) in country *i-th*
$PPPGDP_{UK}$ = GDP adjusted for PPP (purchasing power parity) in UK
i = country
γ = income coefficient
β = size coefficient

Information about forest areas designated to recreational activities by country is drawn from FAO/FRA 2005. Marginal values are computed in €2000, and then converted into €2007. Lastly, values are projected from 2007 to 2050 using projections on population, *PPPGDP*[6] and forest area in different biomes and land cover types (from COPI project), according to the following computation for inter-temporal transfer:

(10) $$V_{i,T_1} = V_{i,T_0} \left(\frac{H_{i,T_1}}{H_{i,T_0}} \right) \left(\frac{S_{i,T_0}}{S_{i,T_1}} \right)^{\beta} \left(\frac{PPPGDP_{i,T_1}}{PPPGDP_{i,T_0}} \right)^{\gamma}$$

Where:
T_1 = year 2050

[6] Population and GDP per capita in PPP are computed in year 2000 and projected in year 2050, according to the figures used in the COPI project (see Braat et al. 2008). As for population, the UN projections based on a "medium" scenario are used, showing a stabilization of the world population at around 9.1 billion inhabitants by 2050 (UN, 2005). Almost all of this increase is expected in the developing world. As for GDP, the baseline scenario in the COPI project expects a positive and uniform growth in real GDP of 2.8% per year between 2005 and 2050.

T_0 = baseline year (2000 for population, *PPPGDP* and forest size; 2007 for monetary values)

3.5.3 Value transfer for forest passive use

As for passive use, the transfer procedure is based on somewhat different methodological assumptions. Due to lack of information on protected forest sites for different types of forest, the approach developed for recreation cannot be used for passive use values, which are strongly influenced by the type of forest ecosystem. After screening the available literature, we select few high-quality valuation studies providing marginal values (at country level) associated with specific forest typologies (see Table 7). When several representative case studies are available, the mean marginal value is used.

Table 7: Original studies selected for the first step value-transfer

OECD world Region	Original case study	Reference study	Forest type
EUR	UK	Garrod, G.D. and Willis, K. G. (1997) Hanley, N., Willis, K, Powe, N, Anderson, M. (2002) ERM Report to UK Forestry Commission (1996)	Temperate
EUR	Finland	Kniivila, M., Ovaskainen, V. and Saastamoinen, O. (2002) Siikamaki, Juha (2007)	Boreal
EUR	Spain	Mogas, J., Riera, P. and Bennett, J. (2006)	Warm mixed
NAM	USA	Phillips, S., Silverman, R. (2007) Loomis and Ekstrand (1998) Walsh, R.G., J. B. Loomis and R. A. Gillman (1984)	Temperate
BRA	Brazil	Horton, B., Colarullo, G., Bateman, I., Peres, C. (2003)	Tropical
CHN	China	Kontoleon, A. and Swanson, T. (2003)	Temperate
AFR	Madagascar	Kramer, R.A., Sharma, N., and Munashinghe, M. (1995)	Tropical

Estimates for forest types from original case studies are then scaled up to the corresponding higher geographical region and forest biome, by taking into account the effect of the size of the forest area under valuation, β:

(11) $$V_{wr,b} = V_{i,b}\left(\frac{Sc_{i,b}}{Sc_{wr,b}}\right)^{\beta}$$

Where:
$V_{wr,b}$ = estimated annual value per hectare by world region *wr* and forest biome *b*
$V_{i,b}$ = annual value per hectare for country *i-th* by forest biome *b-th* (from representative case studies for different forest biomes)
$Sc_{i,b}$ = forest area designated to conservation in country *i-th* by forest biome *b-th*
$Sc_{wr,b}$ = forest area designated to conservation in the world region *wr-th* by forest biome *b-th*
i = country
wr = world region
b = forest biome

Lastly, similarly to what done for recreation values, we transfer forest biome values to world regions not yet covered, by correcting for income and population effects, as illustrated in Equation (12):

$$V_{WR,b} = V^{*}{}_{wr,b}\left(\frac{N_{WR}}{N_{wr}}\right)\left(\frac{S_{wr,b}}{S_{WR,b}}\right)^{\beta}\left(\frac{PPPGDP_{WR}}{PPPGDP_{wr}}\right)^{\gamma} \qquad (12)$$

Where:
$V_{WR,b}$ = estimated annual value per hectare by region *WR* and forest biome *b*
$V*_{wr,b}$ = annual value per hectare by region *wr-th* and forest biome *b-th* (first step estimation)
$Sc_{wr,b}$ = forest area designated to conservation in region *wr-th* by forest biome *b-th*
Sc_{WRb} = forest area designated to conservation in region *WR* by forest biome *b-th*
N_{WR} = number of households in region *WR*
N_{wr} = number of households in region *wr-th*
$PPPGDP_{WR}$ = GDP adjusted for PPP (purchasing power parity) in region *WR*
$PPPGDP_{wr}$ = GDP adjusted for PPP (purchasing power parity) in region *wr-th*
$w_{r,b}$ = world region (first step valuation)
$W_{R,b}$ = world region (to be estimated)
b = forest biome

Data on forest areas designated to biodiversity conservation by country are taken from FAO/FRA2005. Marginal values are computed in €2000, and then converted into €2007. Finally, values are projected from 2007 to 2050, by using projected population, *PPPGDP* and forest area in different biomes and landuse types, following using Equation (9).

3.6 Estimation of total economic value changes

The estimated marginal values for 2007 and 2050 are combined with information about forest size (by world region, forest biome and land use type), in order to compute the value of total economic changes for the four ecosystem services in the two time frames. The difference between the two values represents the cost or benefit associated with biodiversity loss in year 2050. For this purpose we use the estimated forest size, calculated within the COPI project in the baseline year 2000 and projected figures for 2050. For provisioning services, we use only the forest areas actually designated to production (within the managed forest)[7]. Carbon sequestration is instead expected to occur in both natural and managed forests, so all the forest areas are considered to compute total economic values. As for cultural services, we use the forest area designated to recreation (which might occur in both natural and managed forest) or conservation of biodiversity (in natural forest). This information is available from FAO for the year 2005 (see FAO/FRA 2005). For projections in 2050, we assume no variation over time in the percentage of forest area designated to recreation or conservation. This approach allows us to estimate total economic changes in the value of forest biodiversity services according to three main dimensions: ecosystem service, forest biome and geographical region.

In order to calculate the cost or benefit associated with potential loss of biodiversity, the projected total values in year 2050 are discounted using the conventional 3 percent discount rate (used by the European Commission), and then compared to the total values estimated for the baseline year 2007.

[7] No provisioning service exists, by definition, in a natural ecosystem.

