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Adapting to climate change: the challenge for European agriculture and rural areas

accompanying document to the

WHITE PAPER

Adapting to climate change: Towards a European framework for action

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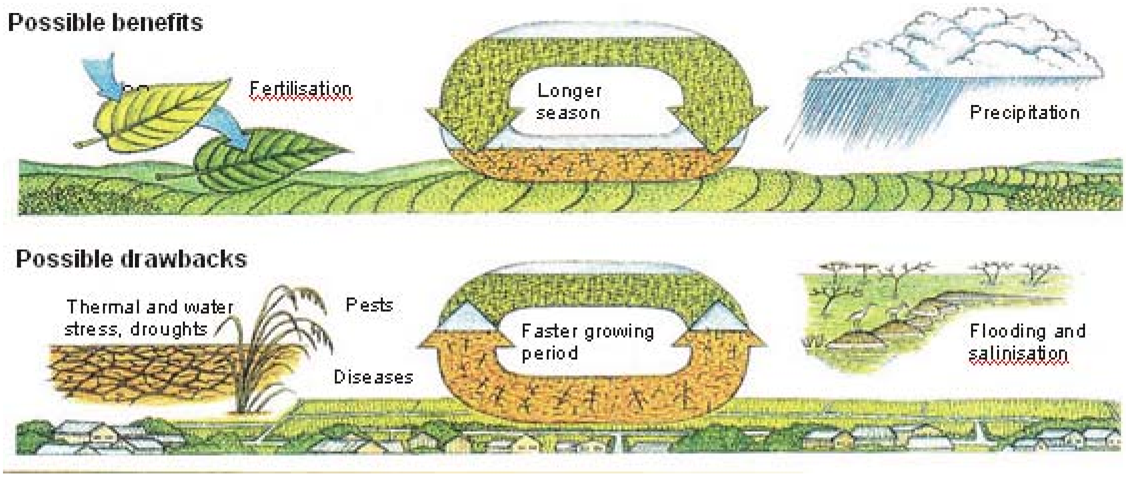
Overview of main climate risks for EU agriculture

Although agriculture is a highly evolved economic sector, it is still directly dependent on climatic and bio-physical conditions, since heat, sunlight and water are the main drivers of crop growth. Climate change will bring a wide range of small and large, positive and negative, unquantifiable and unpredictable effects, which will develop intermittently through time and interact with other environmental, economic, social and adaptive changes. It is thus difficult to forecast the impacts of climatic changes on the level of agricultural productivity and its variability, and the associated implications for prices and farmers' income. The figure below shows the complex agro-climatic interactions.

Agro-climatic processes under climate change



Source: Rosenzweig and Tubiello, 2007 - Adaptation and mitigation strategies in agriculture: an analysis of potential synergies (based on Bongaarts, 1994)

The key climatic concerns to agriculture and food production are briefly outlined below.

Carbon dioxide concentration and temperature changes

The extension of the growing seasons due to warmer temperatures and the enhanced photosynthesis due to higher carbon dioxide (CO_2) in the air will have moderately positive effects on crop productivity and on the range of crops that can be cultivated in certain EU areas. However, temperature increases will also accelerate the vegetative cycle, which may lead negative effects on grains filling, with less time available for carbohydrate accumulation, affecting both yields and crop quality. The length of the growing season for several crops has already increased at northern latitudes, while a shortening of the crop cycle locally at southern latitudes has been observed. In general, a longer crop cycle is positively correlated with higher yields, since a longer cycle permits maximum use of thermal energy, solar radiation and water. However, shortening of the growth period can also help avoid that stress in areas prone to drought.

Further warming will have increasingly negative impacts, as temperature thresholds linked to particular development stages (formation of seeds and fruits and grains filling) determining plant growth and yields will be exceeded. Also, the beneficial CO_2 fertilisation effect levels out beyond certain temperatures.

Climate variability and climate-related hazards

Despite the difficulty to forecast the occurrence of extreme weather events, it is well established that their frequency is likely to become higher than what can be associated with natural fluctuations. Recent observations of increased climate extremes worldwide may be an indication of climate-related changes already under way. While individual weather events cannot be attributed to a single cause, statistical analyses show that the risk of such events has already increased considerably. In the EU, more frequent hot spells, heavy rains and a decreasing number of cold extremes have occurred in the past fifty years and this trend is projected to continue. Weather-related disasters have had important negative consequences for agricultural output in recent years.

Adaptation to short-term seasonal or inter-annual climate variability is inherent to agriculture, although its extent varies regionally. For instance, Mediterranean areas have less stable climatic conditions and agricultural production than continental areas. Climate change is likely to expand the areas subject to high climate variability, and the extent of short-term variability is likely to increase all over Europe. This means that farmers will have to deal with more variable inter-annual conditions than at present.

At least in the next decades, the frequency and intensity of extreme weather events are likely to have more serious consequences for agricultural production levels and stability than the projected changes in the mean temperature and rainfall, which may not be felt until 2050 or later in the century. Extreme weather conditions happening during critical phases of crop growth may severely disrupt production. These impacts, likely to be highly localised, are a particular concern due to the difficulty of anticipating them.

Extreme weather events such as floods, or storms, may also cause significant damage to farm infrastructure.

Precipitation patterns and water resources

Inter-annual and seasonal changes in precipitation patterns, evaporation, hydrological cycles, and their ultimate impacts on water resources have a significant impact on agriculture. However, rainfall projections are even more uncertain than those on temperature, because rainfall is a more complex variable to model and it is characterised by high natural variability.

A decrease in annual water availability is likely in southern areas and parts of central Europe due to an expected reduction in summer rainfall combined with increased evaporation due to warmer temperatures. This will lead to a progressive increase of water requirements for irrigation. In western and Atlantic areas, annual rainfall is expected to increase, but as summers are likely to be dryer and hotter, reduced water resources during this season may lead to conflicting demands between agriculture and other uses also in these regions.

Warming will lead to changes in the seasonality of river flows, particularly in areas where much of the winter precipitation currently fall as snow, and where winter flows are likely to increase and summer flows decrease. Studies indicate a decrease in annual average water runoff in rivers of 20–30% by 2050 and of 60% by 2080 in these areas, with summer flows reduced by up to 80% (in a high emissions scenario). Annual runoff is projected to increase by up to 50% in northern Europe by 2080.Temperature rise and changing rainfall may also lead to a reduction of groundwater recharge and hence groundwater level.

Water shortages may have major impacts on agricultural production and European landscapes. Many EU areas, notably in southern Member States have used irrigation for hundreds of years to ensure continuous and profitable production. In the face of climate change the sector will need to review irrigation strategies and techniques.

Incidence of pests and diseases

The evolving climatic conditions will also influence pests and diseases presenting risks for agricultural production. Adverse impacts can be expected from the likely rise in the occurrence, spatial distribution and intensity of existing pests, plant pathogens and weeds due to higher temperatures and humidity. Studies in Western EU have already documented changes in spring arrival and/or geographical range of many insects, linked to climatic changes. Impacts on beneficial insects (pollination) and other organisms can have further negative consequences. Disease pressures on crops are most likely in regions where an increase in humidity and frequency of heavy rainfall are projected. The overall effect is difficult to assess, but the incidence of these problems is likely to be vary between, and within, countries and regions.

The challenge of dealing with increased pests and diseases will have to be met with the support of research and within the EU's legal frame work for pesticide authorisation and use.

Impacts on soils

Climate change will affect the chemical, physical and biological characteristics of soils influencing their structure, quality and fertility with important implications for the future development of agriculture. Raising temperatures, increased rainfall and more extreme weather events can contribute to increased soil degradation through processes such as erosion, organic matter decline, compaction, salinisation, and loss of biodiversity. Climate change could exacerbate the risk of desertification, which is already affecting the southern EU Member States.

Soil constitutes the second biggest carbon pool in the planet after the oceans, holding around 1 550 billion tonnes of organic carbon. Of these, around 75 billion tonnes are found in EU soils. Maintaining and optimising organic carbon levels through proper soil management in agriculture can contribute to climate change adaptation and mitigation. Indeed, improving soil structure will improve water infiltration, decrease evaporation, increase water retention capacity (soil organic matter can absorb up to twenty times its weight in water), avoid soil compaction and reduce the risk of run-off. It will help adapting to the impacts of extreme rainfall intensity and more frequent and severe droughts and other climate change impacts.

