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Review article

Climate change in Europe. 3. Impact on agriculture and forestry. A review*

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Abstract – This article reviews major impacts of climate change on agriculture and forestry.

climate change / agriculture / forestry / CO_2 / growing season / crop yield / frost damage / phenology / flowering / crop cycle / temperature / sowing date / grapevine / maize / wheat / water demand / irrigation / drought / carbon cycle / fire danger

Contents

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1. INTRODUCTION

The impacts of medium and long-term climate change on agriculture and forestry are often difficult to analyse separately from non-climate influences related to the management of the resources (Hafner, 2003). However, there is growing evidence that processes such as changes in phenology, length of growing season and northwards shift of crops and forest species can be related to climate change (IPCC, 2007). There are also increasing impacts due to an increased frequency of some extreme events which can be attributed to climate change.

Potential positive impacts of climate change on agriculture in general are related to longer growing seasons and new cropping opportunities in northern Europe, and increased photosynthesis and CO_2 fertilisation throughout Europe. These possible benefits are counterbalanced by potentially negative impacts that include increased water demand and periods of water deficit, increased pesticide requirements and crop damage, and fewer cropping opportunities in some regions in southern Europe (Olesen and Bindi, 2002; Maracchi et al., 2005; Chmielewski et al., 2004; Menzel et al., 2003). In general, changes in atmospheric CO_2 levels and increases in temperature are changing the quality and composition of crops and grasslands and also the range of native/alien pests and diseases. These may affect livestock and ultimately humans as well as crops. In addition, the increase in ozone concentrations related to climate change (Meleux et al., 2007) is projected to have significant negative impacts on agriculture, mainly in northern mid-latitudes (Reilly et al., 2007).

The link of forestry with climate change is twofold. Forests play a fundamental role in mitigating climate change because they act as sinks for carbon dioxide. However, they are also very vulnerable to changes in temperature, precipitation and extreme weather events which can have destructive impacts and reduce the carbon sequestration potential of the forest. Events such as forest fires have an even more negative effect since destroying the forest increases the amount of carbon dioxide in the atmosphere. The majority of forests in central Europe are growing faster than in the past, partly because of regional warming. In contrast, the extended heat-wave of 2003 caused a significant reduction in biomass production of forests (Gobron, 2005).

Although the economic impacts of climate change on agriculture and forestry in Europe are very difficult to determine because of the effects of policies and market influences and continuous technological development in farming and silviculture techniques, there is evidence of wider vulnerability for both sectors. Management actions can counteract but may also exacerbate the effects of climate change and will play an important role in measures for adaptation to climate change (AEA, 2007).

The indicators included in this section are related to agricultural production, phenology, forestry growth and distribution, and the observed and projected impacts of forest fires.

Good data availability and quality are essential for monitoring trends and threats relating to European forests and agricultural products. The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forest), originally set up to monitor the effects of air pollution, now includes surveys that could also be used to monitor the effects of climate change (e.g. phenology). Another clear step forward in the collection of relevant information is being achieved by the establishment of the European Data Centres on Soil and Forestry.

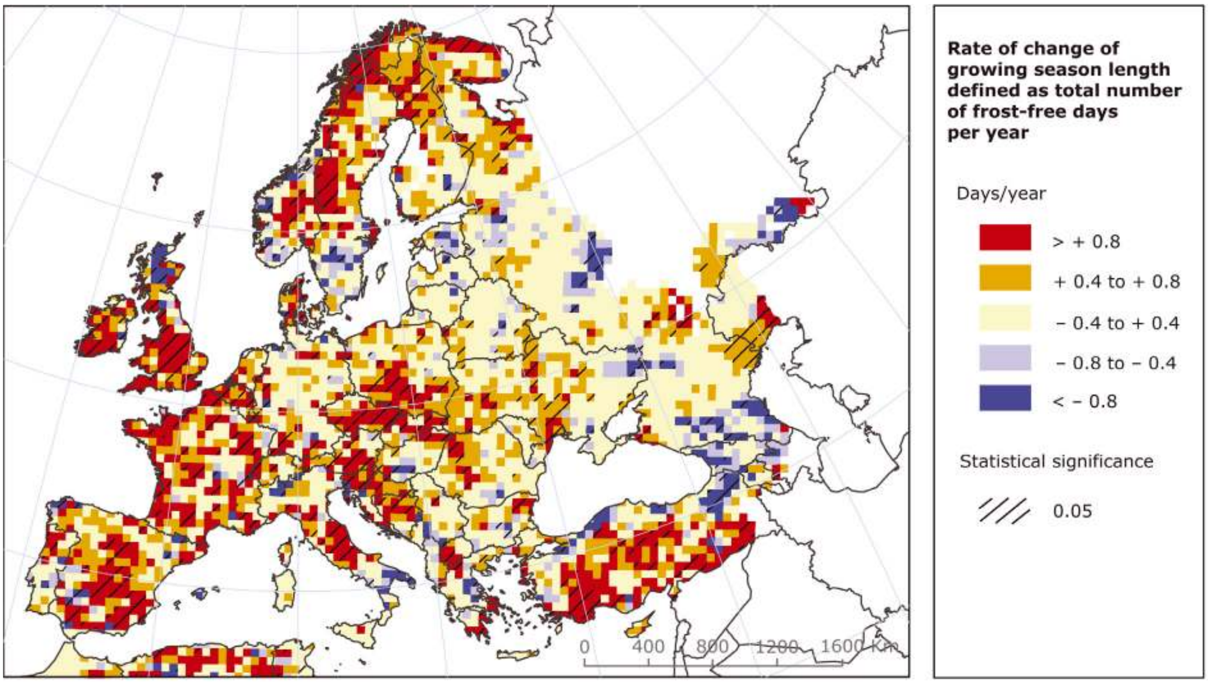
2. GROWING SEASON FOR AGRICULTURAL CROPS

Key messages

- There is evidence that the length of the growing season of several agricultural crops in Europe has changed.
- A longer growing season increases crop yields and insect populations and favours the introduction of new species in areas that were not previously suitable for these species. These observed facts are particularly important for the northern latitudes.
- Locally at southern latitudes, the trend is towards a shortening of the growing season, with consequent higher risk of frost damage from delayed spring frosts.

