POLICY BRIEF

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Climate change, ecosystem services and biodiversity loss: an economic assessment

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ABSTRACT

The present policy brief contributes to the ongoing debate by addressing the economic valuation of the induced climate change impacts on European biodiversity and ecosystem services.

Firstly, we evaluate the impacts of climate change on biodiversity and ecosystem services, building upon the Millennium Ecosystem Assessment (MA) conceptual framework, considering biodiversity as the underpinning of ecosystems and ecosystem services, which in turn contribute to human well-being. In this context, this step encompasses the determination of the role of biodiversity in the creation of provisioning, regulating and cultural services.

Secondly, we develop an integrated, hybrid valuation approach so as to assess the economic magnitude of the involved impacts: integrated because it is characterized by the use of both bio-physical and economic valuation models and hybrid because it is characterized by an integrated use of alternative economic valuation methodologies.

Finally, we extend state-of-the-art general equilibrium frameworks by introducing an additional sector, the 'ecosystem' sector, into the underlying "market-based" general equilibrium assessment. Estimation results show that induced climate change impacts on biodiversity and ecosystem services involve significant welfare losses, of about 145-170 billion US$ and therefore autonomous adaptation cannot be invoked as the solution to climate change.

Furthermore, the distribution of the impacts varies widely according to the nature of the ecosystem service under consideration and to the geo-climatic region. Thus, the decision of including biodiversity and ecosystem services is expected to be a key component of the future climate policy framework, along with the evaluation of mitigation and planned adaptation strategies to be presented at the 15th Conference of the Parties (COP), Copenhagen, 2009.

Policy Challenge

What are the welfare losses induced by climate change impacts on European biodiversity and ecosystem services? How does the re-distributional map of the losses looks like? Do countries face similar welfare impacts? Are the welfare impacts similar across different types of ecosystems? Are the welfare impacts similar across different ecosystem services? Finally, what are the welfare benefits of integrating biodiversity and ecosystem services benefits into a more comprehensive future climate policy regime?

Biodiversity and Ecosystem Services in the Policy Agenda

Human well-being is dependent on biodiversity and "ecosystem services" provided freely by nature, such as water and air purification, fisheries, timber and nutrient cycling. These are predominantly public goods with no markets and no prices. As a result, their loss is often not detected by the conventional economic system.

A variety of pressures resulting from population growth, changing diets, urbanization, and climate change are causing continuous ecosystem degradation and a resultant biodiversity decline. Europe, along with many other countries, experiences these pressures. No longer "exclusive" to the academic and research arena, this topic is already highlighted in current policy agendas. For example, at the recent meeting of environment ministers of the G8 countries and the five major newly industrializing countries in Potsdam in March 2007, the German government proposed a study on "The economic significance of the global loss of biodiversity" as part of the so-called "Potsdam Initiative" for biodiversity. The following wording was agreed upon at Potsdam: "In a global study we will initiate the process of analyzing the global economic benefit of biological diversity, the costs of the loss of biodiversity and the failure to take protective measures versus the costs of effective conservation". This proposal was endorsed by G8+5 leaders at the Heiligendamm Summit on 6-8 June 2007. With this in mind, the German Federal Ministry for the Environment and the European Commission, with the support of several other partners, has jointly initiated preparatory work for this global study, named "The Economics of Ecosystems & Biodiversity (TEEB)". An interim report was presented at the IUCN World Conservation Congress in Barcelona, on 5-14 October 2008.

In this context, we propose to contribute to the ongoing study of the relationship between biodiversity, ecosystem services and human well-being. In addition, this investigation is performed within a context of global change, and in particular global climate change, exploring the associated implications of the results of this study for policy design.

The Importance of Biodiversity and Ecosystems to the post-Kyoto Climate Adaptation Policies

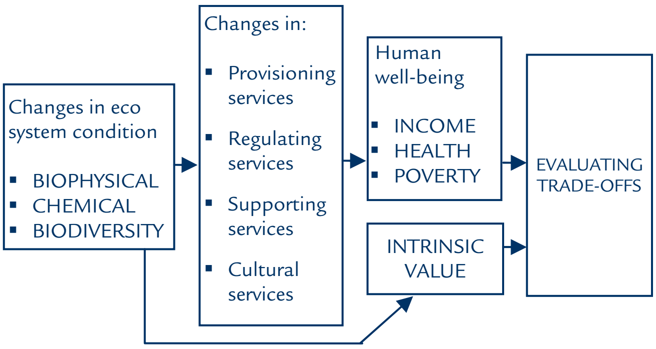
In fact, the impacts of climate change on biodiversity and the importance of biodiversity and ecosystem services to climate change adaption measures have long been a policy concern of the United Nations Framework Convention on Climate Change and United Nations Convention on Biological Diversity (UNCBD).

