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Valuing climate change impacts on European forest ecosystems

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ABSTRACT

This paper presents one of the first attempts to perform a systematic assessment of the climate change impacts on European forests and its capacity to deliver ecosystem services by developing a hybrid economic valuation model. Different methods are combined to assess climate change impacts on forests by different latitudes, productivity in bio-physical terms and related economic consequences. Our computation shows that countries within the Mediterranean European geo-climatic zone will benefit from the highest welfare gain in moving towards an environmentally oriented scenario. The welfare gain has been estimated around 86% increase in the cultural values, 45% increase in the value of carbon sequestration and 24% increase in the values of wood forest products. The other countries show an intermediate state of affairs with mixed results. On the other hand, high welfare losses are always expected when moving to the more economically oriented scenarios, with the highest impacts among the Northern European countries. Results show that all storylines describe significant impacts on human wellbeing. These economic magnitudes contribute to a better understanding of the potential welfare loss across different regions and therefore will have important policy implications, such as developing the ecosystem-base adaption measures for Europe to cope with climate change.

1. Introduction

Climate change is already impacting ecosystem and biodiversity in various world regions, in particular on the forest biomes located in the high-altitude and high-latitude regions (IPCC, 2001). These impacts can impose *pressure* on the forest ecosystem, and lead to the changes in the *state* of ecosystem functioning and biodiversity, which in turn affect the overall provision of forest ecosystem goods and services (EGS), such as wood forest products, carbon sequestration, forest recreation and passive use benefits, and ultimately have an *impact* on human-wellbeing – see Fig. 1. However, the economic assessment of these impacts is still a growing literature.

Tol (2008) has conducted a literature survey in 2008, which showed an exponential increase in the number of papers published in international peer reviewed journals on the topic of climate change, from 1,714 to 11,652 papers, respectively in 1995 and 2008. Among all the reviewed literature, only a very small proportion has centred within the economics literature (about 33 papers in 1995 and 218 papers in 2008), most of which have focused on market-related impacts of climate change (Tol, 2005). The use of a monetary metric to express economic impacts of climate change on forest and ecosystems services provision is not present in this review, mainly due to the mixed nature of ecosystem services and the lack of recorded market information (Pearce et al., 1996; Tol, 2005). Recent literature has moved forward to exploring methodologies that can examine the relationship between ecosystem services and climate change, in order to explain how changes in climate conditions may affect the provision of ecosystem services. In this regard, two remarkable studies should not be ignored. First of all, Ojea et al. (2010) developed a meta-transfer regression of worldwide forest ecosystem services values, whose architecture also introduced a climate change variable that aimed to capture the impact of climate change on ecosystem services. More recently, Ding and Nunes (2014) developed a 3 stage regression model to empirically estimate the relationship between climate change, biodiversity and the value of EGS provided by European forests, which constituted a first attempt of its kind.

In this setting, the present paper attempts to enrich the economics literature of climate change impacts on ecosystem services, by undertaking an empirical application of various economic valuation techniques to estimate the economic impacts of climate change on European forests and the corresponding provision of EGS. Different from the previous studies, the present study will

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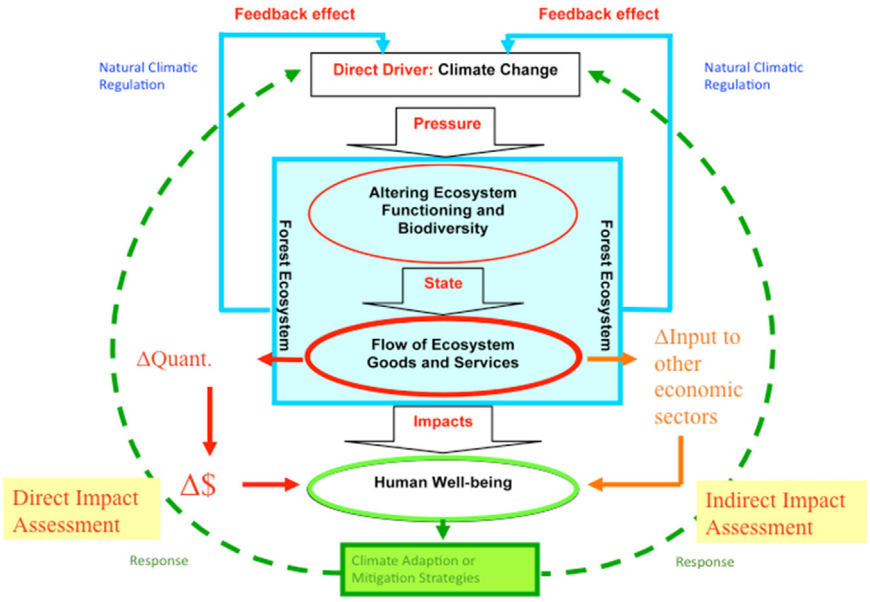