2.1. Relevance

Increasing air temperatures are significantly affecting the duration of the growing season over large areas of Europe (Scheifinger et al., 2003). The number of consecutive days with temperatures above 0 °C can be assumed to be the period favourable for growth. The timing and length of this frost-free period is of interest to naturalists, farmers and gardeners among others. The impact on plants and animals is reported mainly as a clear trend towards an earlier start of growth in spring and its prolongation into autumn (Menzel and Fabian, 1999). A longer growing season allows the proliferation of species that have optimal conditions for development and an



Note: The rate of change (number of days per year) of the duration of the growing season (defined as total number of frost-free days per year) as actually recorded during the period 1975–2007.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 1. Rate of change of crop growing season length 1975–2007.

increase in their productivity (e.g. crop yields, insect population), and the introduction of new species (very sensitive to frost) in areas previously limited by unfavourable thermal conditions. Changes in management practices, e.g. changes in the species grown, different varieties, or adaptations of the crop calendar, can counteract the negative effects of a changing growing season (pests) and capture the benefits (agricultural crops).

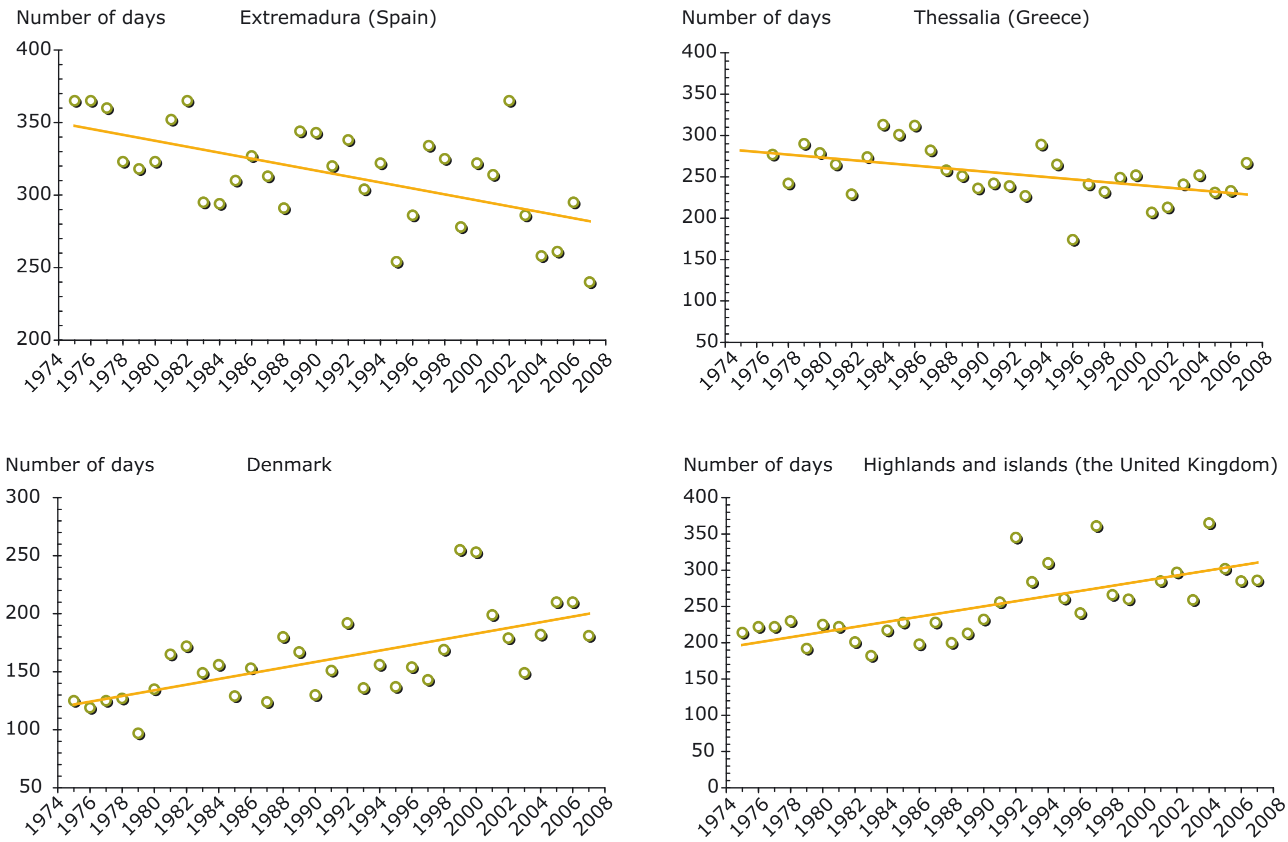
2.2. Past trends

Many studies report a lengthening of the period between the occurrence of the last spring frost and the first autumn frost. This has occurred in recent decades in several areas in Europe and more generally in the northern hemisphere (Keeling et al., 1996; Myneni et al., 1997; Magnuson et al., 2000; McCarthy et al., 2001; Menzel and Estrella, 2001; Tucker et al., 2001; Zhou et al., 2001; Walther et al., 2002; Root et al., 2003; Tait and Zheng, 2003; Yan et al., 2002; Robeson, 2002; Way et al., 1997). An analysis of the growing period in Europe between 1975 and 2007 (Fig. 1) shows a general and clear increasing trend. The trend is not uniformly spread over Europe. The highest rates of change (about 0.5–0.7 days per year) were recorded in central and southern Spain, central Italy, along the Atlantic shores, and in the British Isles, Denmark and the central part of Europe. The extension of the growing season is either due to a reduction in spring frost events or to a progressive delay in the start of autumn frosts. However, a decline has been observed in the Mediterranean countries, in the Black Sea area and in parts of Russia. In areas where a decrease in the length of frost-free period occurred, in particular in southern Europe, the plants are more at risk from frost damage due to a delay in the last winter-spring frost (Fig. 2).

2.3. Projections

Following the observed trends (which have accelerated even more in the past decade) and in line with projections for temperature increase, a further lengthening of the growing season (both an earlier onset of spring and a delay of autumn) as well as a northward shift of species is projected. The latter is already widely reported (Aerts et al., 2006). The length of the growing season will be influenced mainly by the increase in temperatures in autumn and spring (Ainsworth and Long, 2005; Norby et al., 2003; Kimball et al., 2002; Jablonski et al., 2002).

