Question 4

How has climate change affected EU forests and what might happen next?

Authors: *Marcus Lindner (EFI), Hans Verkerk (EFI)*

Climate change is ongoing and recent global temperatures are already more than one degree above the pre-industrial levels, with some regional differences (stronger warming especially in higher latitudes). Besides the warming trend, extreme events have been amplified with extended periods of hot spells and drought. For example, the years 2018 to 2020 were exceptionally warm and in large parts of Europe also particularly dry. Consequently, in recent years, European forests have been affected by severe droughts, widespread wildfires, a series of windstorms, rapidly expanding bark beetle infestations and several other pest and disease outbreaks. Evidence is increasing that these events have become much more frequent and more threatening because of climate change (Seidl et al., 2014; Seidl et al., 2017).

These changes constitute a major challenge for future forest management. Climate change and associated extreme events are already affecting the growth and stability of forests in Europe. While the analysis of forest growth changes in the late 20th century showed nitrogen deposition as a major explanatory factor with only limited contribution of CO_2 fertilization and climate change (Kahle et al., 2008), empirical growth trend analysis extending to 2010 showed that climate warming and extended growing season explained a substantial part of the growth enhancement observed around the year 2000 (Pretzsch et al., 2014). Increased forest productivity due to climate warming was observed in high latitudes (Henttonen et al., 2017) and in higher altitudes of mountainous regions (Sedmáková et al., 2019). Dendrochronological studies indicate that tree growth responses at low elevations differed from higher elevations and growth of spruce and beech declined 1991–2012 compared to 1961-1990 in the sub-montane belt (Sedmáková et al., 2019). Where temperature increases occurred in combination with extended periods of below average amounts of precipitation, trees may suffer from drought stress. Drought induced growth declines have increasingly been observed at the dry distribution limits of species such as in the Wallis in Switzerland (Bigler et al., 2006), but also in temperate lowland forests in Belgium (Kint et al., 2012).

The recent exceptionally long and intensive drought in Central Europe from 2018 onwards drastically exceeded previous impacts and resulted in widespread mortality in different species (Buras et al., 2020; Schuldt et al., 2020). A major consequence of the intensive drought was the widespread bark beetle outbreak affecting Norway spruce forests in Central Europe (Jakoby et al., 2019; Netherer et al., 2019), causing exceptionally large amounts of sanitary fellings and salvage cutting on more than a million hectares of spruce forests with subsequently saturated wood markets and collapsing saw log prices on wood markets for example in the Czech Republic, Austria and Germany. In Mediterranean forests in southern Europe intensified drought impacts affected tree mortality, resulting in shifting species distribution limits (e.g. Dorado-Liñán et al., 2019; Peñuelas and Boada, 2003; Vayreda et al., 2016).

Another direct impact of climate change on European forests has been increased wildfire damages (Fernandes, 2019; Moreira et al., 2020; San-Miguel-Ayanz et al., 2013). Due to increased temperatures and extended drought periods, more forest area across Europe is exposed to high fire risk, for longer periods of time. In recent years devastating megafires occurred with high numbers of fatalities e.g. in Portugal (2017) and Greece (2018), but also countries like Sweden, UK, Germany or Poland had excessive burned areas at levels not experienced in the recent past.

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The future evolution of climate change impacts can hardly be predicted due to a number of fundamental uncertainties about the future development of anthropogenic climate forcing and the resulting earth system dynamics:

1. The uncertain level of climate warming during the 21st century. It is obvious that European forests will continue to be impacted by continuously changing climate conditions and extreme events. These impacts will directly relate to the success of global climate protection policies. If the world succeeds in curbing and eventually reversing the growth of greenhouse gas concentrations in the atmosphere according to the Paris agreements under UNFCCC, the scale of impacts will stay more manageable. With every additional degree of climatic warming, the climate and biogeochemical systems will further reach into unchartered terrain. Recent climatic extremes have already demonstrated far reaching shifts in large scale global weather patterns (Kornhuber et al., 2020; Kornhuber et al., 2019), but there is no empirical basis available to simulate future changes in these global scale processes, as melting Arctic and Antarctic ice shields and a slowing gulf stream may act as tipping points in the earth system with unknown consequences (Lenton et al., 2019).

2. The future evolution of extreme events in the changing climate. The intensity of forest damage in recent years has increased more than expected as climate change induced extreme events were more severe than previously projected (Lorenz et al., 2019). It is unknown, how unusual or rare the recent extreme weather patterns of 2018-2020 will turn out to be when we look back from the year 2030 or 2050. In a positive scenario, Europe may experience more average climate conditions in the coming years and the length of the drought from 2018 to 2020 in Central Europe could stand out as exceptional for many years. However, it is equally possible or likely that exceptionally dry and wet periods will become the new normal, or even worse, that future extreme events will become even more extreme. European forests are thought to be resilient and are likely to recover from the present extreme events (Honkaniemi et al., 2020; Seidl et al., 2019) but with more frequent and more devastating extreme events, the resistance of present forest types may reach critical thresholds (McDowell et al., 2020).

3. The effect of CO_2 fertilization on forest productivity and water use efficiency. Projected impacts of climate change in European forests are quite sensitive to the impacts of increasing CO_2 concentrations in the atmosphere (Reyer, 2015), but model validations against observations revealed large uncertainties in projections of current process-based vegetation models (Piao et al., 2013). Essentially it is still difficult to generalize from CO_2 fertilization experiments to forest ecosystem responses under changing conditions, but it is highly likely that increases in terrestrial carbon storage as a result of increased CO_2 will decline into the future (Walker et al., 2020).

4. The future integrated effects of productivity changes and disturbance impacts. European forests have been a carbon sink for many decades (Luyssaert et al., 2010), but the future balance between productivity changes and disturbance impacts is uncertain (Nabuurs et al., 2013; Reyer et al., 2017). Forest management has the potential to mitigate some of the expected enhanced disturbance impacts (Fernandes, 2013; Hlásny et al., 2019), but this will require concerted efforts at many different levels (Castellnou et al., 2019; Verkerk et al., 2018).

5. The adaptive capacity of trees and forest ecosystems. Forest trees have considerable adaptive capacity (Aitken et al., 2008), but the extent of environmental changes expected is exceeding historical precedents. The present rate and magnitude of climate change exceeds the natural migration and adaptation capacity of tree species. Future species suitability is difficult to predict as we do not know well how trees can adapt to adverse conditions. Existing models still need improvement to make them really useful in guiding forest management (Dyderski et al., 2018; Pecchi et al., 2019). Assisted migration will be needed to a considerable extent to support sustainable forest management (Fady et al., 2016).

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