

Chapter V: Mapping the risk to European forests with a changing climate

Barry Gardiner, Mart-Jan Schelhaas and Bruce Nicoll

Background

Insects and diseases, storm damage, wildfires, drought, and herbivore grazing are the main agents affecting forests within Europe although their importance varies by region. The level of damage is increasing at the same time that European forests are being asked to provide an increasing range of ecosystem services and therefore understanding the impact of forest management and the changing climate on forest disturbance is one of the big current challenges for forest science.

European Forest Disturbance

The primary abiotic damage in Europe is due to wind and fire and the primary biotic damage is due to bark beetles. However, these damage agents are quite localised so wind tends to be more important in Western and Northern Europe and fire more important in the Mediterranean region, and beetle damage is important in Atlantic temperate, Alpine and Mediterranean forests, whereas mountain and boreal forests are more affected by fungi and wildlife. The economic consequences of this damage to forests can be profound: for example fire caused €5 billion of damage in Greece in 2007 and €0.8 billion in Portugal in 2005, and wind caused €6 and €1 billion in France in 1999 and 2009, respectively, and €2.4 billion in Sweden in 2005.

The overall increase in European damage levels appears to be due primarily to an increase in the forest growing stock together with changes in climate and land management (Figure 1). Such changes are expected to continue in future. For example, wind damage is predicted to increase by at least a factor of 2 by the end of the century and extend further east across the continent. In addition, warmer and drier summers will increase fire risk. For example, in France the high levels of forest fire danger currently limited to the Mediterranean area, will extend to the western part of France by 2040 and to most of the country by 2060. Global warming is expected to enhance the winter survival of bark beetles triggering increases in population abundance and risk of outbreaks.

European forests will, therefore, be under increasing threat from a range of existing and new damaging agents and it is important to be able to predict the level of risk now and into the future. Furthermore, because major damage events and outbreaks of pests and diseases can affect large areas and many countries such calculations need to be carried out from the regional to the European scale.

Modelling Disturbance at the Landscape to European Scale

It is now possible to work at regional to European scales without losing sight of the detailed mechanisms controlling tree damage which operate at the tree scale or lower. This is because of recent developments in computer science, complex system modelling and artificial intelligence. However, high-resolution modelling of risk to forests from different hazards at the European scale presents serious challenges. In particular there are requirements for detailed data on forest structure (species mixture, tree height, diameter, spacing, ground vegetation, etc.) and site (soil type, elevation, climate, etc.) and to have available models that are able to calculate risk across Europe for the range of site types, forest species, forest management regimes and climate that occur. For illustration, we present here modelling of the risk of wind damage and bark beetle attacks across Europe.

Mapping of wind damage risk for Europe

To map wind damage risk across Europe requires knowledge of the current and future wind climates, information on the forest stands (tree species, tree diameter and height, stocking), and soil type and rooting depth. In this study we used high resolution wind climate data for the past and future climate that is available at 25 km resolution from the EU ENSEMBLES project (Figure 2). Information on the forest structure was obtained from the Synthetic European Forest Structure Database, which has a resolution of 1 km and is based on a species distribution map of Europe and a collection of National Forest Inventory (NFI) measurements. The FAO soil map that was used to construct the species map was also used to assign soil type and rooting depth. The stand and soil data described above were used as inputs to the wind risk model ForestGALES2.3, which calculates the critical wind required to damage a stand. The output from the ForestGALES model run is shown in Figure 3. Only areas where the land cover is more than 10% forest are shown. From this figure it can be seen that there are areas of Central Europe, southern Sweden, Southern Finland and Estonia which have the lowest critical wind speeds. If the critical wind speeds are combined with the wind climate from Figure 2 it is possible to calculate a probability of damage for the whole of Europe and data on future wind climates allows the future risk to be calculated.