According to the IPCC analysis, Europe will warm in all seasons for all scenarios, but warming will be greater in western and southern Europe in summer and northern and eastern Europe in winter. More lengthening of the growing season is therefore expected in these northern and eastern areas, while in western and southern Europe the limited water availability and high temperatures stress during summer will hinder plant growth.



Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 2. Length of frost-free period in selected European areas 1975–2007.

3. TIMING OF THE CYCLE OF AGRICULTURAL CROPS (AGROPHENOLOGY)

Key messages

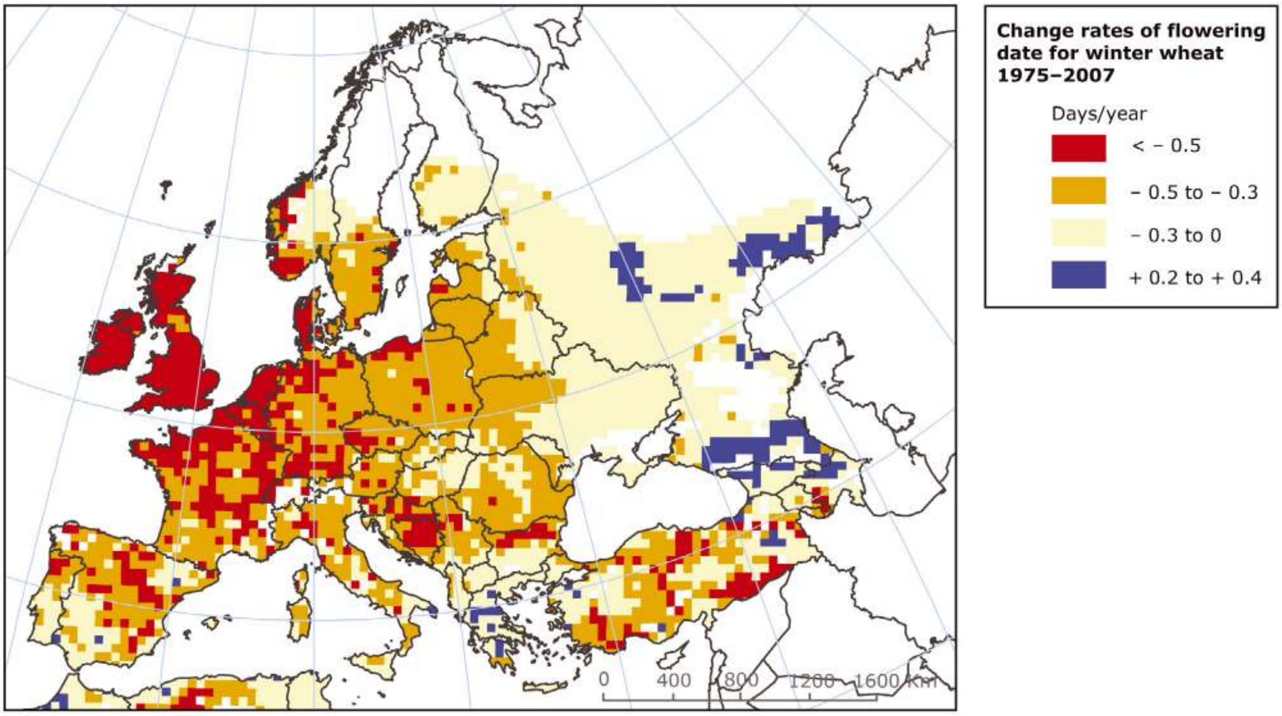
- There is evidence that the flowering and maturity of several species in Europe now occurs two or three weeks earlier than in the past.
- The shortening of the phenological phases is expected to continue if temperatures continue to increase.
- Adaptations of farm practices will be crucial to reduce or avoid negative impacts of crop-cycle shortening.

3.1. Relevance

Changes in crop phenology provide important evidence of responses to recent regional climate change (IPCC, 2007). Although phenological changes are often influenced by management practices and new farming technologies, recent warming in Europe has clearly advanced a significant part of the agricultural calendar (Fig. 3). Specific stages of growth (e.g. flowering, grain filling) are particularly sensitive to weather conditions and critical for final yield. The timing of the crop cycle (agrophenology) determines the productive success of the crop. In general, a longer crop cycle is strongly correlated with higher yields, since a longer cycle permits maximum use of the available thermal energy, solar radiation and water resources. The impacts of unfavourable meteorological conditions and extreme events vary considerably, depending on the timing of occurrence and the development stage of the crops. However, shortening of the growth period can also help avoid summer stress conditions in areas prone to drought. European farmers have already adapted their practices to the changing climate by selecting suitable varieties or adapting the crop calendar, and can be expected to do so increasingly in the future.

3.2. Past trends

Several studies have collected data and observed changes in the phenological phases of several perennial crops in Europe, such as the advance in the start of the growing season of fruit trees (2.3 days/10 years), cherry tree blossom (2.0 days/10 years), and apple tree blossom (2.2 days/10 years), in line with increases of up to 1.4 °C in mean annual air temperature in Germany (Chmielewski et al., 2004), and the advance of apricot and peach tree flowering by 1–3 weeks over the past 30 years for in France (Chuine et al., 2004). Sowing or planting dates of several agricultural crops



Note: The day of the year of flowering has been simulated by using a crop growth model (CGMS — Crop Growth Monitoring System).

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 3. Modelled change of flowering date for winter wheat 1975–2007.

have been advanced, by 5 days for potatoes in Finland, 10 days for maize and sugar beet in Germany and 20 days for maize in France (IPCC, 2007).

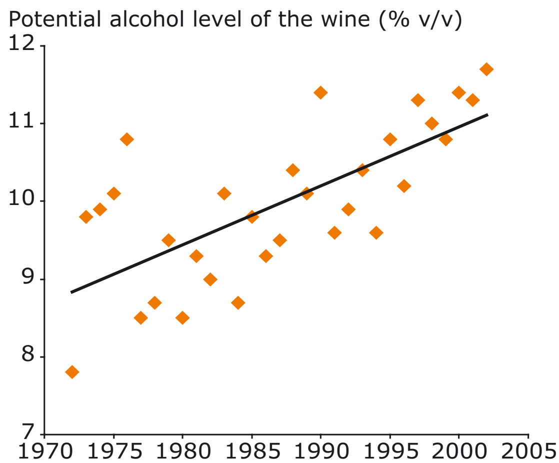
3.3. Projections

Assuming that the warming trend will continue, further reductions in the number of days required for flower opening (anthesis) and maturity may be expected for areas in western Europe, where phenological changes are strongly accelerating (ECCE, 2005). However, the rate of the reduction of these phases may gradually decrease with a further increase in temperature due to a reduced efficiency of photosynthesis at high temperatures.

