Forestry

Book Chapter

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Publication date:
2017

Permanent link:
https://doi.org/10.3929/ethz-b-000234375

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Key messages

Some climate-induced changes in European forests are expected to occur relatively smoothly over time, whereas others may occur as "shocks", passing thresholds or tipping points.

- In climate change scenarios considered here, there is a clear north-south gradient regarding the impacts of climate change on forests, excluding other factors such as CO_2 physiological effects and nitrogen deposition. High latitudes and elevations potentially benefit from climate change, and forests at low latitudes potentially lose as a result of projected shifts towards drier conditions, particularly in the Mediterranean region. Different regional climate outcomes could result in different impacts.

- Increased CO_2 concentrations have a potentially positive effect on forest productivity. In the absence of acclimation of trees to elevated CO_2, this driver could modulate the impact of climatic change by either further increasing forest productivity (e.g., at high latitudes or elevations), or at least partly compensating for negative climatic effects.

- Forestry can be adapted to the changing climate by switching to climatically better adapted species, and moving towards forestry systems that include more than one tree species at the stand scale.

- European forests and forest products are significant contributors to the European greenhouse gas balance, constituting a major carbon sink that can help to reach EU climate targets.

Policy context

To date, there is no formal EU Forest Policy, but since 1998 has been an EU Forest Strategy (FS) and Forest Action Plan (FAP), the most recent concerning the period 2007-2011. The need for a new FS has long been recognized, as environmental and political circumstances have changed considerably over the past 20 years. The goals for the new FS are that it should (1) develop and implement a common vision of multifunctional and sustainable forest management in Europe; (2) define action priorities and targets; (3) link EU and Member State funding strategies and plans; (4) strengthen coherent cross-sectoral activity planning, funding and implementation; (5) establish clear mechanisms for monitoring, evaluating and reporting; and (6) revise stakeholder involvement (EU 2013).

Besides the FS and FAP, many other policies are affecting forests, including the Resource Efficiency Roadmap; the Rural Development Policy (which is providing 90% of the funding for European forestry); the Industrial Policy; the Climate and Energy Package; the Plant Health and Reproductive Materials Strategy; and the Biodiversity and Bioeconomy Strategies. Particularly relevant to EU decision-making is the plan to include emissions and removals from Land-use, Land-use Change and Forestry (LULUCF) in the EU's 2030 climate policy framework. Furthermore, elements of the Sustainable Development Goals are also relevant for European forestry, particularly SDG 15.2 to promote by 2020 the implementation of sustainable management of all types of forests.

Forests are influenced by a multitude of processes and at many different scales over long time periods, and hence management today only translates into effects after several decades. This leads to the necessity of long-term planning, taking into account future trends in environmental and societal drivers of forest dynamics, and a consideration of the societal demands for a wide range of forest ecosystem services, with considerable regional differentiation. Future drivers of forest change include increasing temperatures in cold regions; heat waves and severe droughts in warm regions; increasing frequency and severity of natural disturbances (e.g., forest fires, windstorms, pest and pathogen outbreaks); physiological effects of further increasing atmospheric CO_2 levels; nitrogen deposition; global prices for timber, pulp and bioenergy; intrinsic value of aesthetics and biodiversity; and future subsidies.

Policy insights

1. What are the major impacts on forests under high-end scenarios?

Some changes will be occurring smoothly over time, whereas others will be coming as “shocks” (thresholds, tipping points).

‘Chronic’, continuous changes of driving forces like climate, atmospheric CO_2 concentration or N deposition will lead to continuous changes in key forest variables such as primary productivity, and thus timber production (Figure 17), as well as many other ecosystem services such as water and air purification. Considering climate change alone (i.e., in the absence of natural disturbances, CO_2 or N fertilization effects), forest productivity is projected to decrease in many regions of Europe by 2100, on average by 1 to 4 m^3 ha^{-1} $year^{-1}$ (annual volume increment), i.e. about -10 to -50% compared to the current climate. Details depend on the nature of regional climate change, which is uncertain due to different results from different models. In the scenarios considered here, regions that consistently experience reductions in forest productivity include the drought-prone Mediterranean basin and the dry continental interior of the continent. Productivity increases of the same order of magnitude are expected where tree growth is currently limited by cold temperatures and is not expected to be limited by precipitation in the future, typically for high latitudes and high elevations. These variations will be mostly gradual (in the absence of other perturbations) but can happen more quickly and be more or less pronounced locally, depending on the region (Figure 17) and tree species (Figure 19).