In 2002, following a UNCBD formal request, the Intergovernmental Panel on Climate Change (IPCC) prepared a technical report on Climate Change and Biodiversity. According to this report climate change is recognized as impacting ecosystems and their biodiversity and at the same time "it is also possible that the current effort to conserve biodiversity and sustainably use ecosystem can affect the rate and magnitude of projected climate change" (IPCC, 2002: 41).

This is because change in genetic or species biodiversity can lead to changes in the structure and functioning of ecosystems and can thus affect the water, carbon, nitrogen, and other major biogeochemical cycles. These in turn will impact the overall provision of ecosystem goods and services. Finally, since ecosystem goods and services are constituents of human-wellbeing, the consequences of climate-change-induced change in biodiversity, in the structure and functioning of ecosystems and in the provision of ecosystem goods and services are ultimately detected in terms of welfare losses – see Figure 1.

Alternatively, biodiversity conservation and sustainable use of ecosystem goods and services can affect the rate and magnitude of projected climate change and can thus play a potential role in adaption policies, including land-use based options. Therefore the economic value of estimation results of climate-change-caused impacts on biodiversity and ecosystem services are important to shed light on the significance of this policy mechanism within any post-Kyoto climate negotiations.

Figure 1. Biodiversity, ecosystem services and human wellbeing



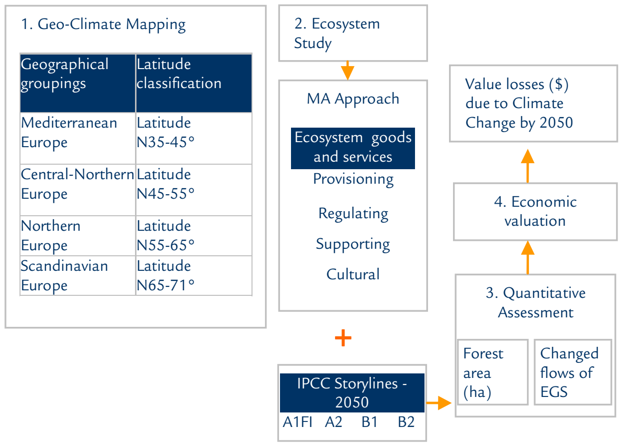
SOURCE: Millennium Ecosystem Assessment (2005)

A First Attempt to Value Losses of Biodiversity and Ecosystem Services in Response to Climate Change

The proposed economic valuation of ecosystem goods and services in the context of climate change is based on a three-step approach. The first step is the determination of the role of biodiversity in creating relevant ecosystem services. The second step is the calculation of the reduced quantity and quality of these ecosystem services resulting in loss of human welfare under alternative climate scenarios, which contain the four A1, A2, B1 and B2 scenarios proposed by the IPCC. The third step is the (monetary) valuation of that loss – see Figure 2.

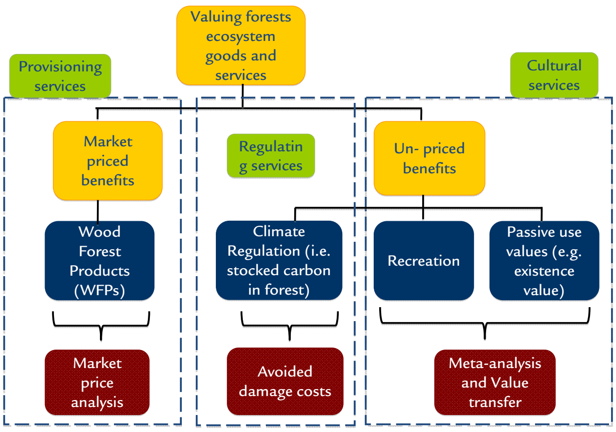
The monetary valuation exercise, in turn, is based on the application of an integrated, hybrid valuation model: integrated because it is characterized by the use of both bio-physical and economic valuation models and hybrid because it is characterized by an integrated use of alternative economic valuation methodologies – see Figure 3.

Figure 2. Valuation of ecosystem goods and services in the context of climate change



SOURCE: Nunes et al (2009)

Figure 3. Hybrid approach to the economic valuation of ecosystems goods & services



SOURCE: Nunes et al (2009)

The present study is applied to four European[1] ecosystem types. They refer to forest, agriculture, freshwater and coastal ecosystems. Table 1 provides an overview of the relevant ecosystem goods and services being valued across the ecosystem under consideration.