Grapevine phenology

Wine quality is determined by various parameters: grape variety, rootstock, soil type, cultivation techniques, and climatic characteristics. The first three are generally constant over time, while cultivation techniques are most often responsible for long-term variability. Climate influences year-to-year variability and is responsible for variations in the amount and quality of wines (Fig. 4).

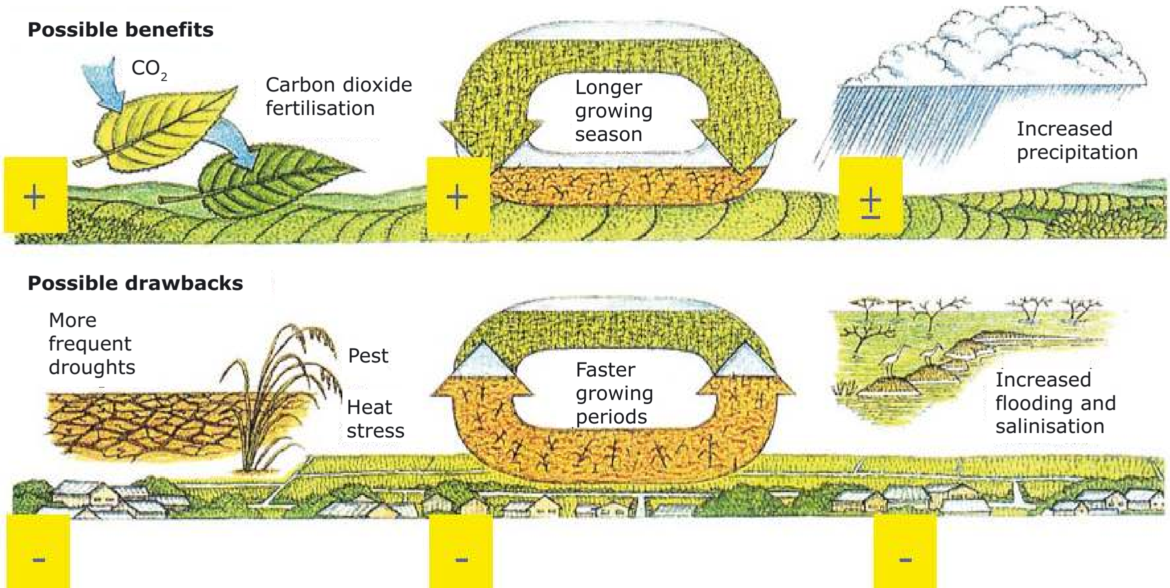
Wine production areas, and particularly those for premium wines, are limited to regions climatically conducive to growing



Note: Reprinted with permission from Duchêne and Schneider, Grapevine and climatic changes: a glance at the situation in Alsace. Agron. Sustain. Dev. 25 (2005) 93–99. Copyright: 2005 INRA, EDP Sciences. Permission has been kindly given by Dr. Eric Lichtfouse, Editor-in-Chief of Agronomy for Sustainable Development. http://www.agronomy-journal.org.

Source: Duchêne and Schneider, 2005.

Figure 4. Potential alcohol level at harvest for Riesling in Alsace (France) 1972–2003.



Note: A changing climate will affect agro-ecosystems in various ways, with either benefits or negative consequences dominating in different agricultural regions. Rising atmospheric CO_2 concentration, higher temperatures, changing patterns of precipitation, and changing frequencies of extreme events will have significant effects on crop production, with associated consequences for water resources and pest/disease distributions.

Source: Bongaarts, 1994.

Figure 5. Agro-ecosystem processes and a changing climate.

grapes with balanced composition and degree to which they reflect their origin ('varietal typicity'). Three conditions are required: (i) adequate heat accumulation; (ii) low risk of severe frost damage; and (iii) the absence of extreme heat. Moreover, vines are resistant to limited water availability in summer and it is essential to have no rainfall during harvest time, in order to increase sugar concentration and reduce disease development.

Observed climate change during recent years has resulted in a general increase in wine quality, due mainly to the increase in temperature and reduction of rainfall, particularly during the last part of the ripening period, with a gradual increase in potential alcohol levels (Duchêne and Schneider, 2005). Future possible impacts are:

- seasonal shift: a move forward in time of all the phenological phases with an increase of frost risk and a shortening of the ripening period. As a possible effect, the harvest time may occur during periods of high temperatures, with negative effect on wine quality;
- expansion of wine production areas, to north and more elevated regions;
- water stress due to a reduction of available water;
- modification of pest and disease development;
- increase of sugar concentration resulting in wine with high alcohol and low acidity. The consequence is a reduced possibility of wine ageing and poorer phenolic ripening;
- modification of natural yeast composition.

4. CROP-YIELD VARIABILITY

Key messages

- Climate and its variability are largely responsible for variations in crop suitability and productivity in Europe.
- Since the beginning of the 21st century, the variability of crop yields has increased as a consequence of extreme climatic events, e.g. the summer heat of 2003 and the spring drought of 2007.
- As a consequence of climatic change, such events are projected to increase in frequency and magnitude, and crop yields to become more variable. Changes in farming practices and land management can act as risk-mitigating measures.

4.1. Relevance

Climate change introduces new uncertainties for the future of the agricultural sector. Climatic conditions are projected to become more erratic with an increase in the frequency of extreme events (floods, hurricanes, heat waves, severe droughts) (Parry, 2000). Biomass production of plants, and thus crop yields, are fundamentally determined by climatic conditions, i.e. the stable availability of energy (radiation, temperature) and water (rain) to support growth. Other environmental and anthropogenic factors, such as soil fertility, crop varieties and farming practices, also influence crop yields (Fig. 5). These factors imply that, in principle, many adaptation options are available to adjust agricultural practices to the changing climate, but that opportunities differ between regions.