These climate-driven changes are modulated by other drivers such as CO_2 fertilization, which may have a positive effect on forest productivity and could therefore increase the positive effects of climate change or partly compensate its negative effects. Yet, the relative importance of the direct effects of elevated CO_2 concentrations on vegetation productivity and biomass will depend on a number of factors, including ‘climate sensitivity’ (i.e., the response of the climate system to a given increase in CO_2). HELIX is investigating this by simulating large-scale vegetation responses at different levels of global warming – 1.5°C, 2°C and 4°C – reached in different climate models at different rates (Figure 18). Under climate change projections from a climate model with high climate sensitivity, such as the IPSL model, warming is faster and thus reaches a higher level for a given CO_2 concentration, compared to a low sensitivity model such as the GISS model. Under the low sensitivity scenario, global vegetation biomass increases more than under the high scenario, because CO_2 concentrations are higher for a given level of global warming (Figure 18). There is therefore considerable uncertainty associated with the simulated effects of elevated CO_2 on vegetation productivity, which is related not only to the model used but also to the maintenance of the fertilization effect over time. Vegetation may indeed acclimate to higher CO_2 concentrations, and/or other factors may become limiting (e.g., nutrients, water). Further research is needed to better understand the combined impacts of climate and elevated CO_2 on forest productivity.

In addition to these gradual effects, single extreme events (e.g., windthrow), and particularly series of such events (e.g., several drought years in a row), will trigger strong and sudden changes in both system properties (e.g., timber volume, carbon stock) and system dynamics, including