4 Results

Results are presented for each ecosystem service, by forest biome and world region, in terms of marginal values in year 2007, projected marginal values in year 2050, and total economic losses in year 2050.

4.1 Provisioning services

Table 8Table 8 reports the marginal values of provisioning services, estimated by world region and forest biome, adjusted for profitability, and converted in €2007. Differences in marginal values across world regions and forest biomes can be interpreted as the combined result of: i) total production values by forest product and distribution of wood and non-wood sectors across forest biomes and world regions, ii) distribution of forest area across world regions, and iii) incidence of forest area designated to production in each world region. Wood forest products represent the most relevant part of the economic value.

The reasons for some high marginal values (in AFR, ANZ, JPK and CHN) can be explained as follows. For AFR this is due to the high production value of wood fuel, while for CHN this is explained by the high production value of two sectors, paper and paperboards, and wood fuel. Finally, for ANZ and JPK, the effect is attributable to the small forest area designated to production.

Table 8: Marginal value of provisioning services by world region and forest biome, adjusted for profits (2007€/ha/year)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	740	246	770	1,765	-	96	874	1,134	1,375	147	619	-
Tropical	10	-	2.4	126	368	-	59	17	916	-	300	1,886
Warm mixed	177	14	51	827	98	0.1	550	469	72	-	138	402
Temperate mixed	304	99	943	67	-	73	56	55	-	159	6	-
Cool coniferous	158	107	1,490	-	-	13	372	217	-	91	-	-
Temp. deciduous	155	142	631	252	-	4.9	231	431	1.9	12	1.8	15

Total economic value changes due to biodiversity loss in 2050 are presented in Figures 4-5. Results show large economic losses for provisioning services in all the world regions and forest biomes. This is the result to the combined effect of marginal price estimates and incidence of forest area designated to production. Total costs are expected be around €48 billion worldwide. They range from €374 million for ECA to €17 billion for NAM (Figure 4), which is expected to face the highest costs (more than one third of total costs worldwide). After NAM, the highest costs are foreseen for OAS, CHN and EU, accounting for respectively 14 to 11 percent of total costs. As shown in the Annex (Table A1), the economic value for provisioning services in 2050 is expected to decrease by about 49% globally with respect to the baseline year 2007, ranging from -22% in AFR to -72% in RUS. As regards the forest biomes, the highest loss is expected in boreal and tropical biomes, the former and the latter accounting for 38 (mainly in NAM) and 26 (mainly in OAS) percent of the total global loss respectively (Figure 5 and Table A1 in Annex).

Figure 4: Total economic value changes for provisioning services by world region, in 2050 (Million Euro 2007, r=3%)

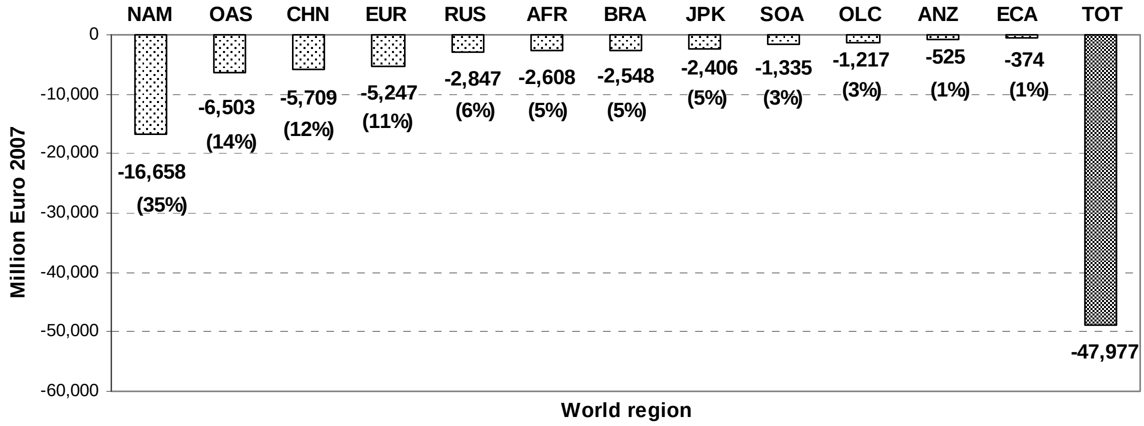
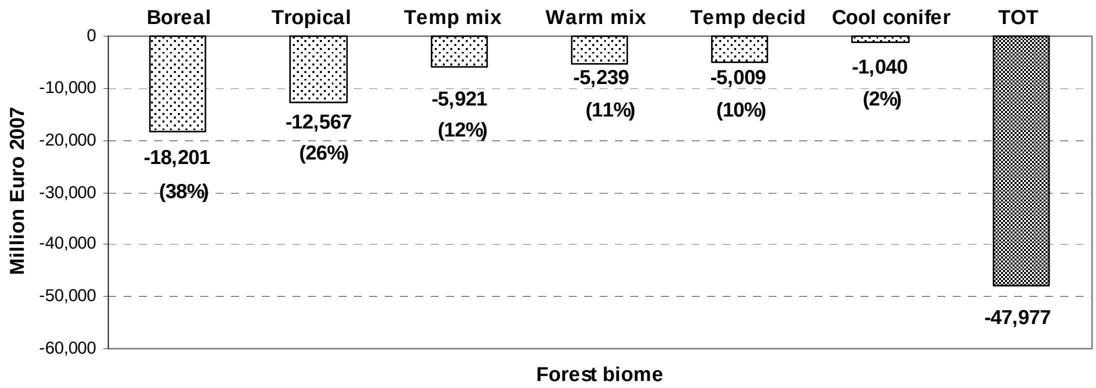


Figure 5: Total economic value changes for provisioning services by forest biome, in 2050 (Million Euro 2007, r=3%)



4.2 Regulating services: carbon sequestration

Tables 10-11 show the most conservative estimates for carbon sequestration in terms of annual per hectare values in €2007 and €2050. As expected, given the high capacity of carbon sequestration estimated in tropical and warm mixed forest biomes, the highest marginal values are estimated for BRA, SOA and AFR.