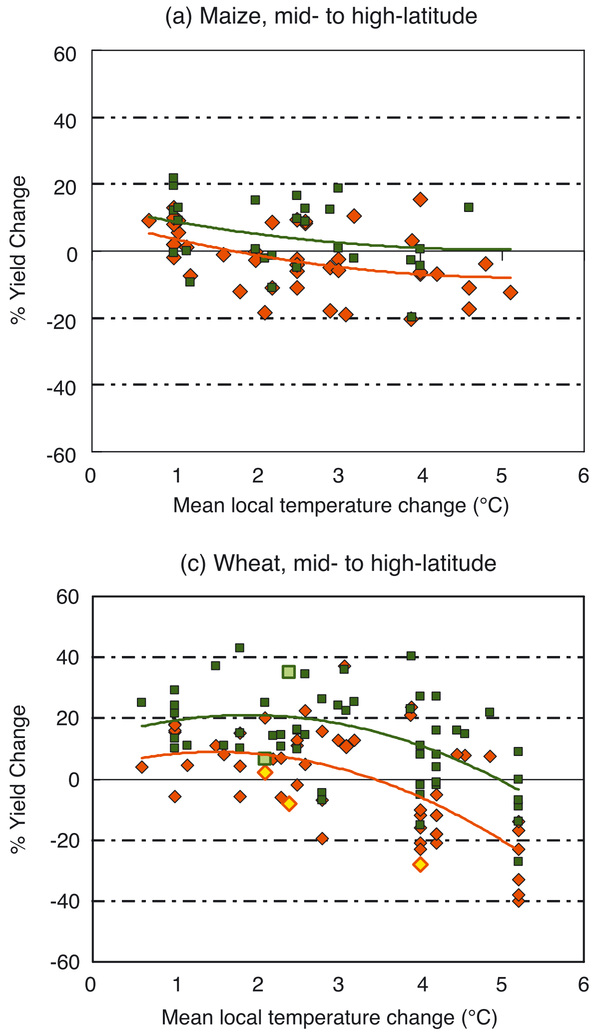
4.2. Past trends

While the area under arable cultivation in most of western Europe has decreased over the past 40 years, crop yields have increased almost continuously (Eurostat). This trend has persisted into the 21st century, although crop-yield variability increased as a consequence of several extreme meteorological events in short succession: a late frost in 2003 followed by a severe drought reduced cereal yields over most of Europe, a drought in 2005 severely affected western Europe (Iberian Peninsula), and an early drought in 2006 was followed by extreme rains during the summer, resulting in lower cereal production, especially in eastern Europe (EC, MARS Bulletins, 2008). Alexander et al. (2006) found a general increase in the intensity of precipitation events observed at the global level. For the Mediterranean area, where climate vulnerability is high, several studies found an increasing trend towards more intense precipitation and a decrease in total precipitation (Alpert et al., 2002; Maheras et al., 2004; Brunetti et al., 2004). In general, it is difficult to separate the climate effects from those of improved agricultural techniques in the development of historic crop yields. Adaptive management is expected to continue to help reduce the risks to agricultural yields from climate change, and to make better use of opportunities.

4.3. Projections

The effects on agricultural yields of increasing mean daily temperatures depend on their magnitude and geographic extent. The production areas of some crops could expand northwards in Europe, e.g. for maize. With an increase in mean annual temperature of 2 °C, cereal yields are expected to increase, partly because of the fertilisation effect of the increase in CO_2 (Parry et al., 2004). However, an increase of 4 °C or more will shorten the crop cycle and the CO_2 effect will not compensate for the resulting loss of yield. Crop yields are also at risk from more intensive precipitation and prolonged periods of drought, particularly in areas bordering the Mediterranean basin.

Figure 6 shows the sensitivity of maize and wheat yields to climate change, as derived from the results of 69 published studies. These span a range of precipitation changes and CO_2 concentrations, and vary in how they represent future changes in climate variability. Responses include cases without adaptation (red dots) and with adaptation (dark green dots). Adaptation represented in these studies includes changes in planting dates and crop varieties, and shifts from rain-fed to irrigated conditions.



Note: A small increase in temperature has a positive impact on cereals yield, while a high increase (3–5 °C) has a negative impact. Lines are best-fit polynomials and are used here to summarise results across studies rather than as a predictive tool.

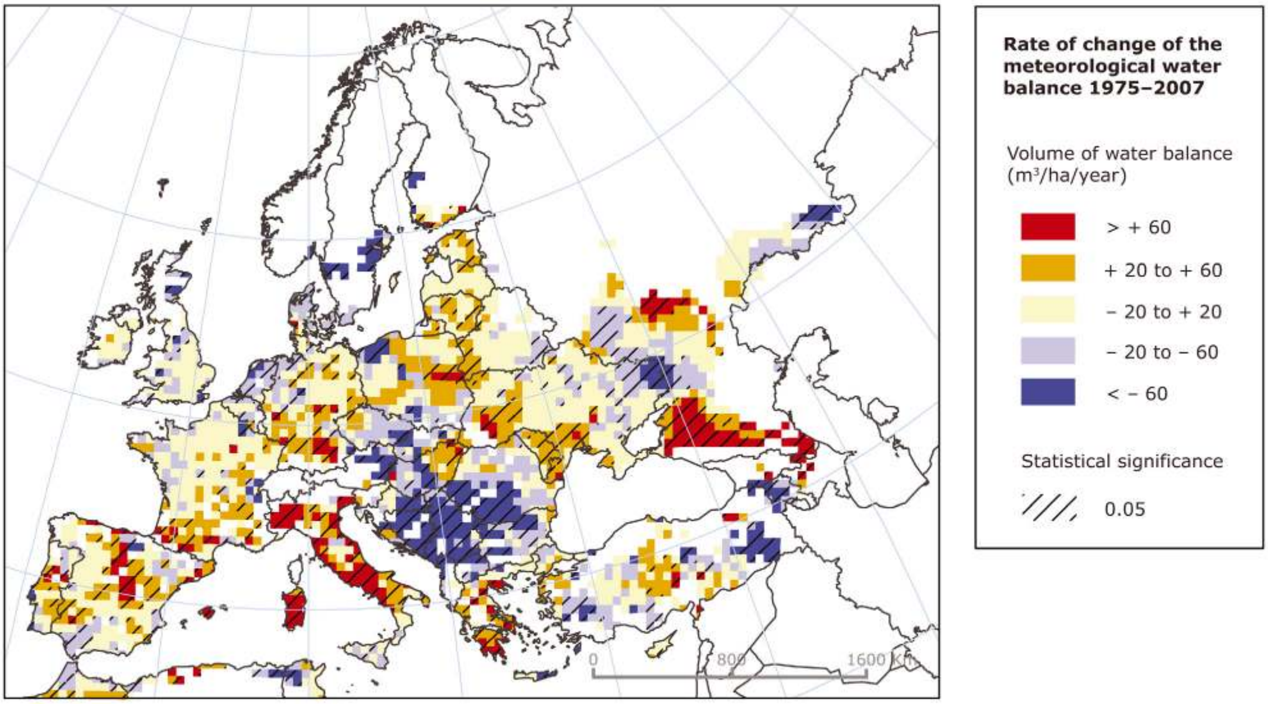
Source: Eastering et al., 2007. Published with permission of the Intergovernmental Panel on Climate Change.