Soil practices (e.g. management of crop rotations and crop residues, ensuring that soils are protected by a permanent vegetation cover) and tilling methods, which can help preventing the loss of soil organic matter and optimising water resources by keeping soil moisture, will be increasingly crucial to cope with potential adverse effects.

Farm practices are already changing in response to new climatic conditions

Some changes in plant growing phases are already observable in Europe providing evidence of responses to recent regional and local changes in mean weather conditions. In southern France, an advance of one to three weeks in apricot and peach tree flowering periods has been observed. In Alsace (eastern France) the warming and lengthening of the vine growing season has led to increases in the average alcohol content of wines. In some southern areas of France, the date of grape harvest has advanced about three weeks in the last sixty years. In the North of France (around region of Champagne Ardennes), the ear-emergence of cereals and the harvest have advanced ten days in the last twenty-five years, following a local temperature increase of 1,2°C over the same period.

In Germany sowing dates for maize and sugar beet have been advanced by around ten days in the last decade of the 20th century, although changes in plant development are still moderate. In southern France maize sowing is on average 20 days earlier than usual. Such changes in the farming calendar suggest that farmers are already adapting autonomously to new climate conditions. Establishment of perennial crops has started in non traditional areas, such as vineyards in England and olives groves in new areas of France.

Changes in climate variables and potential consequences for EU agriculture

Climate variable/ likely changes	EU main affected areas	Main potential impact on agriculture
Atmospheric CO_2		
Increase in CO_2 concentration levels in the atmosphere	All EU	▪ (+) Potential stimulated photosynthesis and increase in productivity (crop growth and leaf area). However, the interaction of warming, precipitations change and more frequent extreme climatic events can limit and overweight the CO2 positive effects ▪ (+) Higher water use efficiency by crops (alterations in leaf stomatal aperture and consequently their conductance for water vapour loss) ▪ (–) Increased weed productivity, competition with crops and needs for more herbicides use
Ozone		
Increase of atmospheric ozone (O_3)	All EU	▪ (–) Risk of yield losses due to: decrease in leaf area, a loss of photosynthetic capacity during grain filling, and earlier senescence of leaves
Temperature		
Temperature increase in all seasons, higher in the summer and autumn than in winter and spring; reduction of frost frequency in autumn and winter; decline in the number of late frosts in spring	All EU, net benefits expected for northern latitudes while rather adverse impacts anticipated in south in the medium term.	▪ (+) Lengthening of growing seasons, particularly in Northern and Central areas (due mainly to changes in frost regime); potential for using more long-cycle varieties in Northern areas ▪ (–) Potential for cultivating new areas and higher crop diversity at Northern latitudes (spring cereals, vegetables, vineyards). In the Nordic countries, the quality of the soils and the light availability may limit some of the opportunities of a longer growing season ▪ (–) Acceleration and shortening of crop cycle leading to a shorter reproduction phase and lower yield potential. Wheat could suffer a negative impact because of the shortening of the grain filling period, that cannot be avoided without substantial variation of genotypic resources ▪ (+) Warmer conditions can be beneficial for wheat in southern Europe in areas of medium-low yield potential characterised by a severe dry period in summer months. In such conditions, the anticipation of the end of the vegetative cycle, causes also a significant avoidance of the water stress in the phenological phases immediately preceding flowering and, more important, during grain filling (–) Higher water needs (because of high evapo-transpiration) that could be compensated, to a certain extent, by higher precocity of crops

		▪ (+) Reduction of late spring frosts could be beneficial for perennial cultivations (fruits, olives), although as flowering is anticipated to advance too, the risk is likely to remain unchanged ▪ (–) For wine its is expected a move forward in time of all the phenological phases with an increase of frost risk and a shortening of the ripening period; the variability of fruit production and quality may be higher than at present ▪ (–) Warmer temperatures in winter could lead to increased risks of attacks of pests and diseases, due to the diminution of protection offered by cold climate. ▪ (+) Moderate to medium warming (1–3 °C) in cold or temperate areas can have overall positive effect on crop productivity (cereals, oilseeds, sugarbeet), provide there is sufficient water. ▪ (+) A moderate warming increases grazing opportunities in winter and livestock productivity in the Northern-Western regions (humid grasslands) ▪ (–) Shortening of grazing period in the Mediterranean area ▪ (–) Increased risk of water pollution (e.g. increased leaching) affecting the quality of water ▪ (–) Increased soil respiration and mineralisation of soil organic matter, leading to increased GHG emissions from soils and affecting soil fertility, soil biodiversity and soil water retention capacity
Increase in the number of hot and very hot days; more frequent warm spells	EU, heat stress periods mostly affect southern areas	▪ (–) Increased vulnerability of crops due to higher risks of to damage by high temperatures during key growth phases of the plants. For instance, damage to flowering and grain formation in case of high temperatures (beyond optimal thresholds) at these stages ▪ (–) Increased activity of some pests ▪ (–) Decrease of grazing period in dry areas ▪ (–) Heat stress implications for livestock (health, nutrition, productivity, reproduction rates, welfare)
Melting of snow and mountain glaciers	Alpine, some Continental	▪ (–) Increased rate of snow melting and glaciers retreat ▪ (–) Increased erosion of unstructured soils ▪ (–) Changes in the seasonal run-off of rivers, with a loss of water reserves for spring and summer

Precipitation patterns		
Increase in winter rainfall	Mainly in Central and North-Western areas	▪ (–) Increased risk of water logging and difficulties for winter-sown cereals (farm operations) ▪ (–) Increased risk of pests outbreaks and plant diseases that could lead to more phyto-sanitary treatments. ▪ (–) Higher need of drainage systems ▪ (+) Recharge of groundwater levels
Increased occurrence and severity of heavy rains, storms, floods	Mainly in Central and North-Western areas, EU southern regions increasingly affected	▪ (–) Increased risk of crop failure ▪ (–) Damages can be particularly severe for perennial crops, as extremes events can damage not only the production bur also the means of production. ▪ (–) Damage to agricultural infrastructure ▪ (–) Increase in cost and range of crop insurance needs ▪ (–) Effects on water quality ▪ (–) Increased soil erosion
Decrease in summer rainfall; more frequent and intense drought periods	EU, most important changes in southern and south-eastern regions, with higher risks of droughts. Reduced summer rainfall also expected in Central and Atlantic areas	▪ (–) Decrease in summer precipitations, combined with rise in evaporation arising from increasing temperatures may lead to important water deficits and increased irrigation needs over the growing season ▪ (–) Higher vulnerability of crops to damage by drought. It varies with developmental stage and type of crops: sugarbeet, potatoes, maize and vegetables are very sensible to summer drought, cereals are more sensible to water limitation in spring. ▪ (–) Increased yield variability with high risk of yield decreases/total crop failure in case of prolonged droughts ▪ (–) Increased risk of soil erosion, soil organic matter decline, loss of soil structure, salinisation and desertification ▪ (–) Productivity decline of pastures during drought events; Negative impact on forage quality ▪ (–) Increase in cost and range of crop insurance needs ▪ (–) Risks for wetlands ▪ (–) Possible conflicts between water users, particularly over drought periods
Sea level		
Sea level rise	Coastal areas, Atlantic and Mediterranean	▪ (–) Potential saltwater intrusion in agricultural land (salinisation) ▪ (–) Risk of salinisation of groundwater aquifers.

Combined changes in temperature and seasonal precipitations		
Spread of pests, diseases and weeds	All EU, but highly regionalised	▪ (+/–) Changes in populations and distribution, and their interaction with crops (highly uncertain) that may lead to changes in plant protection treatments ▪ (–) Higher yield and quality variability ▪ (–) Impacts of new diseases (e.g., bluetongue) on animal health and productivity ▪ (–) Increased economic costs and risks.
Changes in soil and soil functions	All EU, most severe effects on soil quality and structure in the South and on soil structure in Northern latitudes	▪ (–) Modified hydrological balance, decrease in (summer) soil moisture due to increasing evaporation rates under warmer conditions (reduced water retention capacity) ▪ (–) Increased risks of loss of organic matter. Levels of organic carbon content are already very low in southern EU and correspond with areas with high soil erosion rates ▪ (–) Increased GHG emissions from soil, exacerbating climate change ▪ (–) Increased risks of soil erosion and desertification, with implications for fertility and soil biodiversity
Shifts in climatic suitability of crops towards higher latitudes in the long term	From southern EU to northern regions	▪ (–) Unsuitability of certain crops in some areas (e.g., spring-sown crops in Southern regions) ▪ (+) Possibilities for potential diversification of crops in Northern regions (maize, fruits, vegetables, vineyards). However, water requirements and soil types may significantly limit the climatic potential ▪ (–) Increased economic risk and economic imbalances within EU regions ▪ (–) Risk of land abandonment, due to soil degradation and desertification.