Fig. 1. Conceptual model for the climate change, forest biodiversity and human well-being interactions.

focus on the integration of climate science modelling and economic valuation techniques to first assess the magnitude of changes in the biophysical provision of ecosystem services due to potential impacts of climate change under different future scenarios, and then translate these biophysical impacts into economic values, accordingly. The results are therefore anchored in a solid interdisciplinary study covering the fields of natural sciences, socio-economics and climate change modelling, which can play a crucial role in better understanding the economic and environmental consequences of the chosen future development paths and exploring the potential of ecosystem-based mitigation and adaptation policies for fighting against global warming.

The paper is organised as follows. Section 2 analyses the climate change impacts on European forests. Section 3 presents the projections of the provision of EGS under different climate scenarios. Section 4 presents an integrated-hybrid economic valuation methodology that is applied to estimate, in monetary terms, the impacts on human welfare associated to the bio-physical changes in the provision of forest ecosystem services among all countries under consideration. Section 5 discusses the policy implementation of the results and Section 6 concludes.

2. Understanding the climate change impacts on European forest ecosystems

Over the last 30 years, the world has experienced significant temperature increases, particularly in the northern high latitudes, and this trend will continue into the future (IPCC, 2001). In Europe, the average temperature is projected to increase from 2.1 to 4.4 °C by 2050, with the strongest consistent increase in the higher latitudes (IPCC, 2001). Moreover, model simulations suggest a decrease in precipitation in the south of Europe, particularly in summer, but an increase in precipitation over much of northern Europe (Schöter et al., 2005). In the present study, the magnitude of climate change impacts on forest ecosystems, and the respective provision of EGS (in both physical and economic terms) will be estimated under future climate change scenarios. These scenarios are correspondent to different states of the world by 2050 following assumptions made by the IPCC (2000) on Emission Scenarios, namely A1, A2, B1 and B2 storylines. Each is an outcome of an integrated global atmosphere-ocean circulation modelling, including the Hadley Centre Couplet Model Version 3 (HadCM3), together with the coherent use of socio-economic storylines, including population and Gross Domestic Product (GDP) growth, land use, and CO_2 concentrations. (Gordon et al., 2000, Nakicenovic and Swart, 2000; Schöter et al., 2004, 2005) – see Table 1.

The four storylines are distinguished in terms of four future distinct development paths, i.e. 'global economic' oriented, 'regional economic' oriented, 'global environmental' oriented, and 'regional environmental' oriented, respectively. The two economic oriented scenarios (A1 and A2) focus on 'material consumption' and are characterized by a higher population and CO_2 concentration rates. The A1 scenarios also consider different combinations of

Table 1
The specifications of the four IPCC storylines.
(*Source:* adapted from Schöter et al. (2005) and IPCC (2001)).

Indicator	Climatic model–HadCM3 (Scenarios by 2050)			
	Storyline A1FI Global economic	Storyline A2 Regional economic	Storyline B1 Global environmental	Storyline B2 Regional environmental
Population (10^6)	376	419	376	398
CO_2 concentration (ppm)	779	709	518	567
Δ Temperature (°C)	4.4	2.8	3.1	2.1
Δ Precipitation Europe (%)	−0.5	0.5	4.8	2.7
Socio-economic dimensions	High savings and high rate of investments and innovation	Uneven economic growth, high per capita income	High investment in resource efficiency	Human welfare, equality, and environmental protection