Mapping of bark beetle risk for Europe

Tools are not currently available that allow mapping of the risk of bark beetle outbreaks across Europe. However, scientists at BOKU University in Vienna performed a large number of simulations with the PICUS forest growth model, covering a wide range of stand and climatic conditions in Austria. These simulations were then used to construct

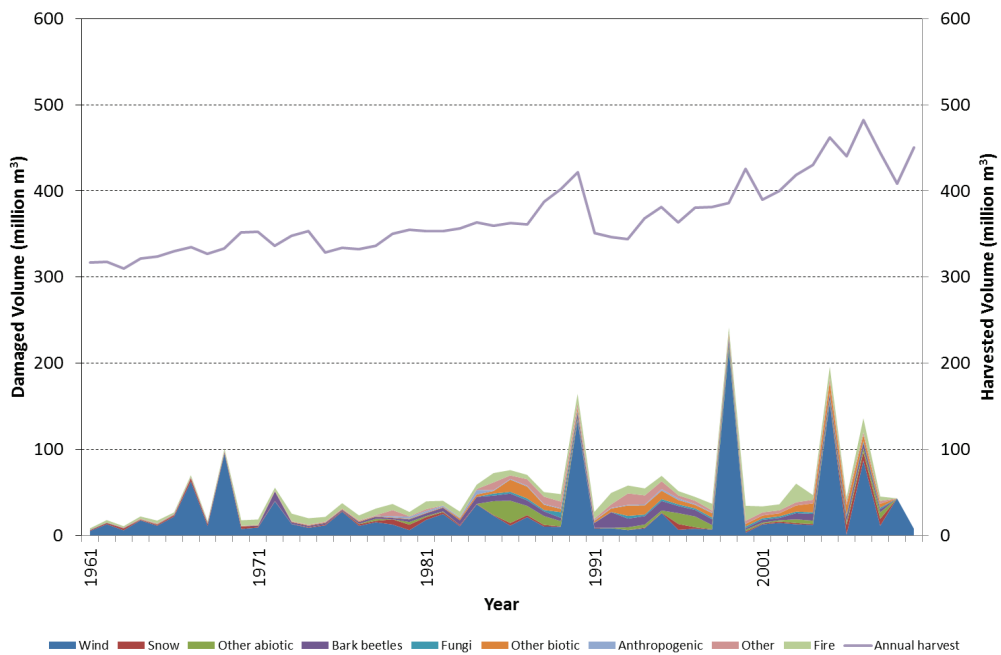


Figure 1. Damage levels, causes of damage and annual harvest rate for European forests (1961–2010).