Source: DG Agriculture, on the basis of literature.

Potential climate change effects for different EU areas

The wide range of anticipated climate impacts for agriculture can be summarised as follows:

EU areas/countries	Main potential impact on agriculture
Southern and south-eastern areas *Portugal, Spain, south of France, Italy, Slovenia, Greece, Malta, Cyprus, Bulgaria, and southern Romania*	These regions will experience the combined effect of large temperature increases and reduced precipitation in areas already having to cope with water scarcity and where there is a heavy dependency on irrigation. In the Iberian Peninsula's annual rainfall may drop by up to 40% compared to current levels by the end of the century. If no effective adaptation takes place, yield decreases could range from 10% to 30% (in the long term) possibly creating domestic food supply risks. By 2050, there may be shifts in the suitability of crops (e.g. spring crops) from southern areas to higher latitudes as climate further changes. Adaptation measures, such as more balanced crop rotations by introduction of less water demanding crops, or maintaining levels of soil organic matter, will be necessary to avoid the most dramatic effects (such as the extension and exacerbation of desertification).
Continental regions *In central European countries (south and east of Germany, Austria, Poland, Czech Republic, Slovakia, Hungary, northern Romania)*	Climate models predict increases in precipitation during the winter and the possibility of large reductions in summer precipitation in several areas, such as Hungary and northern Romania. Climate variability is likely to increase and agricultural activities are likely to be affected by high temperatures and summer droughts, increased risk of soil erosion, soil organic matter decline and the migration of pests and diseases. Some regions, such as Poland, Czech Republic, eastern Germany, may benefit from longer growing seasons that will increase yields and the range of crops.

Western and Atlantic areas *Western and northern France, Belgium, Luxembourg, Netherlands, Germany, the United Kingdom, Ireland and Denmark*	In these areas, the predicted mean temperature increases are more moderate than for other regions. Extreme events such as heavy storms and floods are projected to become more frequent due to warmer temperatures and higher volumes and intensities of precipitation, in particular in winter. But, summers are likely to be dryer and hotter and reduced water resources during this season may lead to conflicting demands between agriculture and other users for this resource. One of the greatest problems to be faced by agriculture may be rising sea levels, leading to the intrusion of saline groundwater and soil salinisation, affecting low-lying land in eastern England and the North Sea coasts of Belgium, the Netherlands and Germany, some of the most productive agricultural areas in those countries.
Northern areas *In the northern areas (Sweden, Finland, the Baltic States*	Violent storms and flash floods, with higher and more intense precipitation, are expected particularly in winter and especially in the northernmost regions (e.g. Sweden and Finland). More positively, it may be possible to cultivate new areas and crops, due to longer growing seasons, and yields could substantially increase under limited warming (below 3°C). But production could suffer from new pests and diseases, which will benefit from warmer conditions, though the effects remain highly uncertain. Warming could also aggravate water quality problems in the Baltic Sea.

Observed agro-climatological changes based on the MARS meteorological database 1975 - 2007

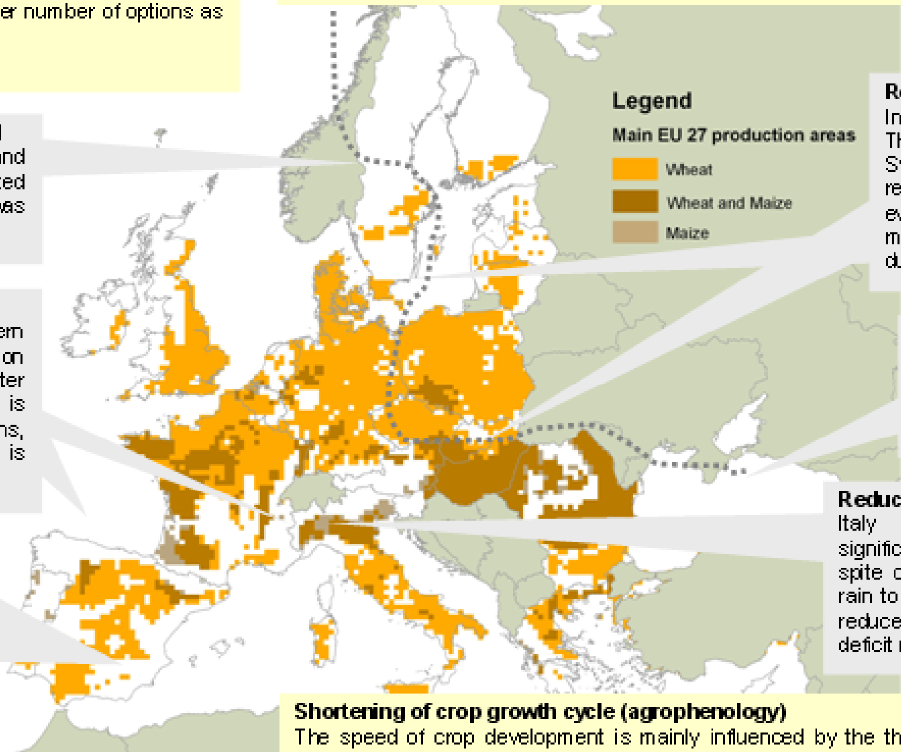
Lengthening of growing season
As a whole, in Europe a lengthening of growing season (defined as frost-free period) was observed. Even if over the continent the magnitude of increase varied, on average the lengthening is estimable in 0.8-1 day per year during the last 30 years. However, in a few and localized areas, due to particular microclimatic conditions, reductions were recorded instead.
In general a longer growing season is related to an increased crop productivity and allowing for a larger number of options as rotations and cultivable crops.

Increased plant heat stress
In parallel to the increase of annual mean temperatures, maximum daily values were shifted upward and more frequent heat stress events occurred.
Worse conditions were recorded in Spain (mainly southern areas), Italy and Black Sea area (mainly Turkey).
However, it must also be highlighted that locally along the Atlantic coast line and in Greece a reduction of frequency of heat stress was recorded

Increased winter and summer rainfall
In Scandinavia, eastern EU, Balkans and Austria a significant increase of cumulated rain both during winter and summer was recorded.

Reduction of winter rainfall
In Italy, Portugal, Greece, southern France and Ireland a significant reduction of cumulated values of rain during winter was recorded. Winter rainfall is particularly relevant in southern regions, where the majority of annual rainfall is concentrated in winter time

Increased irrigation demand
Increase of water deficit (rain-evapotranspiration), mainly due to the reduction of rain during the growing season and partially due to the increase of crops water consumption has been simulated for large parts of southern Europe. Italy, central Spain and southern France presented the largest increases.



Reduction of irrigation demand
In Balkans, Austria, Czech Republic, The Netherlands, Denmark, southern Sweden and northern Poland a reduction of water deficit (rain-evapotranspiration) was recorded, mainly due to the increase of rain during the growing season.

Increased risk of late frosts
The frequency of late frosts has increased westwards of the dotted line bringing a greater vulnerability to this regions.

Reduction of summer rainfall
Italy and southern France show a significant reduction of cumulated rain In spite of the small contribution of summer rain to the whole year cumulated value the reduced summer rain increased the water deficit noticeably.

Shortening of crop growth cycle (agrophenology)
The speed of crop development is mainly influenced by the thermal conditions. Therefore, increase of crops development speed did lead to a shortening of crops cycle over the last decades.
In general short crop cycles are related to a reduced crops productivity, especially if it occurs during the reproductive stages of development (grains/fruits formation). Winter crops were influenced more than summer crops.

Annex 2 – CAP – contributing to adaptation of agriculture

2.1 General orientation of the CAP

The orientation of the CAP since the 2003 reform, reinforced by the Health Check, is marked by a progressive shift of financial support linked to production towards decoupled direct aid, by the strengthening of rural development, and progress in the integration of environmental considerations.