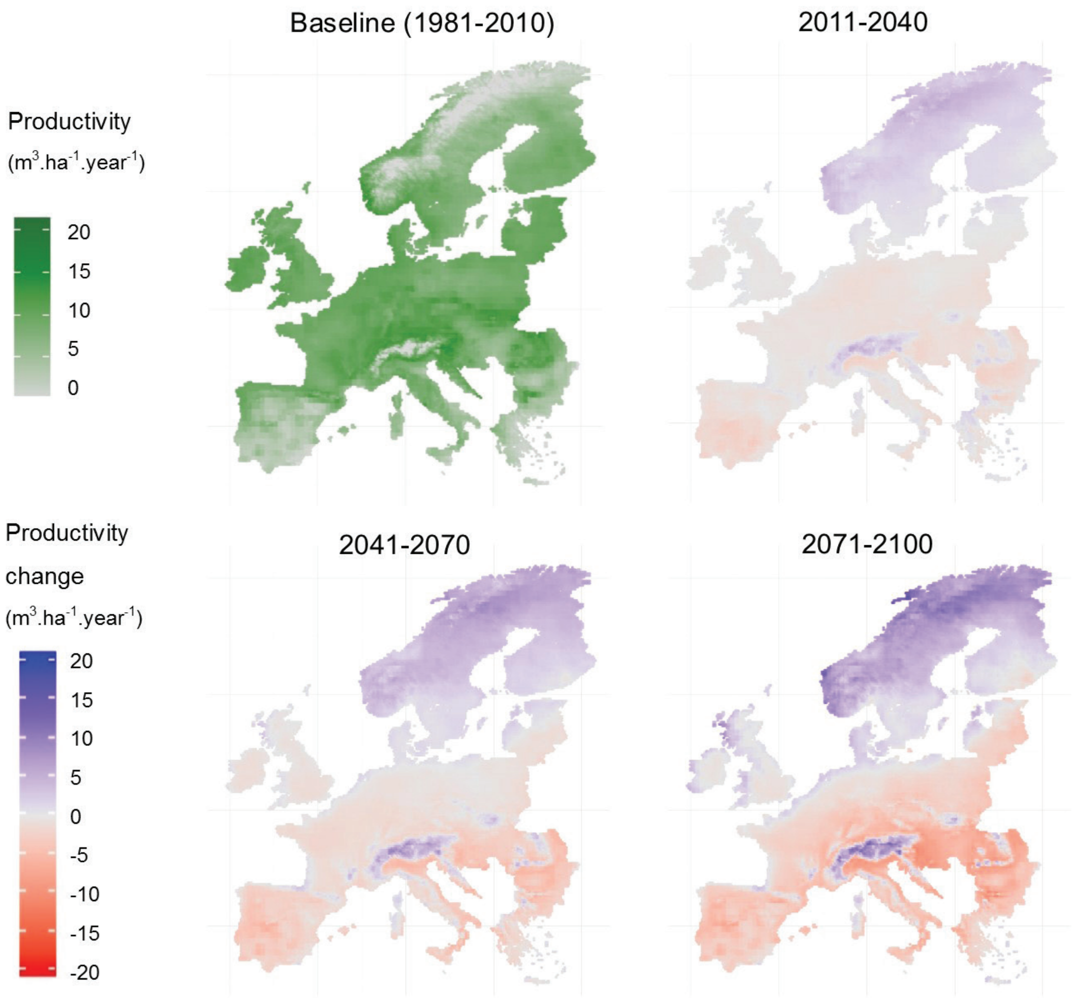

Figure 17. Productivity of Scots pine (Pinus sylvestris) under high-end climate scenarios, from IMPRESSIONS. Annual wood volume increment simulated by meta-ForClim under baseline conditions (top left, shades of green), and development under future climate change alone (productivity decreases from baseline conditions in red, increases from baseline conditions in blue). Results are averaged over three high-end climate change scenarios (RCP8.5-HadGEM2-ES/RCA4, RCP8.5-CanESM2/CanRCM4 and RCP8.5-IPSL-CM5A-MR/WRF) and assuming a mesic soil (water holding capacity of 15 cm).

the potential for widespread tree mortality induced by drought and heat waves, large changes in tree species abundance due to species-specific mortality, and forest expansion beyond current 'cold' treelines at high latitudes and high elevations induced by clusters of climatically favourable years for tree establishment. The results in Figure 17 and Figure 19 are conservative estimates of negative changes to forest productivity because they exclude such disturbances.

Changes in disturbance regimes include not only windthrow and wildfires, but also the outbreak frequency and severity of pests and diseases, such as ash wilt that is currently wiping out ash (*Fraxinus excelsior*) populations across Europe. Furthermore, novel species are likely to establish that may be disruptive to ecosystem function, such as the tree of heaven (*Ailanthus altissima*) that has been present in Europe for a long while, but now is becoming invasive in many European forests, or Japanese knotweed (*Fallopia japonica*) that is increasingly hindering forest regeneration under moist conditions across many European countries.

Thus, the many ecosystem services provided by forests will be affected strongly by these changes in driving forces, be they chronic or induced by extreme events. Whether they are beneficial or problematic must be addressed at the regional level, as the environmental impacts, as well as societal demands, vary strongly by region within Europe.