1 The study focused on 34 European countries: Greece, Italy, Portugal, Spain, Albania, Bosnia and Herzegovina, Bulgaria, Serbia and Montenegro, Turkey, the territory of former Yugoslavia, Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Denmark, United Kingdom, Estonia, Latvia, Lithuania, Finland, Norway and Sweden.

Table 1. Ecosystems goods and services being valued in Europe

Ecosystem	Provisioning services	Regulation services	Cultural services
Forest	☑	☑	☑
Agriculture	☑	☑	☒
Freshwater	☑	☑	☑
Coastal	☒	☒	☑

SOURCE: Nunes et al (2009)

The estimation results of the integrated, hybrid valuation model are presented in Box 1. In short, we can conclude that the economic valuation of the impacts caused by climate change on biodiversity and ecosystem services are multifaceted. All in all, they reveal significant welfare losses, however the respective dimension, and its distribution across the different European countries vary significantly. These, in turn, are anchored on the underlying IPCC storyline, that includes both climatic and socio-economic changes, as well as the type of ecosystem services under consideration. In any case, most of the times the changes involved will signal the presence of winners and losers, or different magnitudes of welfare loss. This aspect, i.e. the unbalanced distribution of climate-change-caused impacts on biodiversity and ecosystem services across the European countries under consideration, signals the relevance of the issue of redistribution when approaching an efficient, broadly accepted international negotiation on carbon reduction.

Furthermore, one should also take into account the transaction costs involved in each of the policy options. At this moment, these elements are beyond the scope of the present analysis but are an important direction for future research.

New Challenge: Can Micro- and Macro-Economic Approaches Meet for Assessing the Total Loss of Climate Change Impacts?

Macroeconomics and microeconomics are two branches of economic theory that focus on the study of consumer and producer, as well as the markets where they meet. They reflect different study perspectives. In the context of economic valuation of climate change impacts, the former explores the use of general equilibrium models (GEM) so as to assess climate change impacts on the entire economic system, via market dynamics at national and regional scales. On the other hand, a microeconomic analysis, such as the one we proposed with the use of integrated-hybrid valuation model, uses a partial equilibrium approach. From this perspective, we are looking at single markets, or benefits (e.g. cultural services provided by European forest ecosystems). Bearing in mind the nature of ecosystem services, this approach allows us to use different economic valuation tools to value the benefits, including those that do not leave a market trace but are anchored in a market-based framework. In this context, we propose to scale up the economic valuation results obtained from the application of the integrated-hybrid valuation model within the GEM framework. This exercise is here applied to a single ecosystem service, carbon sequestration, and one ecosystem, the European forests. In other words, we extend the state-of-the-art GEM framework that brings the "ecosystem" sector to the conventional "market-based" assessment. Since the current application is applied to a single ecosystem service, and to the European context, we label approach as a *partial-general-equilibrium approach*. To our knowledge, this exercise constitutes an original study in the economic welfare assessment of biodiversity and ecosystem services impacts induced by climate change (see Bosello et al. 2009a).

Firstly, the magnitude of climate change impacts on forest carbon sequestration services is isolated and estimated in the integrate-hybrid valuation model. This is anchored by an econometric application forest land use, and forest carbon sequestration productivity is estimated among different IPCC scenarios – see Box 1. Since temperature is an exogenous variable in ICES [2], and its level is decided by the user and calibrated in the model so as to mirror current conditions as closely as possible, the present embedding exercise revises the original data so as to accommodate the information provided by the integrate-hybrid valuation model. Our model also suggests that European forests have a potential to smooth temperatures as low as 0.018°C in 2050.

[2] ICES is an example of computable general equilibrium model.

Box1. Economic valuation results

Forest ecosystems

As regards the value of forest ecosystem services, cultural values reveal a greater sensitivity to climate change. On the contrary, provisioning services are observed to be more resilient to climate change. Estimation results show that climate-change-caused impacts on biodiversity and ecosystem services present significant spatial distributional patterns. Taking the B2 scenario as an example, and 2050 as the year of analysis, Central European countries are ranked the highest in the provision of forest provisioning services (about 48.7 billion$, measured in 2005 USD and corrected for PPP) and carbon sequestration services (about 190.3 billion$) but are ranked second in terms of cultural services provision (about 3.1 billion$). Conversely, Mediterranean Europe demonstrates exactly the opposite welfare pattern, registering the highest cultural value, about 8.4 billion$. The Scandinavian geo-climatic area is the second largest contributor to forest provisioning services in Europe (accounting for 31.9 billion$). Here carbon sequestration services amount to 35.7 billion$ and cultural services 2.2 billion$. In contrast, A1 scenario Mediterranean Europe registers the lowest values regarding cultural services (about 3.9 billion). When compared to B2, Central Europe registers a slight reduction in the forest provisioning services, now with values around 41.2 billion$. On the contrary, Scandinavia in the A1 scenario registers a small increase, with current values around 35.5 billion$. Finally, Central Europe has a high reduction in carbon sequestration values, now amounting to 117.2 billion$. A reduction. of smaller magnitude, is also registered in the carbon sequestration values mapped in the Scandinavian countries, now amounting to 32.8 billion$.