Continuing reform of the CAP has contributed to a more sustainable development of EU agriculture, both from an economic and an environmental perspective. Economic viability of farming and environmental concerns have become key elements of the CAP. In the perspective of climate change these objectives will become even more important. In a world of market volatility, enhanced by the fluctuations that climate change may bring about, the CAP provides a basic level of income security to farmers as well as a framework for good management of the natural environment in which agriculture takes place. These will be the essential pillars also for the adaptation strategy for agriculture.

The recent "Health Check" reform represents a further step in the direction of sustainable agriculture with specific emphasis notably on climate change mitigation and adaptation, water and biodiversity protection, for which further rural development funding has been agreed. The challenge and opportunity for the EU and its Member States in the period up to the end of 2013 is to make the best possible use of the CAP tools available to support adaptation.

2.2 CAP measures favouring adaptation

EU agricultural and rural development policy has an important role to play in enabling farmers to adapt their farm production methods and structures

2.2.1 Income support

The **decoupling of agricultural support** from production allows farmers to be more responsive to various external forces, including market signals. Decoupling also helps farmers to orient their production according to the biophysical environment evolving with climate change.

Decoupled support is accompanied by requirements to manage farming activities in a sustainable way. **Cross-compliance** links the full receipt of CAP payments, including also some rural development payments, to the respect of EU legislation on environment, public, animal and plant health and animal welfare, and the maintenance of the farmed land in good agricultural and environmental conditions. Requirements on the maintenance of permanent pastures and specific soil practices to avoid erosion and to keep organic matter contribute to the sustainable use of resources and to adaptation.

The Health Check led to the inclusion of new environmental requirements into cross-compliance for better management of water, which is one of the key concerns related to climate change. The obligations introduced to meet this objective are twofold: farmers will be required to establish buffer strips along water courses and to respect national authorisation procedures in case of irrigation. The buffer strips requirements, to be implemented not later than 2012, are an important step in improving connectivity in water protection across EU farmland.

The **Farm Advisory System** ensures availability of advice to farmers on the basic environmental requirements. An evaluation of the functioning of the Advisory System is in process and a report will presented by the Commission in 2010 with the view of improving its application. The Advisory

System is an important tool to improve farm management and can play a role in the integration of findings from the physical and agronomic sciences with local knowledge from farmers and land managers, making it an effective tool also for sustaining adaptation.

Facilitating farmers' access to **risk management tools**, such as insurance schemes or mutual funds, also helps them to cope with the economic consequences of greater fluctuations in crop yields or animal diseases. In the Health Check, Member States have been given the option to use part of their national financial envelopes for CAP support for risk management tools[1]. Additional flexibility was also given to the Member States for providing support for actions relevant for adaptation.

Within the operational programmes of producer organisations in the **fruit and vegetables** sector, which are partly financed by the EU budget, it is possible to support harvest insurances safeguarding producers' incomes in case of market losses due to climate-related disasters and the administrative costs of setting up mutual funds. Operational programmes can also include environmental actions, research and experimental production, training and setting up of advisory services, which can be relevant for adaptation of the production systems and structures and enhancing resilience to a changing climate.

Under the revised **wine** market rules[2], national support programmes will provide funding for a range of country-specific measures, including, restructuring and modernisation of vineyards, and preventive measures such as harvest insurance, mutual funds and green harvesting to address crisis situations due to market or climatic conditions.

2.2.2 Rural development support to farmer's adaptation efforts

The current framework

The EU regulation on rural development and the Community Strategic Guidelines[3] for the period 2007–2013[4] contain explicit references to EU objectives for climate change mitigation as well as to the need to anticipate the likely effects of climate change on agriculture. The rural development framework can give an essential contribution to adaptation, as farm-level, local and regional adaptation requires a policy environment that strengthens the conditions for adaptation actions. Rural development policy overall contributes to a balanced development of European rural areas, which will gain in importance as socio-economic disparities are likely to amplify due to the uneven climatic effects on agricultural systems, forestry and rural economies.

Adaptation considerations are already embedded in the three strands of rural development: competitiveness, improving the environment and quality of life in rural areas. Even if in general the measures are not specifically tailored to climate change adaptation, many of the actions funded produce multiple benefits also from a climate perspective.

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[1] Article 68 of Council Regulation amending Council Regulation (EC) No 1792/2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers. Policy compromise of 20.11.2008.

[2] Council Regulation (EC) No 479/2008 of 29 April 2008 on the common organisation of the market in wine.

[3] Council Decision (20 February 2006) on Community strategic guidelines for rural development (programming period 2007 to 2013).

[4] Council Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD).

Under the competitiveness axis, support to **farm modernisation** and **restoring agricultural production potential** can sustain adaptation to climatic changes. For example, preventive mechanisms against adverse effects of climate-related extreme events (e.g. setting up of hail nets) and adaptation of buildings (e.g. housing livestock) can be supported. The **improvement and development of infrastructure** offer possibilities to address water management, complementing modernisation measures providing support for water saving investments and more efficient irrigation equipment.

Support for diversifying crop patterns, structures and agricultural activities as well as diversification into non-agricultural activities is available under axis 2 and 3. This helps make production systems more resilient to economic but also to climatic factors, as diversification is a key strength factor for the stability of agricultural incomes.

Within the environmental and land management axis, **agri-environmental schemes** targeted to better management of soil, water, and landscape have an important role. In particular measures that contribute to reducing pressure on biodiversity, enhancing green infrastructure, and promoting organic agriculture contribute to adaptation.

The support to **Less Favoured Areas** has an important role in ensuring continuation of sustainable farming in vulnerable areas and in preserving valuable landscapes. These zones may be among the most vulnerable to climatic changes due to their socio-economic and environmental fragility and their lower capacity to adapt. A review of the LFA scheme is under preparation in order to make the delimitation and payment system more transparent and effective with a view to its land management objectives.

Investing in **human capital** is an EU priority for rural development, and will also be a key factor with a view to copying with climate risks. All Member States devote support to training, information and diffusion of knowledge oriented to the improvement of farm management or methods for cropping and livestock production, and environmental land management. Support can also be given to setting up of farm management and advisory services and for their use by farmers.

Rural development also plays a role in the conservation and sustainable use of **genetic resources**. This contributes to maintaining a broad genetic resource base which can facilitate selection of genetic material resistant to changing diseases and pests, as well as for developing varieties more tolerant to heat and water stress.

Health check: strengthening rural development

The Health Check[5] allows reinforcing some existing rural development measures by directing additional funds resulting from an increase in modulation as from 2010. The measures that can receive additional financial support are linked to the new challenges for European agriculture including climate change mitigation and adaptation, protection of water resources and biodiversity. In addition, innovation as a horizontal measure can contribute to the development of new technologies, products and processes and thereby underpin the efforts to tackle climate change and water challenges.

Member States which will receive additional funds generated by increased modulation will have to revise their national strategy plans and their rural development programmes to respond to the new

[5] Council Regulation amending Regulation (EC) No 1698/2005. Council compromise of 20.11.2008.

challenges. In this context it is important to ensure that needs for climate change adaptation get sufficient attention.

Indicative list of the main rural development measures related to adaptation of agriculture (on the basis of the rural development regulation as modified by the Health Check)

Adaptation types	Types of actions	Articles and Measures	Potential effects
Prevent, and cope with extreme weather events	Flood prevention and management measures (e.g. projects related to coastal and interior flood protection, introduction of flood-tolerant crops for watershed management)	Article 20: restoring agricultural production potential damaged by natural disaster and introducing appropriate prevention actions	Reduction of the negative effects of extreme weather events, such as floods, on agricultural production potential and on the countryside
	Preventive mechanisms against adverse effects of climate-related extreme events (e.g. setting up of hail nets)	Article 26: modernisation of agricultural holdings	Reduction of negative effects from extreme weather events on agricultural production potential
	Restoration of perennial crops damaged by weather extreme events	Article 20: restoring agricultural production potential damaged by natural disaster and introducing appropriate prevention actions	Cope with impacts of climate-related events on the agricultural production potential
	Adaptation of agricultural infrastructures such as buildings (e.g. ventilation systems in livestock buildings)	Article 26: modernisation of agricultural holdings	Support to investments to cope with, and adapt to, impacts of climatic events on agricultural infrastructure in order to keep farm performance
Water management	– Water saving technologies (e.g. efficient irrigation systems) – Water storage (including water overflow areas) – Water saving production techniques (e.g. adapted cropping patterns, irrigation practices) – Installations for waste water treatment on farms and in processing and marketing	Article 26: modernisation of agricultural holdings Article 30: infrastructure related to development and adaptation of agriculture Article 28: adding value to agricultural and forestry products Article 39: agri-environment payments	Improve the capacity to use water more efficiently and to store water
Soil and landscape management	– Soil management practices, tillage methods, diversified crop rotations, catch crops – Planting of hedgerows; reintroducing/maintaining terraces	Article 39: agri-environment payments Article 41: Non-productive investments	By increasing the ability of soils to hold soil moisture and to better withstand erosion, many mitigation techniques implemented locally for soil carbon sequestration may also help farmers to better cope with droughts and/or floods, both of which are projected to increase in the future