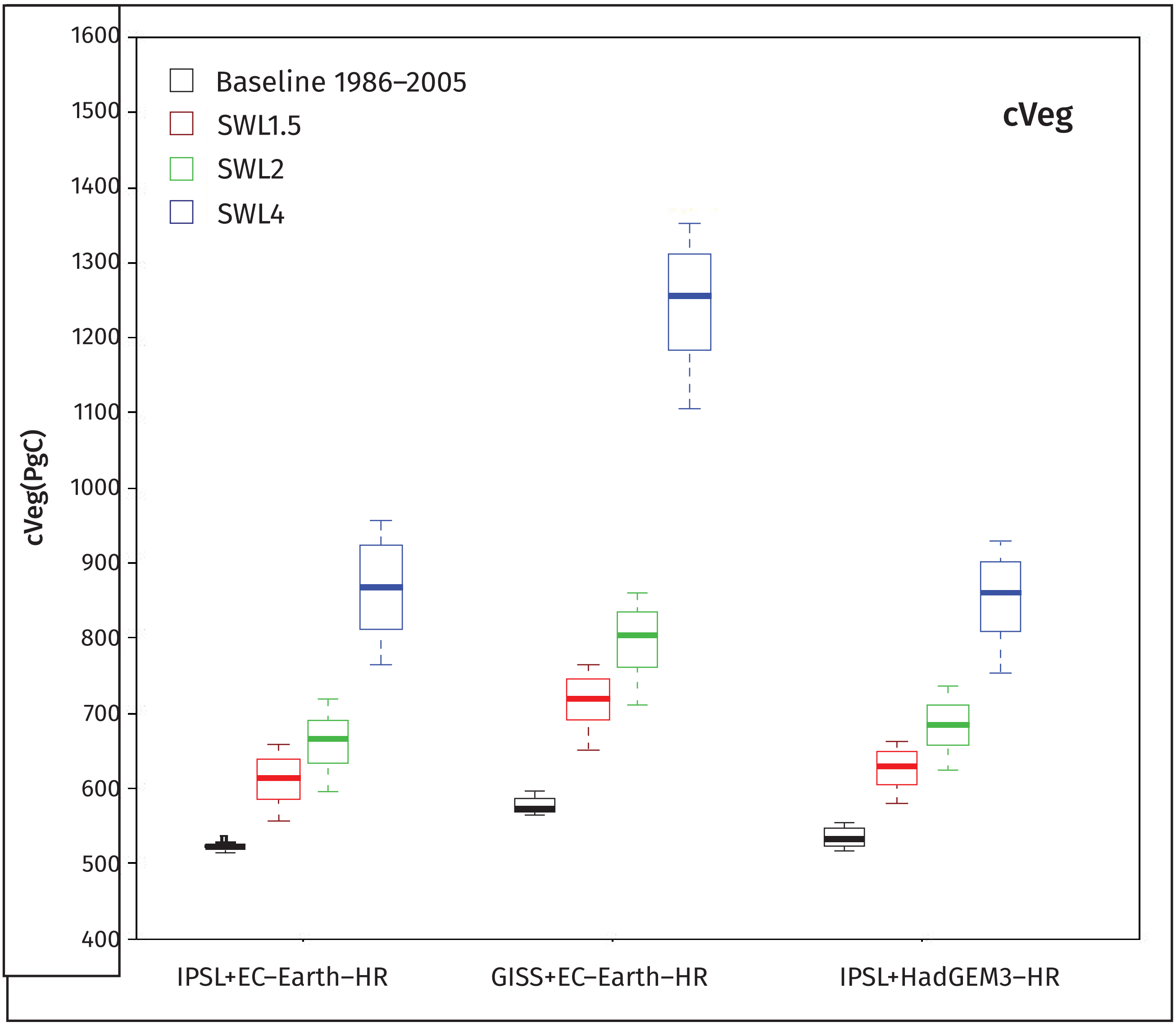

Figure 18. Changes in vegetation carbon at 3 Specific Warming Levels (SWLs) simulated by the ORCHIDEE dynamic global vegetation model driven by climate projections from different climate models, from HELIX. The centre column shows results driven by the low-sensitivity GFDL model whereas the left and right columns used the high-sensitivity IPSL model.

2. Which regions are most likely to be hardest hit by negative impacts of high-end climate change, and which regions may see a net benefit?

Under the climate change scenarios considered here, there is a clear north-south gradient regarding the impacts of climate change on forests (excluding other factors such as CO_2 physiological effects and nitrogen deposition). High latitudes and elevations potentially benefit from climate change, and forests at low latitudes (i.e., towards drier conditions, particularly in the Mediterranean region) potentially lose.

According to these simulations, forest productivity at high latitudes and high elevations is expected to increase (Figure 19), as temperature limitations on growth will be alleviated, whereas precipitation will stay high enough to maintain beneficial levels of soil moisture in spite of projected decreases in summer precipitation. Thus, either extant tree species will become more productive (e.g. Scots pine, Figures 17 and 19; Norway spruce, Figures 17 and 19), or it will be possible to use tree species that have higher economic value than those being used today but cannot be grown under current conditions (e.g., Sessile oak and Holm oak, Figure 19).

In continental, as well as Mediterranean areas, lower forest productivity is projected due to higher summer temperatures and reduced