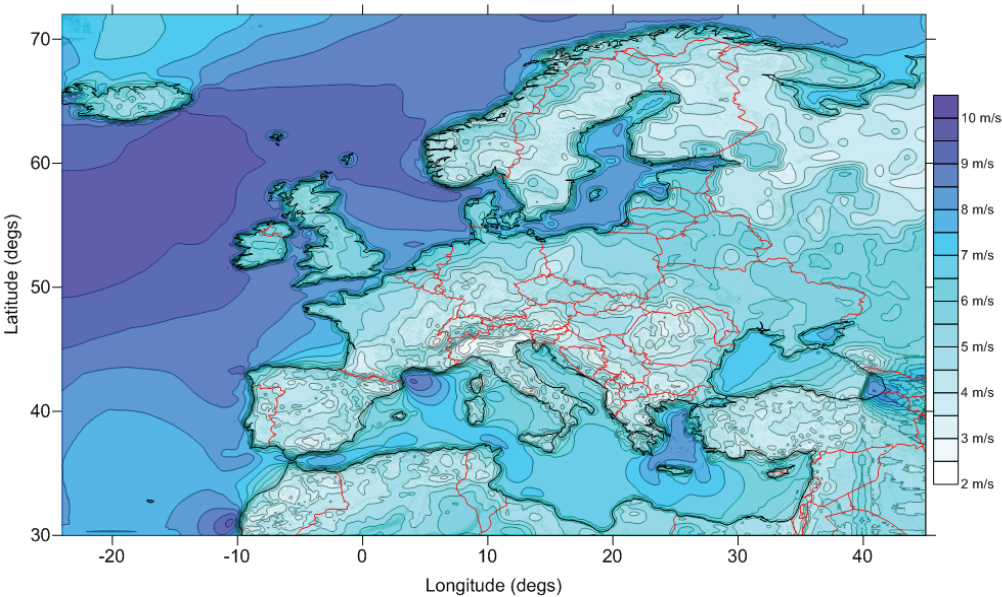


Figure 2. Estimated Weibull A values for current conditions (1991–2010) from ENSEMBLES data. (Darker colours represent areas of stronger annual winds).

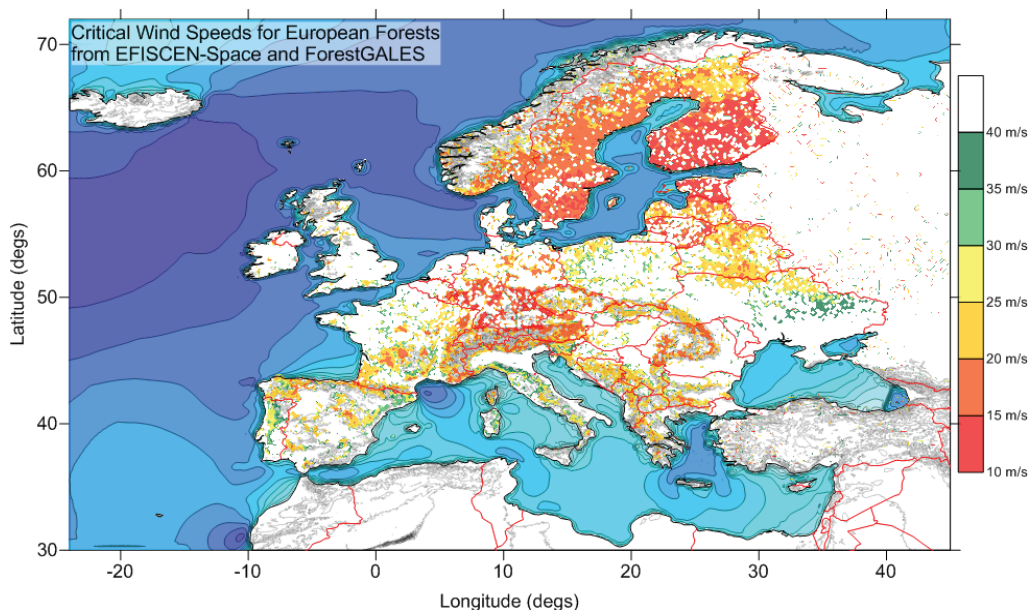


Figure 3. Critical wind speeds to cause damage to forests stands across Europe. Only areas with forest cover of more than 10% are displayed. The sea areas show the same wind climate information as are displayed in Figure 2.

a regression model that predicts the chance of bark beetle infestation based on average annual temperature, total annual precipitation, stand age, stand density and the percentage of the host tree within a stand. If a stand is infested the damage level is then predicted as a function of average annual temperature, total annual precipitation and host tree percentage.

We applied this regression model to the whole of Europe, using the Synthetic European Forest Structure Database (see above) and WorldClim data focussing on spruce. Stand age was estimated from height and soil type, based on yield tables. Climate data were derived from the WorldClim database, as average annual temperature and average annual precipitation. Stand risk was quantified for each cohort in the forest structure database as the product of total volume of spruce, the chance of infestation and the fraction of the stand damaged. The resulting map (Figure 4) gives the endemic risk of bark beetle infestation, so it ignores increased risk due to build-up of the population in previous years, for example due to wind-throw events. Furthermore, this reflects the average long-term weather conditions. As can be seen from the map Central Europe and Southern Sweden are major areas at risk of bark beetles on spruce, which corresponds well with observed damage outbreaks. Although spruce is also found in more northerly areas it is too cold at these latitudes for bark beetles although this could change in the future with a changing climate.