Table 10: Marginal value of carbon sequestration by world region and forest biome (2007€/ha/year) - Lower bound estimates

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	240	240	240	240	-	240	382	166	382	244	219	-
Tropical	592	-	958	958	1,196	0	1,447	617	592	-	958	1,286
Warm mixed	592	592	643	862	1,080	592	1,157	502	502	-	862	1,080
Temperate mixed	328	382	304	328	-	244	1,080	166	-	382	382	-
Cool coniferous	240	240	240	-	-	240	382	166	-	244	-	-
Temp. deciduous	328	382	304	328	-	244	1,080	166	382	382	224	382

Table 11: Marginal value of carbon sequestration by world region and forest biome, projections in 2050 (2050€/ha/year) - Lower bound estimates

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	864	864	864	864	-	864	1,373	596	1,373	878	786	-
Tropical	2,126	-	3,443	3,443	4,298	0	5,200	2,219	2,126	-	3,443	4,622
Warm mixed	2,126	2,126	2,311	3,097	3,882	2,126	4,160	1,803	1,803	-	3,097	3,882
Temperate mixed	1,179	1,373	1,094	1,179	-	878	3,882	596	-	1,373	1,373	-
Cool coniferous	864	864	864	-	-	864	1,373	596	-	878	-	-
Temp. deciduous	1,179	1,373	1,094	1,179	-	878	3,882	596	1,373	1,373	806	1,373

Figures 6-7 present final computations of total economic value changes for year 2050. Total losses are expected to be around €25 billion worldwide. Some regions (mainly located in the developed world) show a benefit, which is explained by an increase in total forest size in those regions. This is specifically due to the fact that the expected increase in total managed forest is higher than the corresponding decrease in natural forests in those regions.

Figure 6: Total economic value changes for carbon sequestration by world region, in 2050 (Million Euro 2007, r=3%)

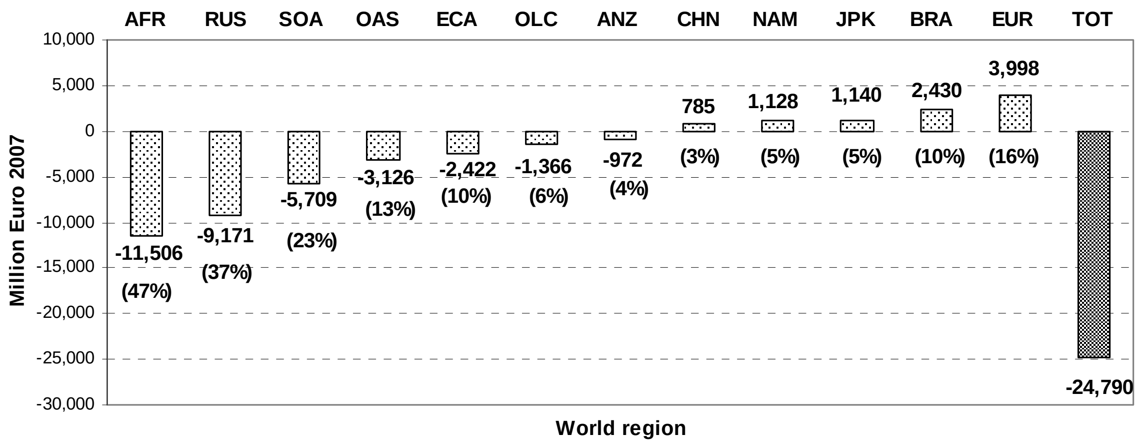
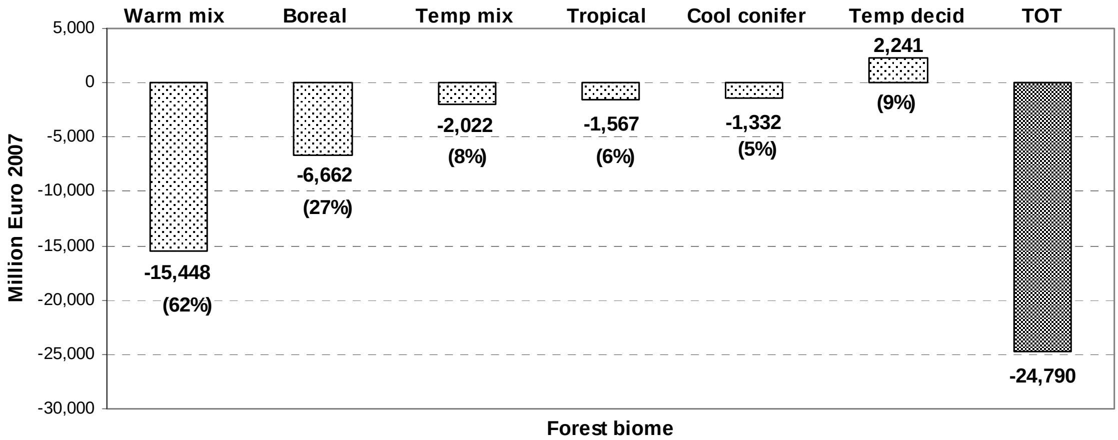


Figure 7: Total economic value changes for carbon sequestration by forest biome, in 2050 (Million Euro 2007, r=3%)



Most of the regions in the developing world, instead, report a loss, ranging from €1.3 billion for OLC to €12 billion for AFR, which accounts for almost 50% of the total loss worldwide. RUS and SOA follow with respectively 37 and 23 percent of total loss (Figure 6). The total economic value for carbon sequestration in 2050 shows a decrease by about 2% worldwide on average (Table A2 Annex) relative to the baseline year 2007. The highest relative loss is expected in ECA with a 27% decrease in value and in SOA with a 16% decrease relative to year 2007. Warm mixed (mainly AFR, SOA and OLC) and boreal forest biomes (mainly RUS) show the highest damage (Figure 7 and Table A2 Annex), while temperate deciduous forests report a benefit, which is explained by the projected increase in managed forest area in that biome.

4.3 Cultural services: recreational and passive use

Below, results for forest recreational use and passive use are reported and discussed separately. In the next sections we present the results of the meta-regression functions, marginal values for the baseline year 2007, projected values in year 2050, and finally total economic losses in 2050.

4.2.1 Recreational use

The results of the meta-regression for recreational forest sites are reported in Table 13. Overall, by using multiple sampling, 59 observations were used in the meta-regression. The β coefficient on forest recreation size (logSIZE) is negative and significant, showing that the marginal value of recreation decreases with a marginal increase in forest area. The γ income coefficient (logINCOME) is positive and significant, showing that the estimated marginal value of recreation increases with a marginal increase in income.

Table 13: Results of the meta-regression function for forest recreational values

Dependent variable: LogWTP	Coefficient (std.error)	T-value
Explanatory factors:		
constant	3.274 (3.698)	0.89
LogSIZE	-0.445 (0.073)	-6.14
LogINCOME	0.599 (0.352)	1.70
Nobs	59	
R^2	0.452	
Adj R^2	0.433	

Tables 14-15 report the results for annual marginal values of forest recreational services by world region and forest biome, in €2007 and €2050. As forest type changes, marginal values remain stable as we assume that this variable does not affect the recreational use of forest, in accordance with the original studies used for valuation where WTP is estimated regardless of the type of forest.