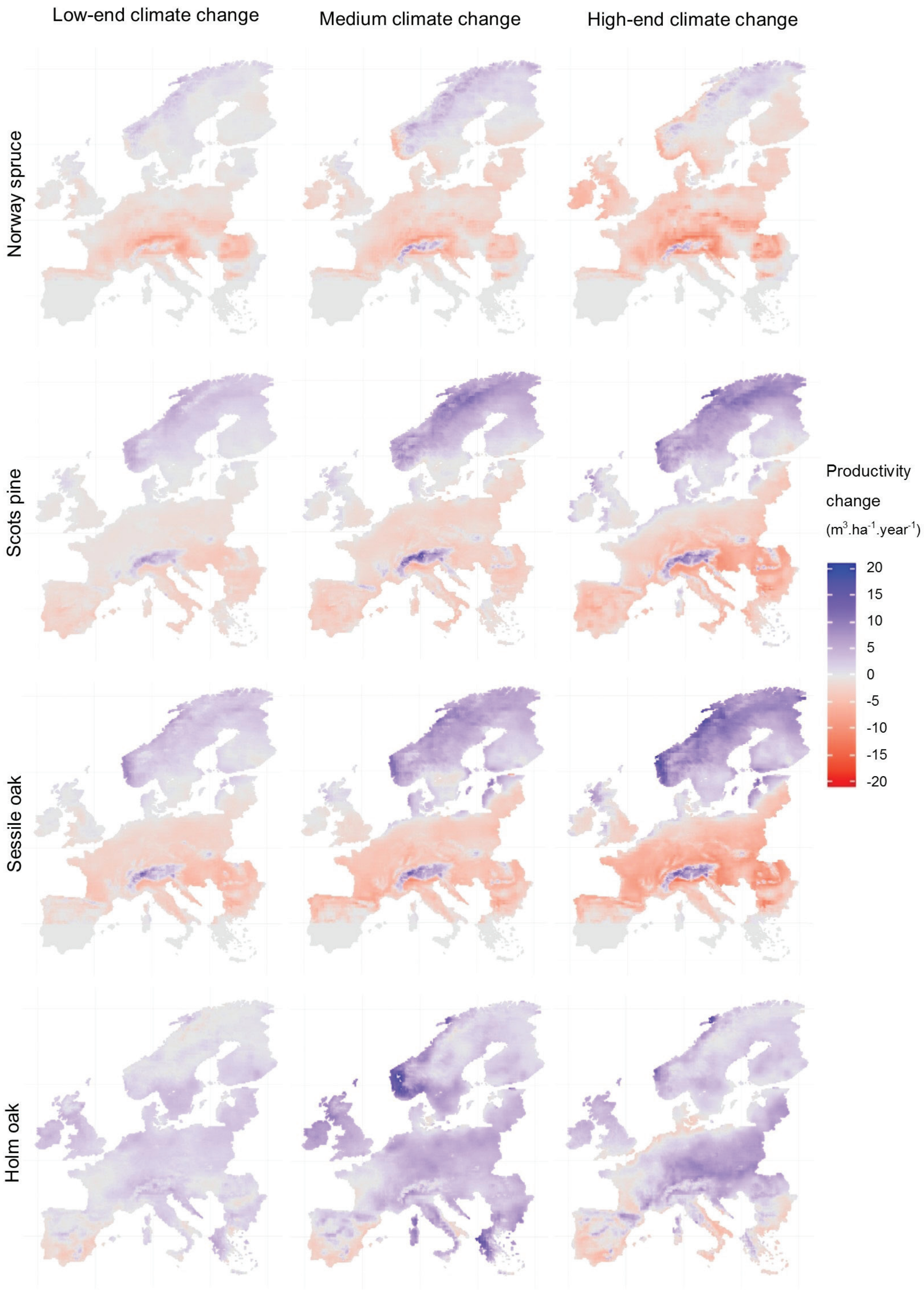

Figure 19. Projected change of productivity by 2100 under climate change for two conifer (top) and two deciduous (bottom) tree species, from IMPRESSIONS. Changes of annual volume increment projected by meta-ForClim under low-end (left), medium (centre) and high-end (right) scenarios of scenarios of HECC for the time window 2070-2100 (decreases are in red, increases in blue). Results are presented for a mesic soil (water holding capacity of 15 cm) and averaged over two or three climate change scenarios depending on the severity of projected HECC: RCP4.5-GFDL-ESM2M/RCA4 and RCP4.5-MPI-ESM-LR/CCLM4 for low-end; RCP8.5-GFDL-ESM2M/RCA4 and RCP4.5-HadGEM2-ES/RCA4 for medium; RCP8.5-HadGEM2-ES/RCA4, RCP8.5-CanESM2/CanRCM4 and RCP8.5-IPSL-CM5A-MR/WRF for high-end.

summer precipitation. These climate changes will cause increased tree heat stress and transpiration, and lead to drier soils and increased frequency and severity of drought events. This is not only expected to lead to a decrease in forest productivity (e.g., Scots pine, Figure 17; Norway spruce and Sessile oak, Figure 19), but it also has the potential to induce large-scale forest dieback, as evidenced in many regions worldwide over the past 15+ years already.