Freshwater and wetland ecosystems

Values are regressed against a series of variables that include biodiversity levels and climatic conditions. The calibration of the meta-analytical model on the current provision of ecosystem services shows that freshwater ecosystem values are found to be subject to income and substitution effects. Biodiversity richness and population density positively influence benefits, while high temperature is negatively correlated with values. Mean values per hectare are high in countries with relative scarcity of freshwater ecosystems (e.g., Portugal and Italy), high population density (e.g., Belgium), and high Gross Domestic Product per capita (e.g., Luxembourg). Aggregation of the values over total freshwater ecosystem area in each country reveals that the highest benefits are experienced where values per hectare are high (e.g., Italy, 46.7 billion US$/annum) or the total ecosystem area is very large (e.g., Sweden, 42,1 billion US$/annum). The impact of climate change on the baseline value estimates is assessed based on the A1, A2, B1 and B2 IPCC storylines. Scenario-specific variations in real Gross Domestic Product per capita, population density, biodiversity and maximum yearly temperature in the year 2050 are included in the model. The values of wetlands and freshwater ecosystems are predicted to decrease in 2050 as a consequence of climate change. Scenarios B2 and A1 are the ones involving the largest welfare losses, while under the most favorable conditions of scenario B1 a decrease of 9% is predicted. In fact, comparative analysis of IPCC scenarios shows that with respect to welfare gains, scenario B1 is ranked higher than A1, A2, and B2 in all the countries considered. The absolute value difference in scenario B1 with respect to the scenario A2 is estimated in 24.8 billion US$/year at the European scale.

Coastal ecosystems

Here also they are estimated by means of a meta-analytical regression model. The calibration of the meta-analytical model on the current provision of ecosystem services reveals that the highest values per person per year are in Mediterranean countries, Greece and Italy in particular, where high temperatures encourage sea, sun and sand recreational activities. Average values range between 78.9 US$/person/annum in Finland and 399.8 US$/person/annum in Greece. Individual values are aggregated at country level based on the number of coastal tourists per year. High aggregated values are found in Mediterranean countries where individual values are high and the tourism industry is particularly developed, and in the United Kingdom. The impact of climate change on the baseline value estimates is investigated through variations in real Gross Domestic Product per capita, population density, biodiversity, minimum monthly temperature and maximum monthly temperature in accordance with the four IPCC storylines (A1, A2, B1 and B2) and for the year 2050. For all scenarios, it follows that individual values in the countries considered in 2050 will generally increase. The largest percentage increase in individual values will be concentrated in Northern European and in Scandinavian countries. Total values aggregated at country level are similarly expected to grow, mainly due to an increase in the number of coastal tourists. A comparison across the four scenarios reveals that the highest increase in values is predicted for the two economic oriented scenarios, in particular for scenario A1.

At that stage we are then able to use ICES to re-compute the new equilibrium caused by biodiversity and carbon sequestration services. Table 2 shows the results.

Table 2. Contribution of carbon sequestration services from European ecosystems to global climate change regulation

Region Model	CGE (1)	CGE & BES (2)	(2) – (1)	Year average (2001-2050)
Med	-34	-34	-0.5	-0.01
Europe	-65	-64	+1.3	+0.03
North	+488	+496	+7.6	+0.16
Europe	+1,360	+1,373	+12.1	+0.25
East	-21	-21	-0.4	-0.01
Europe	-102	-103	-1.5	-0.03
	-1,491	-1,518	-27.1	-0.55
World	-5,576	-5,661	-85.1	-1.74

SOURCE: Bosello et al (2009a)

The first column shows the valuation results from the computable general equilibrium (CGE) model (see Bosello et al. 2009b). The second column shows the estimation results of the CGE with the biodiversity and ecosystem services, BES – see CGE & BES model. The third column depicts the differences. All magnitudes are measured in terms of projected changes in GDP with respect to no climate change baseline, year 2050. There are two value estimates per region, for a mean temperature increase of 1.2 and 3.1. degrees Celsius, respectively.