Farm management	– Organic farming – Integrated pest management	Article 39: agri-environment payments	
	Improve of animal rearing conditions	Article 40: animal welfare payments	Prevent negative effects on farm animals from warmer conditions and heat spells
	Support for areas with natural handicaps in mountain areas and other	Article 37: Natural handicaps payments	Areas that are among the most vulnerable to climatic pressures and a particular risk of marginalisation
	Investments for on-farm diversification and diversification into non agricultural activities	Article 26: modernisation of agricultural holdings Article 53: diversification into non agricultural activities Article 55: encouragement of tourism activities	Diversification of production and income sources to help cope with economic losses driven by climatic conditions and variability. Take advantage of new opportunities brought by climatic changes, in terms of farm production and other activities (e.g. tourism)
Land cover	– Afforestation, – Establishment of agro-forestry systems	Articles 43 and 45: first afforestation of agricultural and non-agricultural land Article 44: first establishment of agro-forestry systems on agricultural land	The establishment of agro-forestry systems combining crop and livestock production with growing trees can help coping with warmer and dryer conditions by providing shelter and higher water holding capacity of soils while promoting wildlife habitats.
Diffusion of knowledge, capacity building	Training and use of farm advisory services in relation to climate change	Article 21: vocational training and information actions Article 24: use of advisory services	Provision of training and advice to farmers in relation to adapt to climate change. This involves background information about climate change and its impacts and practical training, such as sustainable land management of natural resources, cropping patterns and operations adapted to evolving climatic conditions, irrigation practices
Genetic resources	Conservation genetic resources	Article 39: Agri-environmental measures	Conserved genetic material that may be useful for developing new varieties
Innovation	Development of new technologies, products and processes	Article 29: Co-operation for development of new products, technologies, and processes	Innovation can underpin efforts to tackle climate change and water challenges.

Annex 3 – Adaptation strategies in the Member States

National adaptation strategies have the potential to be strong drivers of development for the European agriculture sector. They provide a coherent framework for enabling adaptation actions, by informing, providing analytical tools, encouraging action, and developing policy support. By covering multiple sectors and horizontal issues, they help avoid possible conflicts in adaptation measures.

EU Member States are at different stages of preparing, developing and implementing national adaptation strategies, generally depending on the magnitude and perception of the observed impacts, and the assessment of current and future vulnerability. Tables below present an overview of main national adaptation initiatives as well as the main measures relevant for agriculture.

Many Member States have carried out general assessments of climate change impacts, including within the agriculture sector, but progress on implementing adaptation actions has been relatively slow, due to several factors: the long-term nature of climate change effects or respective perceptions by policy makers and the sector, the complexity of the information required for decision-making, and the important number of stakeholders involved. However, the recent understanding of the importance of adaptation as a complement to mitigation has lead to the progressive and continuous development of general national adaptation strategies.

Some adaptation plans are being developed as individual stand alone documents with important differences across Europe in the degree of elaboration and development. In general, the central and Northern Member States have advanced further in the definition and development of their adaptation strategies. Almost all Member States are making progress in improving the knowledge-base.

Existing national adaptation plans elaborated also differ widely regarding the targeted groups, the types of measures proposed, and the definition of responsibilities. However, the uncertainty in the magnitude and direction and possible impacts of climate change remain the main common obstacle in defining appropriate adaptation strategies.

National policies on adaptation in agriculture have not yet been clearly articulated, but specific adaptation strategies for the agriculture sector are being developed in a number of countries. The main focus of much of the effort made to date has been on management of flood risk and drainage in the central and northern EU, while water scarcity and desertification risks aggravated by climatic perspectives seems to be the outstanding issue for the southern regions.

The insufficient accurate regional projections of climate change has lead to the design of adaptation plans applying the "no-regret" and "precautionary principle". This approach allows for the formulation of integrated strategies in which climate change is factored among other driving factors. Existing uncertainties has also lead to the definition of adaptation measures in general terms, as none of the existing adaptation plans can be built on the basis of accurate projections that allow for the evaluation of economic implications or time horizons for application.

Examples of adaptation initiatives in the Member states

Country	Adaptation initiative	Scale/ Sectors covered	Projections/ Impact assessment	Main approach and proposed measures	Feasibility assessment
Spain	National Climate Change Adaptation plan (2006)	National Special chapter for agriculture	Not Specified General evaluation of impacts Initial definition of methodology (CMNUCC, 2004)	Different action lines Climate modelling Crop modelling Monitoring Identification of vulnerable areas Extension services Awareness rising R&D Valorisation Integration with existing policies Indicators Agricultural management Defined Institutional structure for development	No Proposes temporal horizon of implementation of measures
Finland	National Strategy for Adaptation to Climate Change (2005)	National Specific chapter for agriculture	FINADAPT scenarios Does not specify climate scenarios GCM based Simulations for crop yield evaluation Economic analysis with DREMFIA model	Policy development Crop management Soil management Market modelling	No
Netherlands	Climate adaptation in the Netherlands (2006)	National Agriculture Ecosystems Water Transport Energy	KNMI-2100 ATEAM WINN (water)	Climate modelling Impact modelling Monitoring Agricultural management Eco-labelling Awareness rising Financial mechanisms Institutional coordination Private sector Energy strategy Conservation Focus on water/land management	Economic evaluation of some measures Proposes temporal horizon of implementation of measures

France	National Strategy for adaptation to Climate change France (2006)	National 2006 Not specific for agriculture	IPCC	Knowledge improvement Indicators development Awareness rising/Capacity building International cooperation Flood risk management Public dissemination oriented Promote regional/local action Set up of a National Observatory of climate change impacts (ONERC)	No
Romania	National Strategy on Climate Change of Romania 2005–2007 (2005)	National	Not specified	Climate modelling Monitoring Institutional coordination Management Policy development R&D Awareness rising	Economic estimation of some measures Definition of staff expertise requirements
Ireland	Ireland National Climate Change Strategy (2007)	National 2007–2012	Interpreted by the National University of Ireland and the C4I	Flood risk assessment and relief Mainly focused on mitigation actions	No
Latvia	Adaptation to Climate Change Strategy for Latvia (2007)	National Not specific for agriculture	Not specified	Climate modelling Awareness rising Cost benefit analysis Institutional coordination Policy development Definition of process for adaptive capacity building Identification of barriers for adaptation	No
Portugal	Portugal (under development)	National	Not specified	Policy coordination Agricultural management Energy strategy	No
Denmark	Adapting to the climate of the future Denmark (2004)	National	Danish Meteorological Institute (DMI)	Land use Transportation Urban planning Technology Oriented to public dissemination Importance of sea level rise	No
Austria	The national climate strategy. Austria (2007)	National	–	General climate change strategy Mainly focused on emissions reduction	–

Germany	Adaptation strategy for Germany (under development)	National	Federal Environmetal Agency 2100	Modelling Monitoring Early warning systems Awareness rising R&D Management Conservation Urban planning	No
Germany	Adaptation policy in North Rhine-Westphalia (Initial stage)	Sub-national Not specific for agriculture	Not specified	Monitoring Vulnerable areas Flood control Extension services Awareness rising International cooperation R&D	No
UK	Adapting to climate change. A framework for Action (2008)	National Not specific for agriculture	Hadley Centre Tyndall Centre UKCIP	Awareness rising Modelling of impacts Monitoring of adopted measures Regional approach Public dissemination oriented UKCIP identifies impacts and adaptation options Stresses the importance of sustainability, integration and collaboration Four working streams: Evidence, awareness rising, monitoring, policy action	Under development
England	Climate Change Mitigation and Adaptation Implement. Plan for the Draft South East Plan (2006)	Sub-national Not specific for agriculture	Not specified	Awareness rising Policy modification Land use planning Risk assessment water management Public dissemination oriented Synergies between mitigation and adaptation Identification of barriers to implementation Identification of responsibilities for the proposed actions Indicators for climate change monitoring	Yes 2006–2010 + 2010
Hungary	National Strategy Climate change (2008)	National Not specific for agriculture	–	–	–