Figure 6. Sensitivity of cereal yields to climate change for maize and wheat.

5. WATER REQUIREMENT

Key messages

- Between 1975 and 2006 clear trends, both positive and negative, were evident in water requirement across Europe, with marked spatial variability. A significant increase in water demand (50–70%) occurred mainly in Mediterranean areas; large decreases were recorded mainly in northern and central European regions.
- Current trends and future scenarios depict an increase in the demand for water in agriculture, potentially increasing competition for water between sectors and uses.



Note: The rate of change of the 'meteorological water balance', expressed in $m^3\ ha^{-1}\ y^{-1}$ The map provides an estimate of the increase (red in the map) or decrease (blue in the map) of the volume of water required from irrigation in order to ensure that crop growth is not limited by water stress.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 7. Rate of change of the meteorological water balance 1975–2007.

5.1. Relevance

Climate change may affect agriculture primarily through increasing atmospheric $CO_{2'}$, rising temperatures and changing rainfall. Where rainfall does not limit crop growth, these conditions allow for earlier sowing dates and enhanced crop growth and yield (see previous indicators). Where reduced rainfall is predicted, however, the increased requirement for irrigation water can have an overall negative impact in economic and environmental terms. In these areas, increased water shortages are expected to increase competition for water between sectors (tourism, agriculture, energy, etc.), particularly in southern Europe where the agricultural demand for water is greatest. Several adaptation options are available to mitigate the risks of water shortage. Increased irrigation can further burden surface and groundwater resources and increase greenhouse gas emissions, adding to the mitigation challenge.

5.2. Past trends

Systematic observations of water demand for agriculture do not exist at the European scale, however local trends can be reconstructed by using meteorological data (Figs. 7, 8). On average, the rate of increase in water demand is around 50 m^3/ha/year, but in some cases (Italy, Greece, Maghreb, central Spain, southern France and Germany) it is more than 150–200 m^3/ha/year. Areas with upward trends in the water balance (due mainly to an increase in rainfall), have been observed in the Balkan Peninsula, the Alpine region, Scandinavia, Scotland, Benelux, the Czech Republic, Slovakia, Poland and Hungary, as well as in many Turkish areas. In the Mediterranean area, a worsening meteorological water deficit (declining water balance) has been observed over the past 32 years.

5.3. Projections

No quantitative projections of irrigation demand are available. Many climatic projections for Europe (IPCC, 2007) foresee a very likely precipitation increase in the north and a decrease in the south, especially during the summer. Also the extremes of daily precipitation are projected to increase in the north and the annual number of rainy days to decrease in the Mediterranean. The risk of summer drought is therefore likely to increase in central Europe and in the Mediterranean area. Agricultural crops will be affected, among other factors, in positive and negative ways by changes in the length and timing of the vegetative cycle. Crop management will have to be adapted in order to try to avoid crucial development stages

Note: Surplus means positive values of meteorological water balance.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 8. Meteorological water balance in selected parts of Europe 1975–2007.

sensitive to water-stress (flowering, grain filling, etc.) occurring during generally dry periods.

6. FOREST GROWTH

Key messages

- In much of continental Europe, the majority of forests are now growing faster than in the early 20th century.
- A changing climate will favour certain species in some forest locations, while making conditions worse for others, leading to substantial shifts in vegetation distribution.
- The distribution and phenology of other plant and animal species (both pests and pollinators) are likely to change, leading to further alterations in competitive dynamics in forests that will be difficult to predict.
- Periods of drought and warm winters are increasing pest populations and further weakening forests.