Overall, recreation marginal values appear to be rather small, ranging from 0.11 to 4.74 €2007. This result is mainly driven by the large forest area dedicated to recreational use, which leads to a low value per hectare. Highest values are estimated for CHN and JPK. As regards CHN, this is due to a population effect (i.e. high number of households). As for JPK, the high value signals an income effect. As for OAS, the marginal value is mainly influenced by the value estimated for Singapore, characterized by high income level and very small forest size. Finally, for SOA, the high value can be explained as a result of the small forest recreational size registered in Bangladesh and Pakistan; while the low marginal values in NAM are due to large forest recreational areas.

Table 14: Marginal value (WTP estimates) of recreational forest services by world region and forest biome (2007€/ha/year)

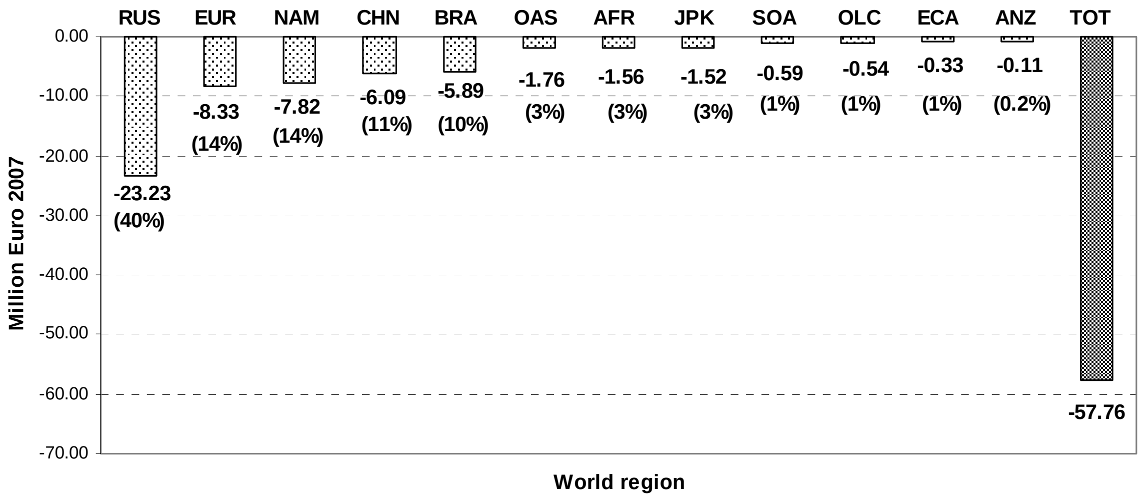
Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	2.28	0.20	0.30	-
Tropical	0.46	-	3.28	0.11	0.32	-	2.50	4.74	2.28	-	0.30	0.57
Warm mixed	0.46	1.33	3.28	0.11	0.32	0.28	2.50	4.74	2.28	-	0.30	0.57
Temperate mixed	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	-	0.20	0.30	-
Cool coniferous	0.46	1.33	3.28	-	-	0.28	2.50	4.74	-	0.20	-	-
Temperate deciduous	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	2.28	0.20	0.30	0.57

Table 15: Marginal value (WTP estimates) of recreational forest services by world region and forest biome, projections in 2050 (2050€/ha/year)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	4.70	0.41	0.62	-
Tropical	0.94	-	6.75	0.22	0.66	-	5.15	9.76	4.70	-	0.62	1.17
Warm mixed	0.94	2.74	6.75	0.22	0.66	0.58	5.15	9.76	4.70	-	0.62	1.17
Temperate mixed	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	-	0.41	0.62	-
Cool coniferous	0.94	2.74	6.75	-	-	0.58	5.15	9.76	-	0.41	-	-
Temperate deciduous	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	4.70	0.41	0.62	1.17

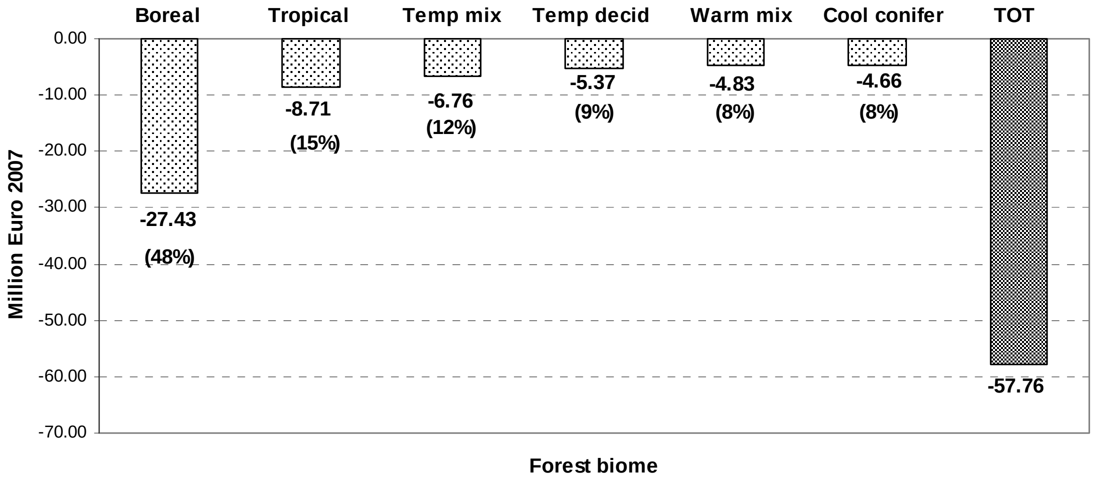
The estimated marginal values are applied to derive total values attributable to forest areas designated to recreation and the expected economic loss in year 2050, as reported in Figure 8 and 9.

Figure 8: Total economic value changes for recreational services by world region, in 2050 (Million Euro 2007, r=3%)



Results show an economic loss for all the regions and all the forest biomes, although rather low if compared with the figures estimated for provisioning and carbon sequestration. Total costs are expected to amount to €58 million in 2050, ranging from €0.11 million for ANZ to €23 million to RUS, which accounts for 40% of the total loss of recreation services. EUR, NAM, CHN and BRA account for 14% to 10% of total losses (Figure 8). Inter-temporal comparison between year 2050 and year 2007 shows a decrease in recreational values of about 47% globally, ranging from -42% in JPK and BRA to -83% in SOA (Table A3 Annex). As regards the forest biomes, the highest costs are registered in the boreal forests (mainly in RUS), followed by tropical (mainly in BRA) and temperate mixed forests (mainly in EUR) (Figure 9 and Table A3 Annex).

Figure 9: Total economic value changes for recreational services by forest biome, in 2050 (Million Euro 2007, r=3%)



4.2.2 Passive use

The results of the meta-regression for forest passive use are reported in Table 17. A total number of 23 observations are used for the regression. The β size coefficient (LogSIZE) on conservation forest area is negative and significant. The γ coefficient on income (logINCOME) is instead positive and significant, showing a negative correlation of marginal values and income. If compared with the results obtained for recreational activities, these coefficients are higher, showing a higher sensitivity of forest size and income on marginal values.