Over the fifty-year period the net present value (NPV) for the Mediterranean Europe now ranges from, -34 to -65 billion US$, depending on the two temperature scenarios under consideration. Therefore, when compared to the original welfare computations, this implies a higher loss for Mediterranean Europe ranging up to 0.5 billion US$. In other words, climate-change-caused impacts on biodiversity and ecosystem services cause an additional welfare loss to Mediterranean Europe. A similar welfare pattern is registered in East Europe. Note, however, that the North Europe region has a welfare gain due to climate change, whose magnitude is reinforced when BES is embedded. In fact, this is responsible for an additional welfare gain that ranges between +7.6 and +12.1 billion US$, depending on the temperature scenario.

Finally, Table 2 shows that at a global level, and depending upon the climate change scenario, the damage imposed by climate change on carbon sequestration services provided by European forests ranges from 27.1 to 85.1 billion US$. This loss is equivalent to an annual rent that ranges between 0.56 and 1.74 billion US$ over a period of fifty years.

Lessons Learned: Obstacles of Including Economic Values of Biodiversity and Ecosystem Services in Climate Policy Negotiations

GDP value estimates of the climate-change-caused impacts on biodiversity and ecosystems services show that there is no single welfare change pattern. In particular, for Mediterranean Europe the introduction of the Biodiversity and Ecosystems sector, modeled here in terms of the European forest sequestration services, does not imply significant additional welfare changes, when compared to the original CGE estimates. In fact, the magnitude of the welfare losses caused by climate change is approximately the same across the two model specifications under consideration. On the contrary, at a global level the damage imposed by climate change on biodiversity and carbon sequestration services provided by European forests ranges up to 85.1 billion US$. In other words, the key message delivered by this analysis is that the economic assessment of climate-change-cause impacts on biodiversity and ecosystem services highlights a substantive welfare loss. It is also true, that this signals the tip of the iceberg: the analysis is here focused at biodiversity anchored at a single ecosystem type, forest, and a single ecosystem service produced by forests, carbon sequestration.

Taking into account (1) the forty four European countries and (2) the sequestration services from forests alone, climate-change-cause impacts on biodiversity and ecosystem services are responsible for welfare loss amounting to 85 billion USD$. If we also add (3) the biodiversity productivity effects on the agricultural sectors, (4) freshwater and coastal ecosystems (see Table 1) this figure rises up to 145 - 170 billion USD$.

If we consider the World Bank's global ranking with respect to GDP per capita, this amount corresponds to the aggregated GDP of the 22 poorest countries, which constitute 13% of the totality of world countries. These results lead to the main conclusion that autonomous adaptation cannot be invoked as the solution to climate change, but needs to be addressed with proper mitigation and planned adaptation strategies.

Furthermore, autonomous adaptation cannot reverse the adverse distributive implications of climate change. In other words, the present estimation results confirm that (1) climate change brings along significant welfare impacts, (2) biodiversity and ecosystem services play an important role in the determination of the final welfare magnitudes, and (3) not all European countries will have identical impacts, some countries will lose more than others, and some countries will gain, depending on their geographical location, the existing markets and profile with respect to biodiversity indicators and land use patterns. For these same reasons, it is important to use these results in the design of any climate-mitigation, or adaptation, policies.

Note, however, that one also needs to remember that the success of these negotiations will depend inter alia on key issues such as:

1. Uncertainty. Despite the evidence of climate change impacts, high uncertainty is associated with both distributional effects and the magnitude of these impacts. Therefore, a range of value estimates is preferred to a point estimate of the possible damage costs of climate change. The observed uneven distribution of climate change impacts represented a first impediment when scaling up the regional impacts across different geographic regions.
2. Intra-generation equity and vulnerability. Climate change is a global phenomenon, the impacts however tend to be more regional or site-specific in the area where the population is most vulnerable to climate change and usually exposed to extreme poverty. However, the existing micro-economic valuation approaches are mostly designed in favor of the relatively rich regions where willingness-to-pay for autonomous adaption measures such as ecosystem and biodiversity protection for climate is affordable. Therefore, the main difficulties of environmental economics were the scaling up of the damage costs across different populations and the efficient distribution of the benefits of global collective climate policies.
3. Inter-generation equity. The equal rights of future generations to enjoy a stable climate are subject to the choice of discount rate in the literature of environmental economics. It has been widely accepted that the current severe climate change is mainly caused by anthropogenic activities over the past century, but the question of how much of our limited resources we should invest to preserve the environment and stabilize the climate for future generations to come is still open.

All these aspects constitute important areas of debate among leading economists (Stern, 2006; Nordhaus, 2007, Weizman, 2007, and Tol, 2006) but in any case do not deny the significant, and additional, welfare impacts derived from bringing ecosystem services into the assessment of overall climate change impacts.

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