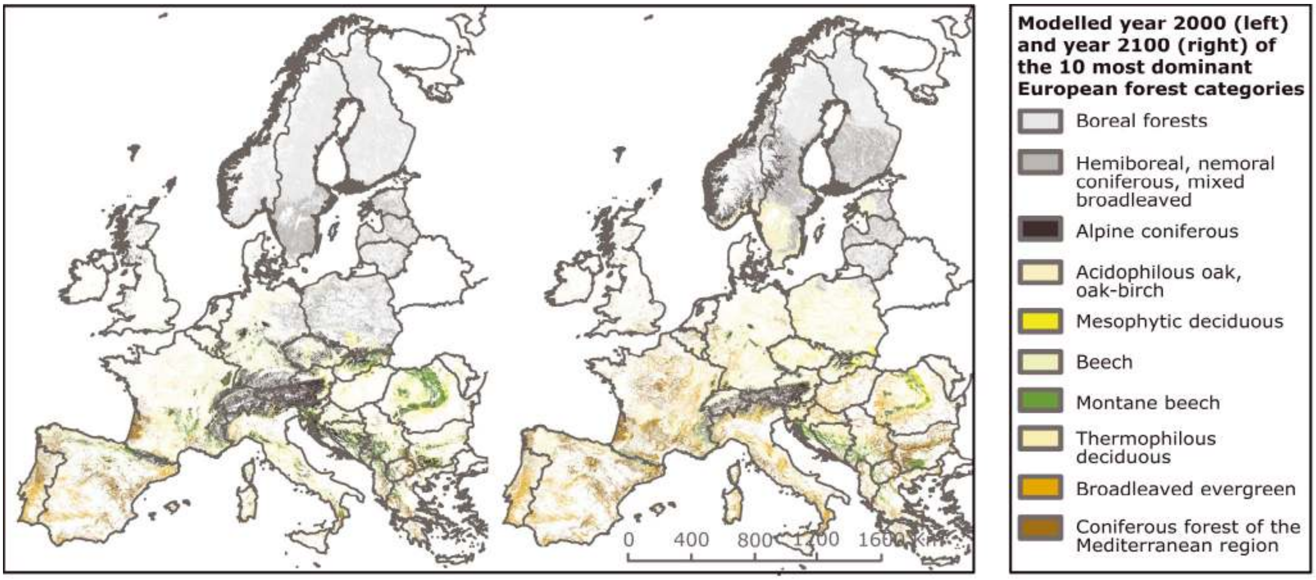
6.1. Relevance

Forests contain 77% of the global carbon pool in vegetation biomass and hence play an important role in the global carbon cycle (Dixon et al., 1994; IPCC, 2007). Forests and woodlands provide many things that society values, including food, marketable products, medicines, biodiversity, carbon reservoirs and opportunities for recreation. In addition, they regulate biogeochemical cycles and contribute to soil and water conservation. Changes in global climate and atmospheric composition are likely to have an impact on most of these goods and services, with significant impacts on socioeconomic systems (Winnett, 1998).

Management has a significant influence on the development of the growing stock and forest productivity. Adaptation measures include changes to plantation practices and forest management, the planting of different species mixtures, better matching of the species to the specific site, planting of similar species from their places of origin and non-native species in anticipation of climate change (Broadmeadow et al., 2003), and the restoration of forest typologies that could offer greater flexibility to climate change (Kölling, 2008).

6.2. Past trends

For many centuries, most European forests were overexploited. Growth rates were reduced and biomass stocks were depleted until the middle of the 20th century, when growth rates started to recover (Spieker et al., 1996). Much of this increase can be attributed to advances in forest management practices, genetic improvement and, in central Europe, the cessation of site-degrading practices such as litter collection for fuel. It is also very likely that increasing temperatures and CO_2 concentrations, nitrogen deposition, and reduction of air pollution (SO_2) have had a positive effect on forest growth. Trees have long been known to respond to changes in climate: variations in tree-ring widths from one year to the next are recognised as an important source of climatic information.



Note: Modelled to evaluate the change of habitat suitability coverage of the ten most dominant European Forest Categories (EEA, 2006), used IPCC SRES A1B scenario and NCAR CCM3 model.

Source: Casalegno et al., 2007.

Figure 9. Current (2000) and projected (2100) forest coverage in Europe.

Warmer winter weather is likely to increase productivity by extending the length of the growing season (Cannell *et al.*, 1998).

Elevated atmospheric CO_2 concentrations can have a fertilising effect.

Cold and snow-related damage are likely to become less common.

Reduced summer rainfall may reduce tree growth and severe droughts may kill increasing numbers of trees.

Elevated atmospheric ozone concentrations may have a negative impact on growth (Sitch *et al.*, 2007; Karnosky *et al.*, 2005).

Violent storms may occur more often, and more trees are likely to be damaged or blown down.

Possible increase in spring frost damage as trees become more susceptible through earlier leafing.

Damage by forest fires and insect pests is projected to increase.

Source: Produced by Tracy Houston Durrant (Joint Research Centre (JRC)) for this report.

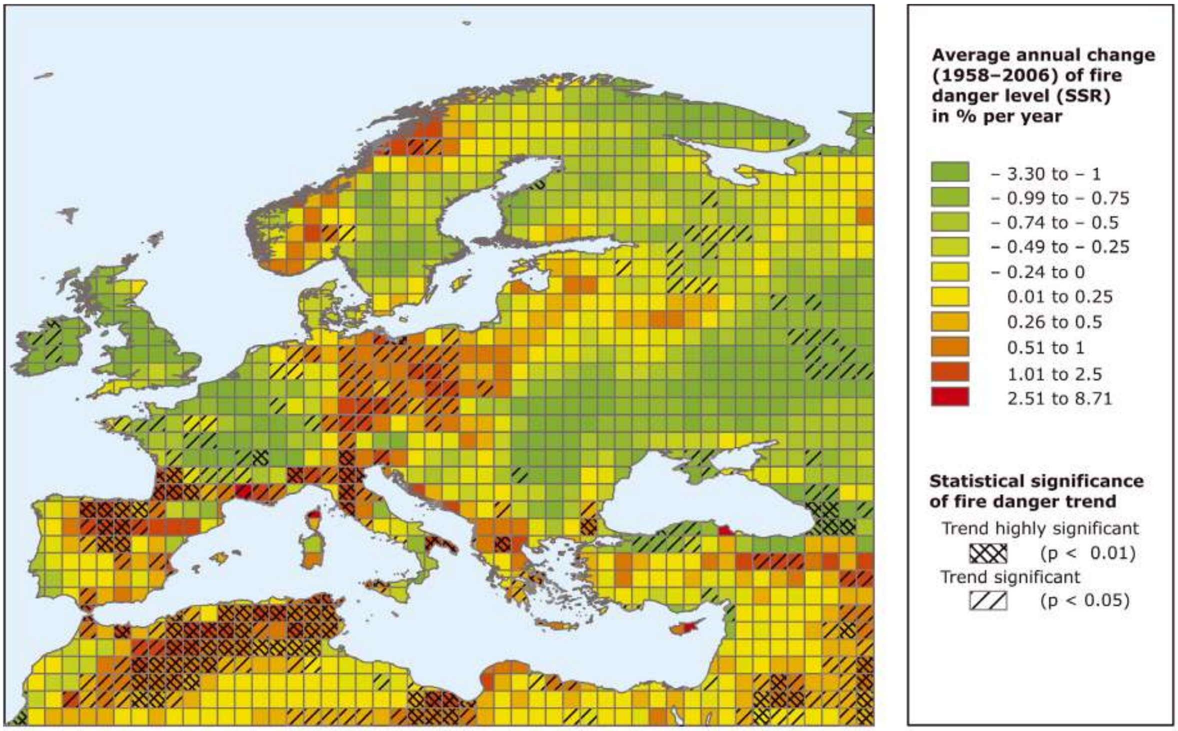
Figure 10. Impacts of climate change on forest growth and forest conditions.

Several studies have already noted changes in dates of budburst and therefore longer growing seasons in several species, shifts in tree-line, and changes in species distribution. A northeast shift of forest categories has already been observed for European forest species (Bakkenes et al., 2002; Harrison et al., 2006).