Table 17: Results of the meta-regression function for forest passive use values

Dependent variable: LogWTP	Coefficient (std.error)	T-value
Explanatory factors:		
constant	3. 972 (2.835)	1.40
LogSIZE	-0.603 (0.079)	-7.58
LogINCOME	0.889 (0.255)	3.49
Nobs	23	
R^2	0.797	
Adj R^2	0.797	

Table 18 presents the results from the first step value-transfer, estimating the marginal values from the original case study based on a country level to the corresponding world region.

Table 18: Value transfer results of passive use values from country level to the corresponding world region ($2000).

Forest type	Original case study country	COPI region	Designated forest area for conservation in the studied country (ha)	Designated forest area for conservation in EU (ha) (FAO/FRA 2005)	Value transfer of marginal value by forest type for Europe (2000$/ha)
Temperate	UK	EUR	42,988	12,602,559	119
Boreal	Finland	EUR	267,455	7,022,622	99
Warm mixed	Spain	EUR	274,235	1,745,662	254
Temperate	USA	NAM	11,524,983	21,912,059	501
Tropical	Brazil	BRA	16,350,329	16,350,329	53
Temperate	China	CHN	210,908	449,327	203
Tropical	Madagascar	AFR	4,143,307	33,898,452	10

Tables 19-20 show final results about annual marginal values for forest passive use services by world region and forest biome, in €2007 and €2050. These estimated marginal values are applied to derive total values of passive use applicable to forest areas designated to natural conservation. Outlier values, such as the one for tropical biomes in Japan are due to very small forest sizes.

Table 19: Marginal value (WTP estimates) of passive use by world region and forest biome (2007€/ha/year)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	22**	99*	855**	11**	-	2**	87**	113**	471**	14**	17**	-
Tropical	947**	-	7,404**	62**	53*	-	171**	847**	59**	-	30**	10*
Warm mixed	60**	254*	1,102**	3**	17**	243**	42**	108**	39**	-	7**	26**
Temperate mixed	501*	119*	293**	153**	-	8**	29**	203*	-	6**	8**	-
Cool coniferous	34**	99*	350**	-	-	3**	88**	185**	-	12**	-	-
Temperate deciduous	501*	119*	145**	46**	-	16**	42**	203*	207**	12**	57**	113**

Note: Some of the marginal values displayed have been estimated in the first step value-transfer, for which representative original studies exist (*), while the others (**) have been estimated by transferring these latter to the other world regions taking into account the forest type.

Table 20: Marginal value (WTP estimates) of passive use by world region and forest biome, projections in 2050 (2050€/ha/year)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	59	212	1,482	30	-	7	579	678	2,107	61	53	-
Tropical	2,511	-	12,837	164	142	-	1,146	5,095	262	-	96	62
Warm mixed	159	546	1,910	8	46	1,028	279	648	175	-	22	160
Temperate mixed	1,328	256	508	404	-	35	193	1,221	-	28	25	-
Cool coniferous	90	212	607	-	-	13	589	1,113	-	50	-	-
Temperate deciduous	1,328	256	252	122	-	69	281	1,221	925	50	182	692

Figures 10-11 show an economic loss for all the regions and all the forest biomes in year 2050, except for CHN and AFR. Total loss is estimated around €6 billion. The highest costs are expected in developed countries. NAM accounts for 62 percent of global damage (€3.6 billion), followed by EUR with 15 percent of total loss (€900 Million) (Figure 10). Total economic value associated with passive use of forests in 2050 is projected to decrease by about 34% worldwide with respect to the baseline year 2007 (ranging from -1% in RUS to -67% in JPK) (Table A4 Annex). As regards the forest biomes, the highest costs are registered in temperate mixed and temperate deciduous forests (NAM and EUR being the main responsible), followed by tropical forest (AFR, OAS and BRA) (Figure 11 and Table A4 Annex).

Figure 10: Total economic value changes for passive use by world region, in 2050 (Million Euro 2007, r=3%)

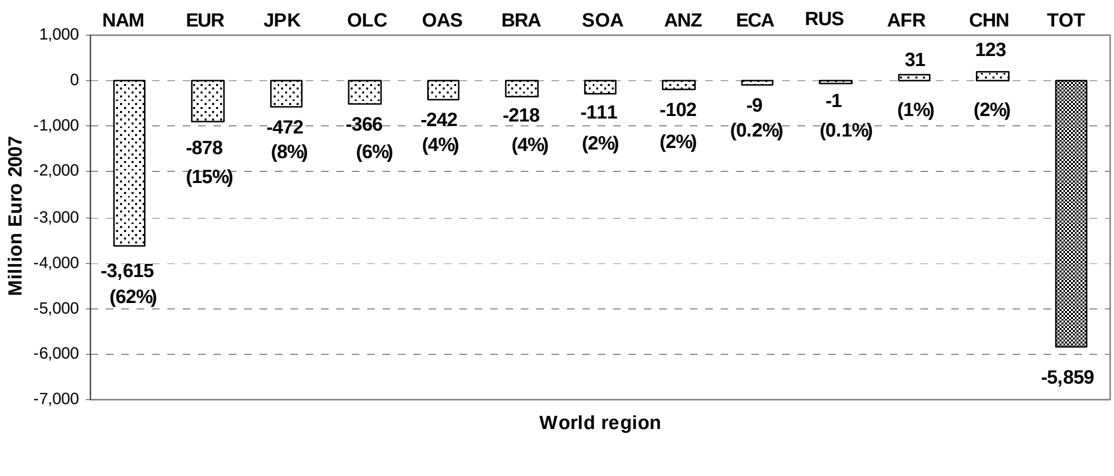
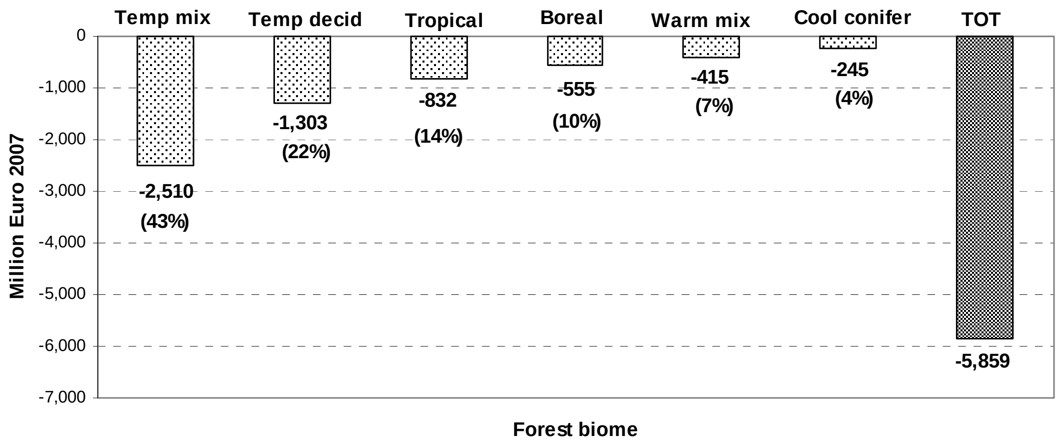