Possible planned adaptation measures in agriculture (as proposed by the Member States)

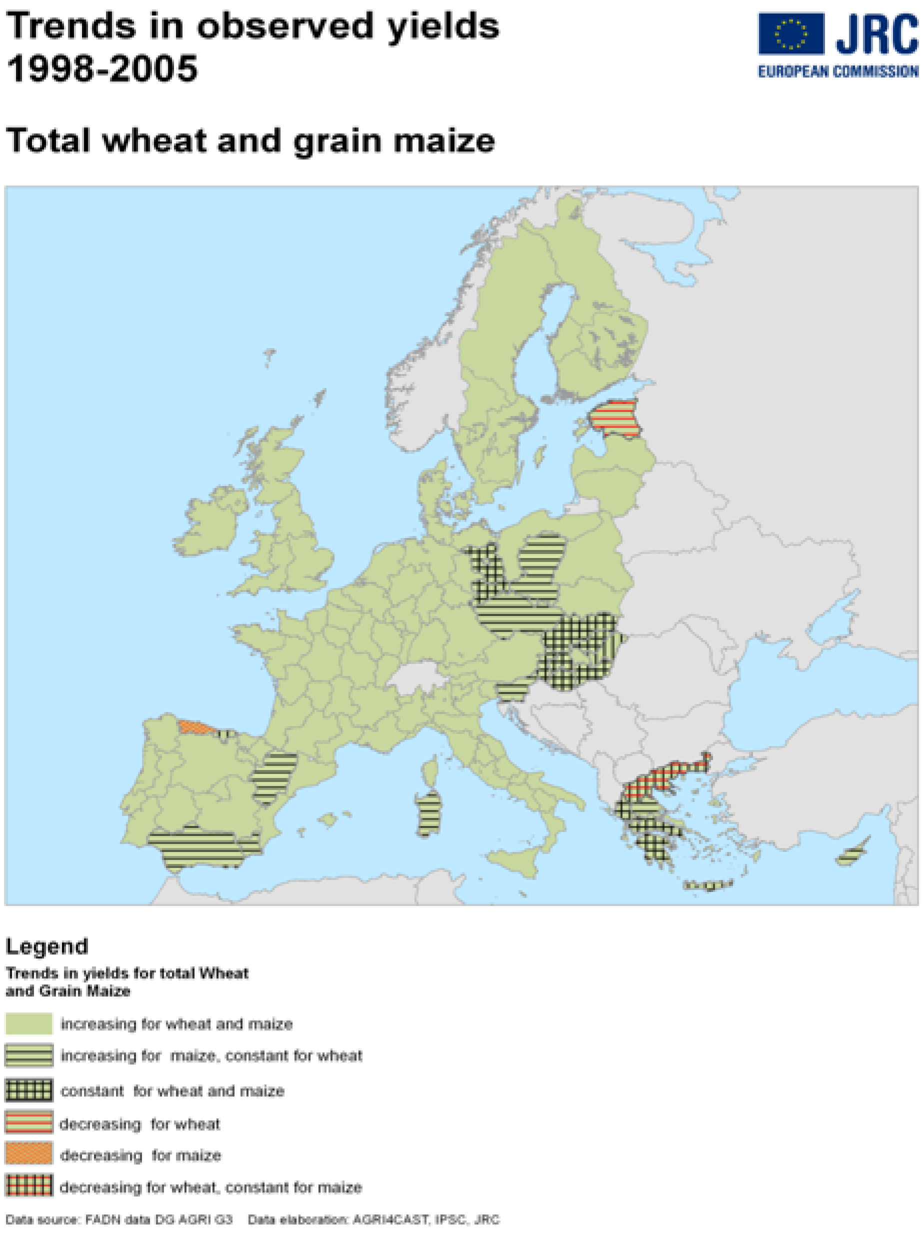
Adaptation type	Potential measures
Monitoring	Cartography of agro-climatic zones modification under different climate projections Indicators for climate change monitoring Develop indicators system for early warning
Modelling	Regional climate change modelling Plant-climate modelling Pest and diseases modelling Irrigation demand Modelling of food markets Development of regional scenarios
Planning	Land use planning Flood prevention and protection Identify flood risk areas and define land use plan Risk Assessment More extensive and diversified farming practices Identification of priority areas Identify the opportunities to grow biomass crops Relocation of farms Alternatives uses for soils subject to salinisation
Financial	Promotion of infrastructure investment Develop cost-benefit analysis Maintain support for agriculture Introduction/development of insurance schemes
Institutional	Develop agricultural policy, make CAP more flexible Coordination of sectoral policies New organisational and political alliances Enhance communication between public and private sector
Awareness rising/ Capacity building	Develop communication between public institutions and farmers Deployment of advisory services
Technology	Plant breeding Technical management strategies Floating greenhouses
Crop management	Change to more resistant varieties Use of different varieties Changing sowing dates Cultivating more resistant varieties suitable for local conditions with a high climate tolerance and lower vulnerability to pests Selection of appropriate crop rotation Changes in range of cultivation and varieties Spatial and temporal adaptation of fertilisation Modifying tillage level

Soil management	Subsidence risk analysis Increase permanent crop cover to avoid nutrient leaching Alternatives for soil management Identification of soils vulnerable to desertification Modelling erosion processes Monitoring of degraded soils Soil-protecting and water-saving forms of farming Use of erosion-reducing and flood-tolerant species for retention areas Soil moisture conservation practices Subsoil drainage Conservational soil tillage
Water management	Water quality assessment Mapping river flows and flood risk evaluation Evaluation/ Development of new water infrastructure to increase supply Water efficiency assessment Introduction of water metering in agriculture Drainage of fields Water management modelling including climate change scenarios Adaptation of irrigation and drainage regime Improve/develop irrigation Develop water storage on farmland
Agri-environmetal management	Review of agri-environmental schemes Management of protected areas and species

Annex 4 – Maps on observed agro-climatic changes and projected impacts

Trends in cereals yields over Europe 1998–2005

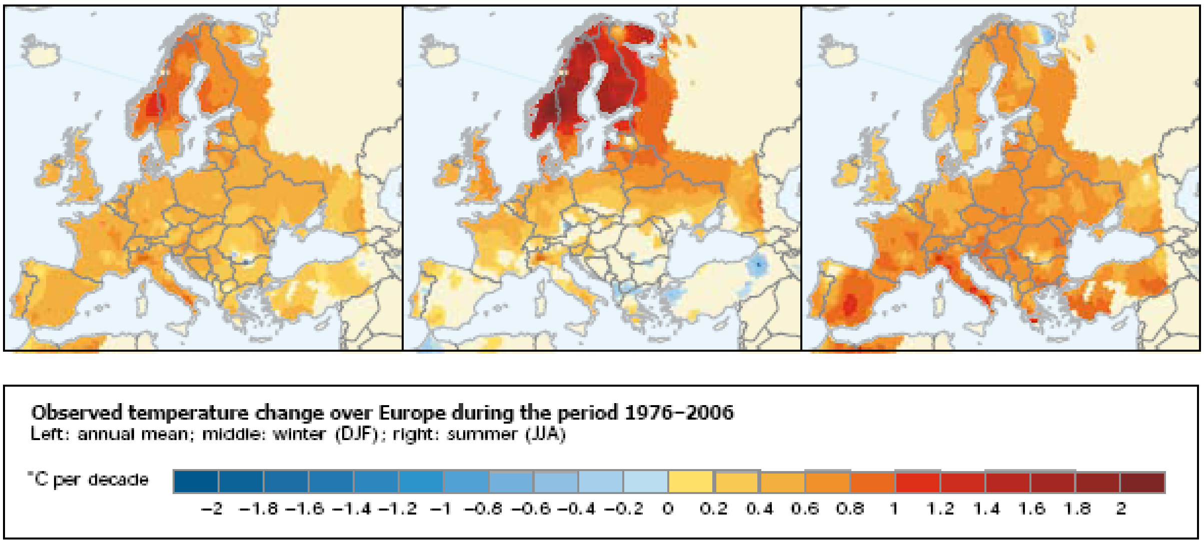
Over most of the EU, the trend in cereals yields (wheat and maize) mainly shows the technological (e.g., use improved varieties, increase of irrigation) and management (e.g., timing of fertilisation and treatments improvements, and the continuous adaptation to weather variability (e.g., sowing and harvesting dates). In general terms, climate change seems to have played a minor role in trends, except possibly a positive impact at Northern latitudes because of the temperature trends which extend the growing season. In Eastern Europe, with the exception of maize in the Czech Republic, Poland and possibly in Slovenia, yields have been stable in the last years. A possible explanation of this trend, while in the other parts of Europe at the same latitudes yields have gone up, might be that technological developments have been lower.