6.3. Projections

Tree growth is controlled by complex interactions between climate- and non-climate-related factors, with forest management also having a significant effect. Possible future responses of forests to climate change include increased growth rates, tree-line movements, changes to forest growth, phenology, species composition, increased fire incidence, more severe droughts in some areas, increased storm damage, and increased insect and pathogen damage (Eastaugh, 2008). Taken together this is likely to lead to a changed pattern of forest cover. Simulation of the IPCC SRES A1B scenario for the period 2070–2100 shows a general trend of a south-west to north-east shift in suitable forest category habitat (Casalegno et al., 2007) (Fig. 9).

Although climate change is projected to have an overall positive effect on growing stocks in northern Europe, negative effects are also projected in some regions (e.g. drought and fire pose an increasing risk to Mediterranean forests), making overall projections difficult (Fig. 10).



Note: Based on use of Seasonal Severity Rating (SSR). The map indicates the increase in fire danger in as a percentage of a historic absolute value which is not shown in the figure.

Source: Camia et al., 2008.

Figure 11. Average annual changes in fire danger level 1958–2006.

7. FOREST FIRE DANGER

Key messages

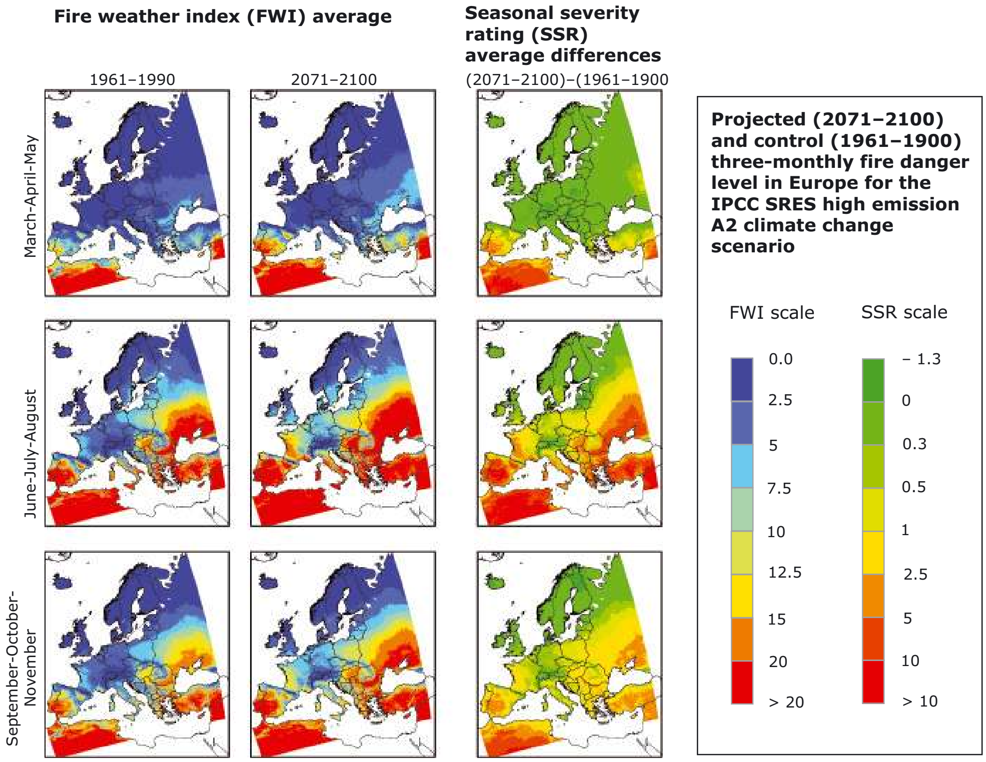
- In a warmer climate, more severe fire weather is expected and, as a consequence, more area burned, more ignitions and longer fire seasons.
- Climate change will increase the fire potential during summer months, especially in southern and central Europe.
- The period during which fire danger exists will become longer as a result of climate change, with a probable increase in the frequency of extreme fire danger days in spring and autumn.

7.1. Relevance

Wildfires are a serious threat to forests and ecosystems in Europe and climate is the most important driving force affecting fire potential changes over time (Flannigan et al., 2000). Although it is generally recognised that the occurrence of forest fires in Europe is due mainly to causes of an anthropogenic nature, the total burned area changes significantly from year to year largely because of weather conditions. Changes in fire regimes may have strong impacts on natural resources and ecosystem stability, with consequent direct and indirect economic losses. On other hand active forest and fire management practices can counteract the impacts of a changing climate to some extent.

7.2. Past trends

Fire risk depends on many factors of a different nature that change over time (e.g. weather, fuel load, fuel type and condition, forest management practices, socio-economic context). Historic fire series can be used to support statements on trends but, unfortunately, long and consistent time series of fire events are rarely available in Europe. In addition, by looking at the historic fire series alone, it is difficult to get a clear picture and recognise the effect of climate on fire potential. In contrast, meteorological fire danger indices, which are designed to rate the component of fire risk that depends on weather conditions, can be usefully employed to analyse fire trends in a consistent way over longer periods. These indices, normally applied on a daily basis, can be summarised on a seasonal basis to rate the overall fire potential of a given year (seasonal fire severity) due to meteorological conditions. The index of Seasonal Severity Rating (SSR) has been derived from daily values of Van Wagner's Fire Weather Index (FWI), Van Wagner (1987), the fire danger assessment method most widely applied throughout the world (San Miguel-Ayanz et al., 2003). Results of a recent study on SSR development are shown in Figure 11. The average trend for 1958–2006 was computed



Note: Based on the IPCC SRES high emissions A2 scenario and the HIRAM model. Fire danger in winter months (DJF) is not shown because it is negligible.

Source: Camia et al., 2008.

Figure 12. Modelled three-monthly fire danger levels in Europe for 1961–1990 and 2071–2100 and change between these periods.

for all the grid cells, but it was statistically significant for only 21% of the cases (15% positive and 6% negative), which appear to be concentrated in specific geographical areas.

7.3. Projections

Projections were derived for the IPCC SRES scenario A2, processing data from the PRUDENCE data archive, namely the daily-high resolution data (12 km) from the HIRHAM model run by DMI, for the time periods 1960–1990 (control) and 2070–2100 (projections) (see Fig. 12). In agreement with a similar assessment performed for North America (Flannigan et al., 2005), the results for Europe confirm a significant increase of fire potential, an enlargement of the fire-prone area and a lengthening of the fire season.

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