Figure 11: Total economic value changes for passive use by forest biome, in 2050 (Million Euro 2007, r=3%)



4.3 *Total biodiversity loss*

Table 22 gives the estimated 'total' biodiversity loss in one year (2050) resulting from business as usual in the way forests are managed and exploited. We put total in inverted commas because not all values are included: we could not value for example, supporting services (primary production like gas, oil, sand, shelves, etc, nutrient cycling and soil formation), some regulating services (air quality maintenance, soil quality, water and temperature regulation, natural hazard control), and some provisioning services (pharmaceutics, ornamental resources and fresh water), due to the difficulties in finding reliable data for value estimates. As the figures show, however, the quantified losses are significant. The total figure is around €79 billion, the greatest losses coming from NAM, followed by AFR, RUS and OAS. It should be noted that the high economic loss expected in NAM is attributable to a small reduction in the forest area, estimated around 0.5% (see Table 3). Other regions, like ECA, instead, show a small economic loss against a large reduction in forest area (around 27%, Table 3). Most of the global loss is attributable to provisioning services (€48 billion) and carbon sequestration (€25 billion), while only a minor part is due to loss of cultural services (€6 billion) (Figure 12).–In terms of biomes the greatest losses are from boreal forests followed by warm mixed and tropical forests (Figure 13). These results may be surprising to some who argue that it is the loss of tropical forests, particularly the Amazon that is the most significant. A detailed analysis shows, however, that this is not the case. The best estimates point to greater losses in areas where use and non-use values are highest, which includes North America.

Finally Figures 13-14 show the share of total loss among the three ecosystem services (provisioning, carbon and cultural services) according to geographical regions and forest biome. Most of the economic loss due to carbon sequestration is expected in developing countries (mainly AFR and RUS), in boreal and warm mixed forests. As for cultural services, the highest loss is expected instead in developed countries (mainly NAM), in temperate mixed and temperate deciduous forests. Finally for provisioning services, NAM is expected to face most of the loss, followed by OAS, CHN and EUR, mainly in boreal and tropical forests.

Figure 12: Total economic loss by ecosystem service, worldwide projections 2050 (Million Euro 2007, r=3%)

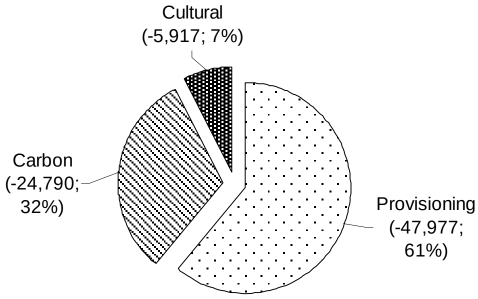


Figure 13: Total economic loss by forest biome, worlwide projections 2050 (Million Euro 2007, r=3%)

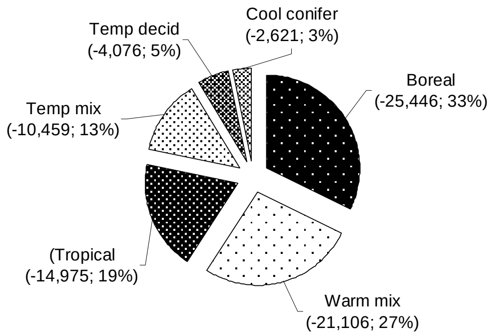


Table 22: Total economic value changes for ecosystem services by world region and forest biome, in 2050 (Million € 2007, r=3%)

Forest Biomes	NAM	AFR	RUS	OAS	SOA	CHN	OLC	ECA	EUR	JPK	ANZ	BRA	Total
Boreal	-11,054	0	-9,402	8	-438	-2,365	-220	-99	-1,883	36	-30	0	-25,446 (32%)
Tropical	53	-9,217	0	-9,494	-57	26	-1,035	0	0	-7	-17	-946	-14,975 (19%)
Warm mixed	-1,406	-9,417	0	-372	-5,147	-1,397	-3,628	0	113	32	-1,346	604	-21,106 (27%)
Temperate mixed	-4,450	0	-1,589	0	-465	-1	-38	-2,502	-416	-929	-76	0	-10,459 (13%)
Cool coniferous	-666	0	-952	0	-219	-88	0	-42	-839	185	0	0	-2,621 (3%)
Temp. deciduous	-1,630	-57	-99	-13	-831	-982	-6	-162	890	-1,057	-130	0	-4,076 (5%)
Total	-19,152 (24%)	-18,691 (18%)	-12,042 (15%)	-9,872 (13%)	-7,156 (9%)	-4,807 (6%)	-4,927 (4%)	-2,805 (4%)	-2,135 (3%)	-1,740 (2%)	-1,599 (2%)	-342 (0.4%)	-78,684

Figure 14: Total economic value changes by world region and ecosystem service, in 2050 (Million Euro 2007, r=3%)