Source: JRC-MARS, AGRI4CAST Action.

Observed temperature change over Europe 1976–2006

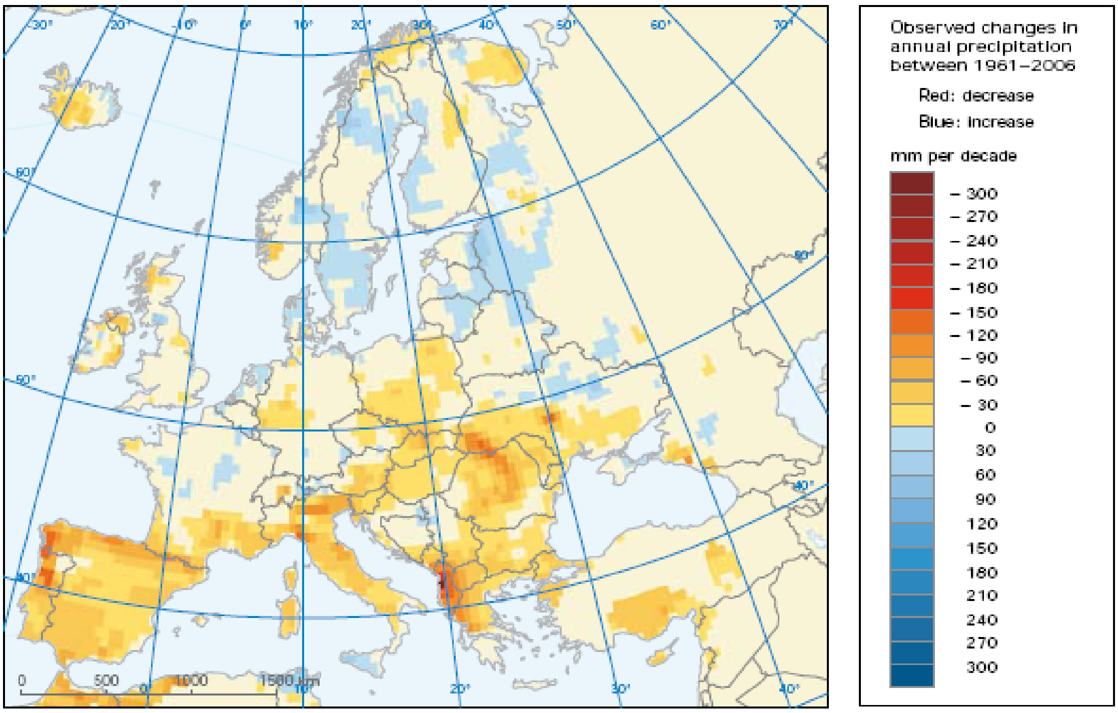
Europe has warmed more than the global average. The annual average temperature for the European land area up to 2007 was 1.2° C above pre-industrial levels, and for the combined land and ocean area 1° C above, with the largest warming over eastern and northern Europe in winter, and over south-western and Mediterranean Europe in summer.



Source: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate — 2008 indicator-based assessment

Observed changes in annual precipitation 1961–2006

Annual precipitation trends in the 20th century showed an increase in northern Europe (between 10–40%) and a decrease in some parts of southern Europe (up to 20%).



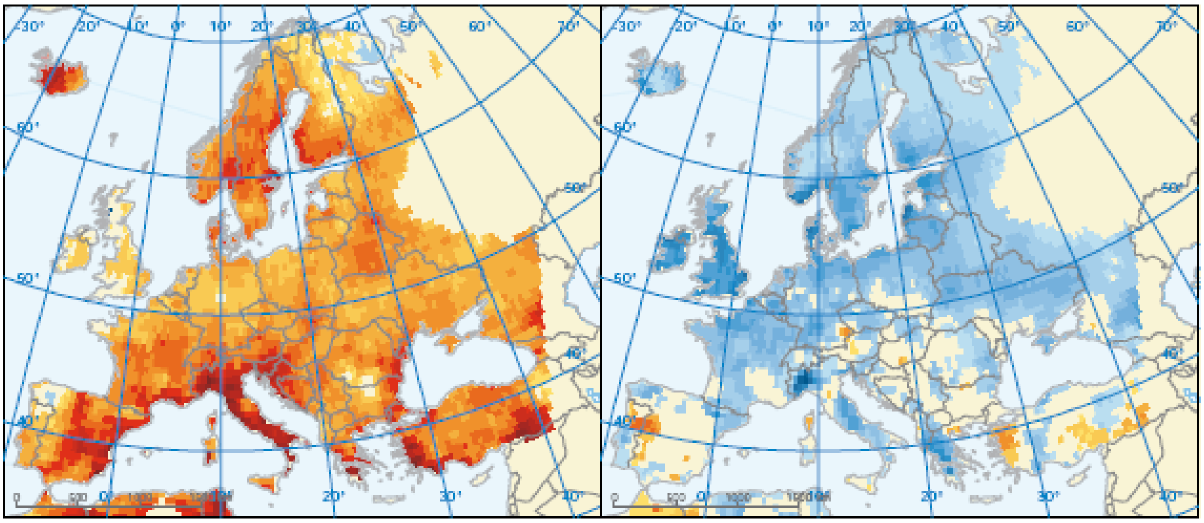
Note: Data are in mm per decade, blue means an increase, red a decrease. The observations indicate that large decadal scale variability in precipitation amount is superposed on the long time scale trends described above. This variability is partly related to the decadal scale variability in atmospheric circulation anomalies (see Box 5.1). Calculating trends over shorter time periods may therefore lead to different results.

Source: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate

Observed changes in warm spells and frost days indices 1976–2006

Extremes of cold have become less frequent in Europe while warm extremes have become more frequent. The frequency of hot days almost tripled between 1880 and 2005. Extreme hot temperatures can be highly detrimental because plant growth and yields are conditioned by temperature thresholds linked to the key reproductive stages.

Warm spells (summer) **Frost days (winter)**



Observed changes in duration of warm spells in summer (left) and frequency of frost days in winter (right), in the period 1976–2006

Days per decade: − 10 − 9 − 8 − 7 − 6 − 5 − 4 − 3 − 2 − 1 0 1 2 3 4 5 6 7 8 9 10

Source: The climate dataset is from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl).

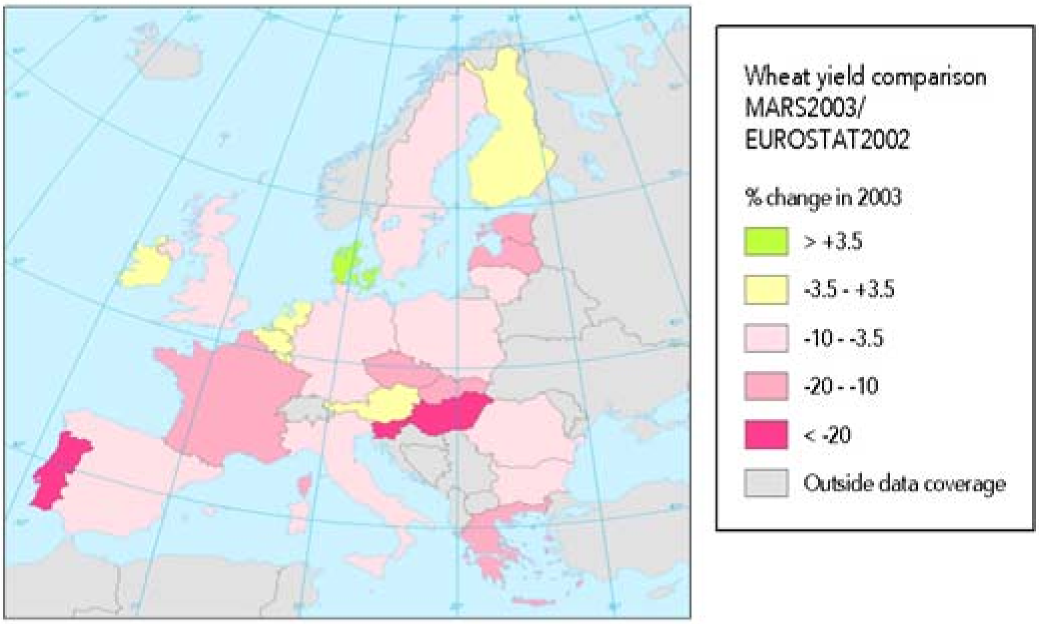
Source: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate — 2008 indicator-based assessment (http://reports.eea.europa.eu/eea_report_2008_4/en/)