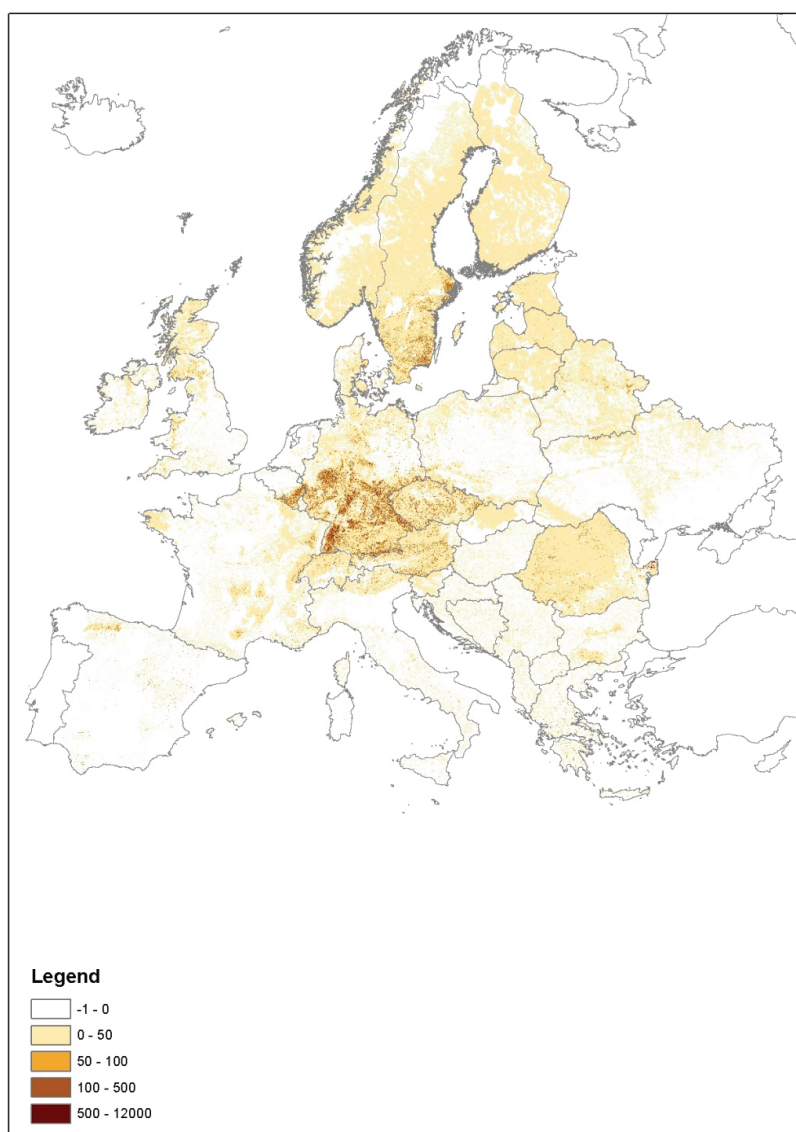


Figure 4. Endemic bark beetle risk for average weather conditions, expressed in m^3 per pixel.

Summary and Conclusions

We have shown that it is possible in a preliminary way to calculate the risk for wind damage and bark beetle attack across the whole of Europe. Such calculations require extensive data sets on European forest condition, and information on the current and future climate. In addition these maps can only be created by models that are able to work across the whole range of forest and site conditions that exist within Europe. The use of informed decisions

on how to adjust these models when data are not available for a particular species or site is also an important requirement. Therefore, these maps have to be treated with caution and we emphasise that at this stage they only demonstrate the possibilities for the future and give some indication of the most vulnerable areas of Europe to these hazards.

With improved data on European forests and soils such as is becoming available from remote sensing it will become possible in the future to put higher confidence in the outputs from such simulations. At the same time it is important that work continues to extend the existing risk models for different damage agents and to start building models for other important hazards such as forest fires for which at present only locally applicable models are available.