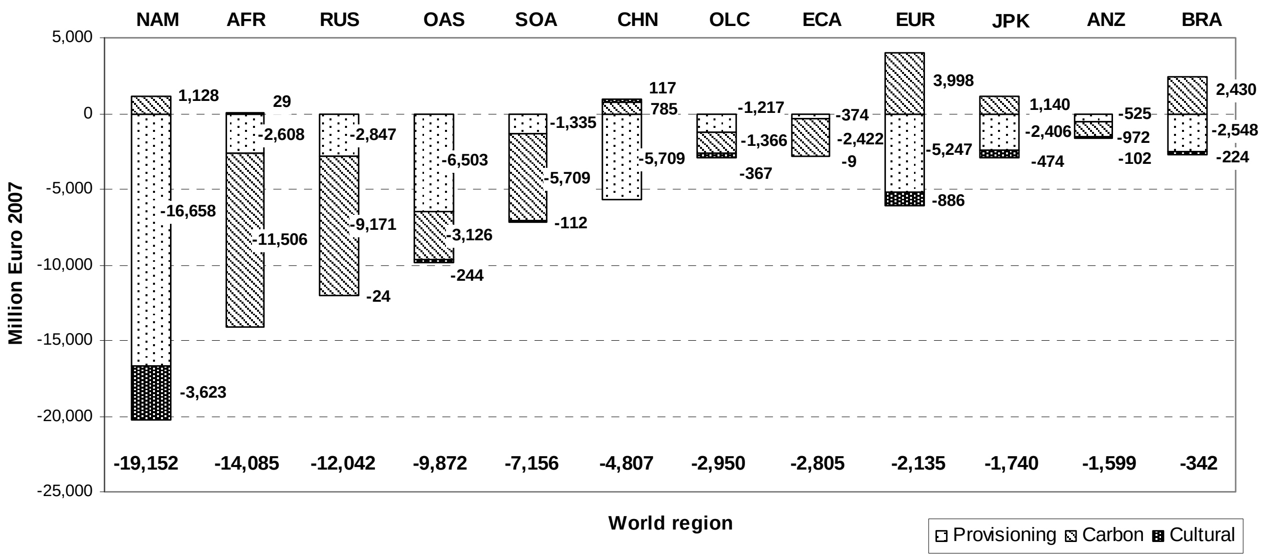
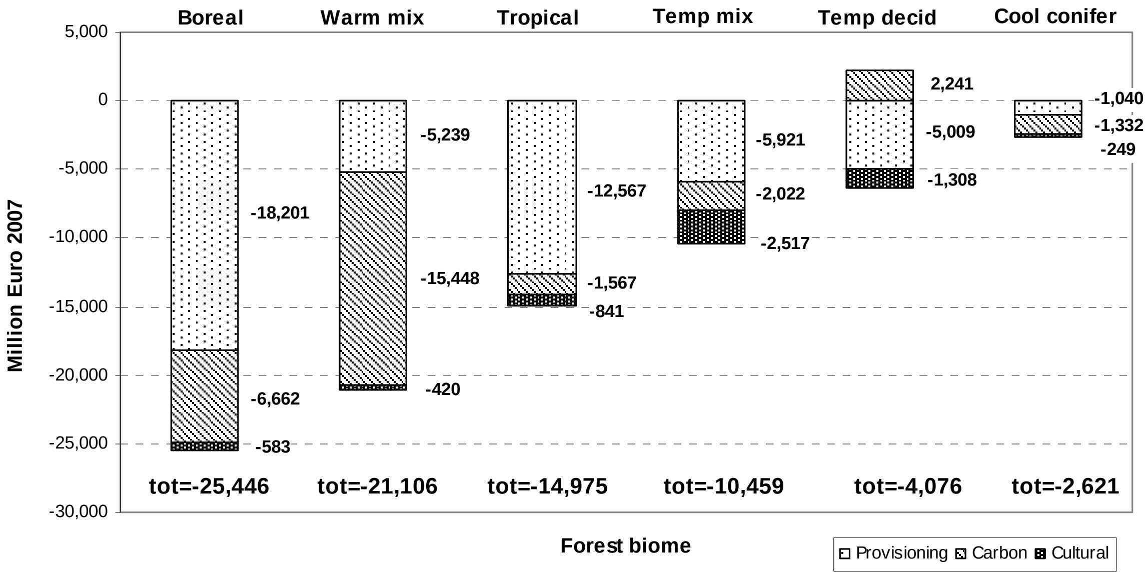


Figure 15: Total economic value changes by forest biome and ecosystem service, in 2050 (Million Euro 2007, r=3%)



5 Conclusions

The paper reports the methodology and the estimation of some of the services provided by forest biomes in different world areas, by applying consolidated methods for the monetary valuation of market and non-market goods. The objective is to provide a methodological framework for estimating marginal values and an outline on how to use value-transfer techniques.

The valuation framework has been applied to forest biomes, and specifically to key ecosystems services identified following the Millennium Ecosystem Assessment (MEA, 2005) taxonomy: provisioning services (wood forest products and non-wood forest products), regulating services (carbon sequestration), and cultural services (recreation and passive use values). This selection has been based on the availability of data and on their relevance to decision-making. The estimation of such services, although not covering the full range of forest instrumental values, allow the quantification of those values which are expected to be relevant to context where it is necessary to make decisions and trade one value against the other. Both market and non-market valuation techniques are applied; however, the present study mainly relies on the existing body of knowledge already available in the literature to draw suitable marginal values for forest services, to be scaled up at the global (OECD regions) level using proper transfer protocols.

Based on the nature of the ecosystem service of concern, we have identified the valuation methodologies already available in the literature for the monetary estimation. Provisioning services have been valued using a market-based approach (based on market prices). Carbon sequestration valuation is based on the Marginal Damage Cost (MDC) approach and the marginal avoidance cost (MAC), with the latter resulting in higher estimates then the first. Finally, cultural services are estimated using non-market valuation methods, based on both stated and revealed preferences approaches (travel cost method, contingent valuation and choice experiments). The valuation framework has been built in order to cover, for each ecosystem service, the highest variability in terms of geographical regions and forest biomes. In this context meta-analysis and value-transfer techniques appear to be the most suitable for cultural services valuation.

Regarding provisioning services, the valuation framework is comprised of two main phases: (i) calculation of total annual values, based on FAO export values at country level by different industrial sectors, and adjusted for domestic production and profits, and (ii) calculation of marginal values taking into account the forest size designated to production only. Marginal values for forest provisioning services have been therefore estimated taking into account the industrial sector (product category, wood forest products and non-wood forest products), the country of production, the forest type, and the size of the forest designated to production (plantations).

Carbon stocks have been estimated by identifying the capacity of carbon sequestration by forest type and country, and applying the monetary value estimated in the EU project CASES (Cost Assessment of Sustainable Energy System), based on damage and avoidance cost methodologies.

For cultural values, the meta-analysis has produced significant results in terms of the marginal effect of forest size and income level on the marginal value of the forest site, showing, as expected under the conventional assumptions, that the estimated marginal non-market value of forest cultural services decreases with an increase of the forest size, and increases with an increase of the income level. Value-transfer methodologies have been applied in order to transfer the estimates available from the original studies to the new policy contexts for which no original study exist. The value-transfer exercise has been developed based on a two-step approach. For recreational values we have first estimated marginal values for United Kingdom which provides a representative picture of forest recreation (value-transfer to UK forest recreational sites). The marginal value estimated for UK has been transferred to other world regions in the second step of the calculation. For passive use values, in the first step we estimated the marginal values by forest biome in some world regions (by transferring the values from country level to the corresponding world region), while in the second step we transferred these values from the estimated world regions to the other world regions. This approach has been applied taking into account not all the forest area, but only those forest sites designated to recreation or conservation of biodiversity.