Some tree species will be less sensitive to future climate change (Figure 19). Although Mediterranean tree species are projected to be negatively affected by extreme drought events in the most southern parts of Europe, their growth is likely to remain constant or even increase elsewhere. This is the case for Holm oak, for example, whose northern expansion along the Atlantic coast of France is already being reported.

These results (Figure 19) may look different, particularly at the regional scale, if different climate scenarios were used. However, the range of scenarios spanned is quite large, ranging from very mild +1.5°C to true "high-end" scenarios (Figure 19). Thus, the range of possible forest responses should be captured well by these simulations.

3. What are the major needs for adaptation of forestry to changing driving forces?

Forestry can be adapted to the changing climate by switching to climatically better adapted species, and moving towards forestry systems that include more than one species at the stand scale.

Given the large magnitude of high-end climate change, some tree species will clearly be outside their environmental niche in many places where they are productive today, such as European beech and Norway spruce. Thus, a change in tree species is needed. The timing of such switches needs to be considered carefully, due to the long production periods in forestry. On the one hand, forest managers must not wait until the first negative impacts are evident, as this may ruin the capital. On the other hand, immediately planting new species that could thrive under the climatic conditions of, say, 2060 or 2080 may not be possible under current climatic conditions, e.g. because of their sensitivity to frosts (e.g. Sessile oak and Holm oak at high latitudes and elevations, Figure 18) or an insufficient length of the growing season that hinders tree growth. Thus, the timing of species switches needs to be determined at the regional scale, and forest managers must take into account both the rates of anticipated future climate change and the ecological properties of extant, as well as new, tree species (so-called "trend-adaptive management"). The rates of change of the regional climate are considerably more uncertain than continental or global-scale trends, which renders climate-adaptive forest management all the more challenging.

Different tree species have widely different sensitivities to driving forces, such as frosts, heat, or drought, or natural disturbances such as fire. Due to this and the unavoidable uncertainty in regional climate projections, it is likely to be highly beneficial to move from single-species to multi-species stands, as an insurance policy against catastrophic losses of timber and ecosystem services at the stand scale. There are multiple examples demonstrating not only the feasibility of mixed stands, but also their high utility in terms of both economic revenue and ecosystem service provision. Examples include Scots pine (*Pinus sylvestris*) – Silver birch (*Betula pendula*), European Beech (*Fagus sylvatica*) – Norway spruce (*Picea abies*) or Norway spruce – Silver fir (*Abies alba*) stands.

4. What is the climate mitigation potential of European forests?

European forests and forest products are significant contributors to the European greenhouse gas balance, constituting a major carbon sink that can help to reach EU climate targets.

Forests play an important role in the greenhouse gas balance of Europe, as forests and their products constitute a carbon pool that continues to increase, thus providing a net sink and helping to mitigate EU carbon emissions.

EU forests and the forest sector currently produce an overall climate mitigation impact that amounts to about 13% of the total EU emissions. Thus, they are a contributor to achieving climate targets, particularly the goal of limiting the global average temperature increase to less than 2°C above the pre-industrial level, although forests and their products alone are certainly insufficient for reaching such goals.

Forest products are also contributing to the bioenergy goals of the EU, as all wood products can – at least in theory – be burnt at the end of their lifetime. Hence it is not only direct bioenergy harvesting from forests that is important, but also the entire value chain of forest products as building materials, furniture, etc.

The large current sink strength of European forests implies that forestry could also contribute to achieving negative emissions (i.e., taking up more carbon than is being emitted by human activities) at the EU level, and hence they should be factored into corresponding policy targets.

The future climate mitigation potential of European forests cannot currently be assessed, as this depends strongly not only on the carbon that is stored on a per area basis, but also and probably even to a larger extent on total forest area, which results from competition with other land-uses (agriculture, urban, etc.). Results on these areal changes are not available yet from the IMPRESSIONS project, but can be supplied soon. However, the Forest Information System for Europe (FISE) and the forest pattern viewer service provided by EFDAC contain projections of these changes based on earlier sources (cf. http://forest.jrc.ec.europa.eu/).