Final results show that total losses are significant. The total figure is €79 billion, the greatest losses coming from North America and Mexico, followed by Africa, Russia and some Asiatic countries (like Indonesia, Thailand, Malaysia, Philippines, Mongolia, Singapore, Vietnam). Most of this loss is attributable to provisioning services (€48 billion) and carbon sequestration (€25 billion), while only a minor part is due to loss of cultural services (€6 billion). In terms of biomes the greatest impacts are expected in boreal forests followed by warm mixed and tropical forests. These results may be surprising to some who argue that it is the loss of tropical forests, particularly the Amazon that is the most significant. A detailed analysis shows, however, that this is not the case. The best estimates point to greater losses in areas where use and non-use values are highest, which includes North America.

Our work suggests that any attempt to provide a monetary estimation of the services provided by biodiversity − here seen in terms of biomes − still represents a very challenging task for researchers. On the one hand this task is made difficult due to the partial lack of original valuation studies providing reliable estimates of the WTP for forest biodiversity values. On the other hand, the worldwide approach adopted here, will need to be reinforced by taking into consideration uncertainty and a lack of information on the local biodiversity conditions that are expected to influence the results of the valuation process.

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Annex

Table 9 A1: Total economic value changes for provisioning services in managed forest biomes by world region, in 2050 (Million € 2007, r=3%)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR	Total
Boreal	-10,703	-2,249	103	-6	0	-2,575	-153	-2,571	0	29	-78	0	-18,201 (38%)
Tropical	-1	0	0	-18	-2,479	0	-8	-2	-6,440	0	-1,056	-2,563	-12,567 (26%)
Warm mixed	-1,676	-22	-9	-468	-69	0	-912	-1,892	-63	0	-83	-46	-5,239 (11%)
Temperate mixed	-2,917	-1,084	-1,258	-1	0	-218	-9	-21	0	-412	0	0	-5,921 (12%)
Cool coniferous	-438	-615	220	0	0	-54	-47	-116	0	10	0	0	-1,040 (2%)
Temp. deciduous	-923	-1,276	-1,463	-32	0	0	-207	-1,107	0	-1	0	0	-5,009 (10%)
Total	-16,658 (35%)	-5,247 (11%)	-2,406 (5%)	-525 (1%)	-2,548 (5%)	-2,847 (6%)	-1,335 (3%)	-5,709 (12%)	-6,503 (14%)	-374 (1%)	-1,217 (3%)	-2,608 (5%)	-47,977
% Δ (2007 baseline)	-51%	-57%	-50%	-54%	-71%	-72%	-35%	-46%	-51%	-67%	-57%	-22%	-49%

Table 12 A2: Total economic value changes for carbon sequestration in natural and managed forest biomes by world region, in 2050 (Million € 2007, r=3%, lower bound)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR	Total
Boreal	-1	563	11	-21	0	-6,814	-281	133	0	-125	-127	0	-6,662 (27%)
Tropical	148	0	5	25	1,748	0	-38	28	-2,834	0	2,056	-2,703	-1,567 (6%)
Warm mixed	436	216	73	-871	682	0	-4,179	489	-284	0	-3,262	-8,747	-15,448 (62%)
Temperate mixed	428	934	572	-40	0	-1,365	-451	15	0	-2,086	-30	0	-2,022 (8%)
Cool coniferous	-126	-138	21	0	0	-894	-163	17	0	-50	0	0	-1,332 (5%)
Temp. deciduous	242	2,423	458	-65	0	-98	-597	103	-8	-160	-2	-56	2,241 (9%)
Total	1,128 (5%)	3,998 (16%)	1,140 (5%)	-972 (4%)	2,430 (10%)	-9,171 (37%)	-5,709 (23%)	785 (3%)	-3,126 (13%)	-2,422 (10%)	-1,366 (6%)	-11,506 (46%)	-24,790
% Δ (2007 baseline)	0.4%	5%	8%	-3%	1%	-3%	-16%	1%	-3%	-27%	-1%	-6%	-2%

Table 16 A3: Total economic value changes for recreational services by world region and forest biome, in 2050 (Million € 2007, r=3%)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR	Total
Boreal	-4.49	-1.97	-0.10	-0.01	0	-18.97	-0.06	-1.74	0	-0.04	-0.03	0	-27.43 (48%)
Tropical	-0.03	0	0	-0.01	-5.29	0	-0.02	-0.08	-1.60	0	-0.39	-1.2	-8.71 (15%)
Warm mixed	-0.79	-0.36	-0.03	-0.06	-0.60	0	-0.32	-2.16	-0.15	0	-0.11	-0.26	-4.83 (8%)
Temperate mixed	-1.10	-2.43	-0.85	-0.01	0	-1.85	-0.03	-0.23	0	-0.25	-0.01	0	-6.76 (12%)
Cool coniferous	-0.83	-0.95	-0.19	0	0	-2.32	-0.03	-0.33	0	-0.02	0	0	-4.66 (8%)
Temp. Deciduous	-0.59	-2.63	-0.35	-0.02	0	-0.08	-0.13	-1.56	0	-0.01	0	0	-5.37 (9%)
Total	-7.82 (14%)	-8.33 (14%)	-1.52 (3%)	-0.11 (0.2%)	-5.89 (10%)	-23.23 (40%)	-0.59 (1%)	-6.09 (11%)	-1.76 (3%)	-0.33 (1%)	-0.54 (1%)	-1.56 (3%)	-57.76
% Δ (2007 baseline)	-47%	-51%	-42%	-46%	-42%	-45%	-83%	-47%	-48%	-62%	-44%	-51%	-47%

Table A4: Total economic value changes for passive use by world region and forest biome, in 2050 (Million € 2007, r=3%)

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR	Total
Boreal	-346	-195	-78	-3	0	6	-4	74	8	-3	-14	0	-555 (10%)
Tropical	-94	0	-12	-23	-210	0	-10	0	-219	0	-324	59	-832 (14%)
Warm mixed	-165	-81	-31	-7	-8	-1	-56	8	-25	0	-22	-27	-415 (7%)
Temperate mixed	-1,960	-262	-242	-35	0	-4	-5	6	0	-5	-2	0	-2,510 (43%)
Cool coniferous	-101	-85	-57	0	0	-2	-10	11	0	-1	0	0	-245 (4%)
Temp. deciduous	-948	-254	-52	-34	0	-1	-26	24	-5	-1	-4	-2	-1,303 (22%)
Total	-3,615 (62%)	-878 (15%)	-472 (8%)	-102 (2%)	-218 (4%)	-1 (0.1%)	-111 (2%)	123 (2%)	-242 (4%)	-9 (0.2%)	-366 (6%)	31 (1%)	-5,859
% Δ (2007 baseline)	-44%	-59%	-67%	-41%	-32%	-1%	-47%	18%	-8%	-37%	-23%	11%	-34%

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