Climate variability – effects of extreme climatic conditions on agricultural production

Several extreme events happened in short succession over the recent years. Most of the EU experienced a particularly extreme climate event during summer 2003, with temperatures up to 6° C above long term means and high precipitations deficits, after a winter with important floods events. However, the annual average temperature in 2003 was only slightly higher than the average of preceding years, which shows that a small change in the annual average temperature can be accompanied by important extreme conditions. Important crop yield losses occurred in Portugal, Italy (–36% in the Po Valley), France (–30% reduction in maize and –25% in fruit production). Winter crops suffered less yield reduction than summer crops (like maize, wine and fruits). Forage production was also reduced on average by 30% in France. The economic losses to farming, livestock and forestry were estimated 10 billion euros, at EU level from the combined effects of drought, heat stress and fire. In Spain and Portugal, forests were also dramatically affected as fires burned nearly 400 000 hectares in Portugal and 127 000 hectares in Spain.

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. The severe spring drought of 2007 in many parts of EU (followed by heavy rains during the summer) also diminished EU agricultural production. In Cyprus, the 2008 severe drought led to a drastic reduction of water use for irrigation and almost the complete lost of the cereals harvest.

Impact of the summer 2003 heat wave and drought on wheat yields

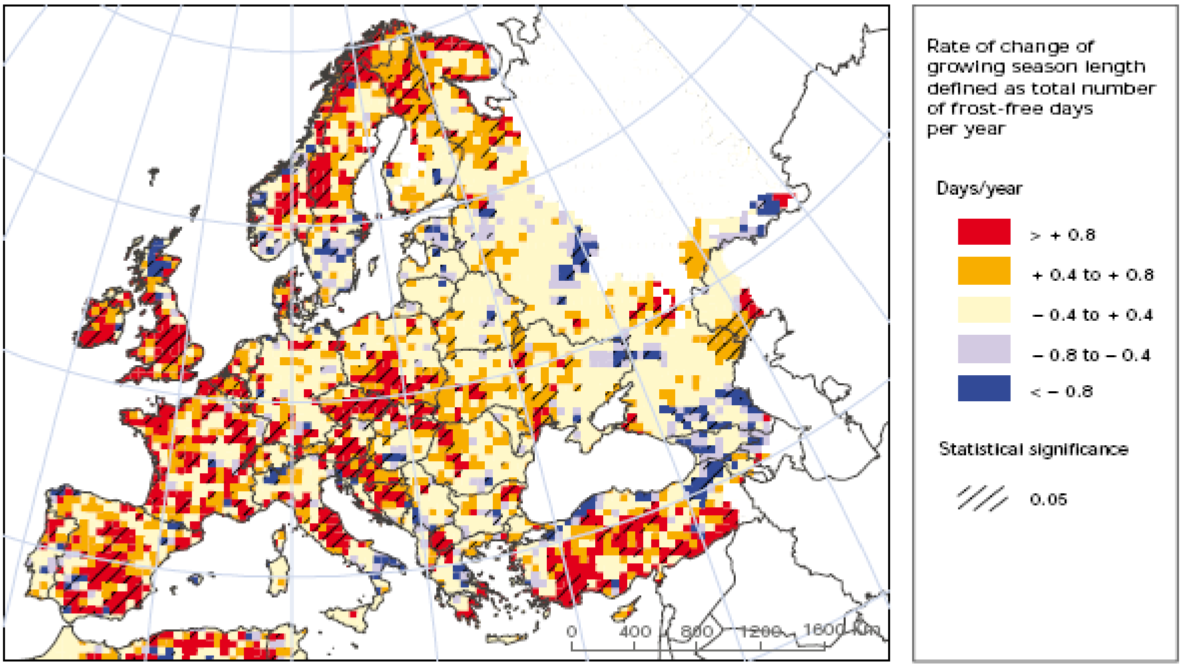


Source: EEA website

Rate of change of crop growing season length 1975–2007

The length of the growing season of several agricultural crops in Europe has changed in the last three decades. A longer growing season increases crop yields and favours the introduction of new crops (and varieties) in areas previously limited by unfavourable thermal conditions (risk of frost). The observed lengthening of the rowing season due to warming is particularly evident for the northern latitudes but has occurred throughout many parts of Europe. Locally at southern latitudes, the trend is towards a shortening of the growing season. A shorter vegetative cycle results in shorter reproduction phase, increased risk o frost damage (from delayed spring frost), smaller plants and lower yield potential.

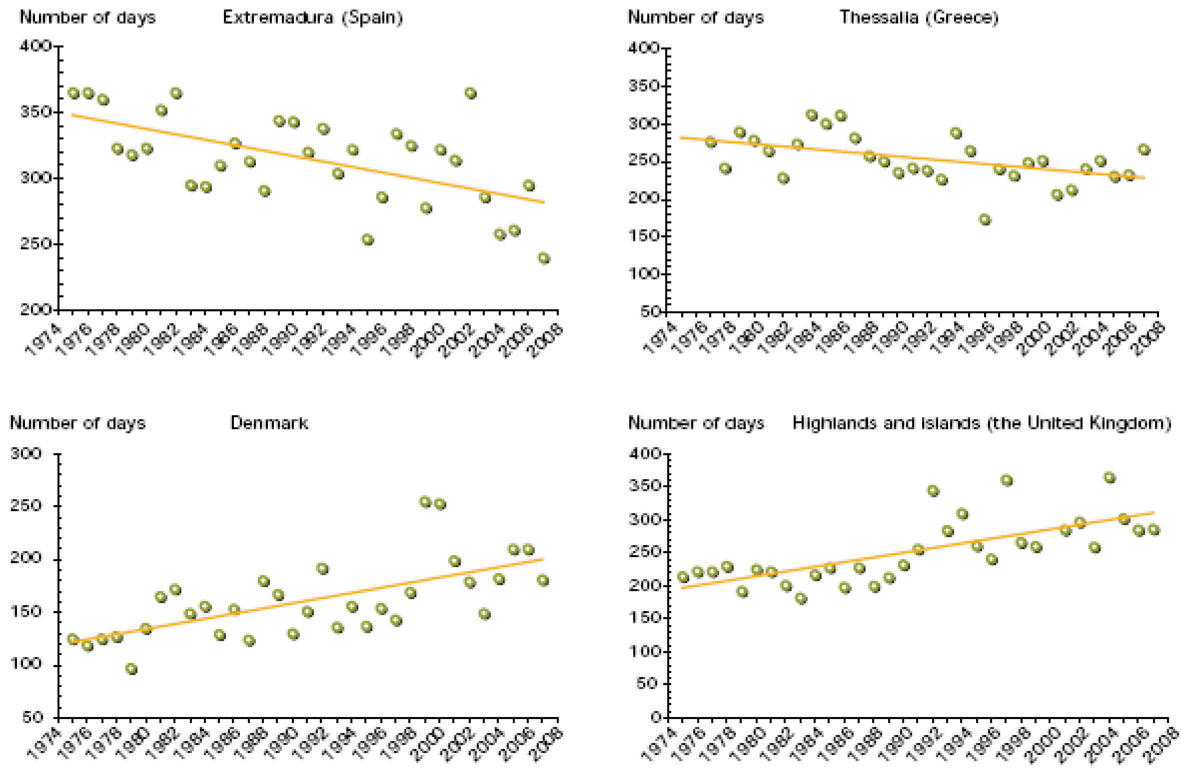
The lengthening and shortening of the cycle of crops in different EU areas is expected to continue as temperatures continue to rise. Adaptation to farm management can reduce or avoid negative impacts of crop-cycle shortening.



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: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate – 2008 indicator-based based on JRC-MARS/STAT database.

Regional examples of length of frost-free period in selected European areas 1975–2007



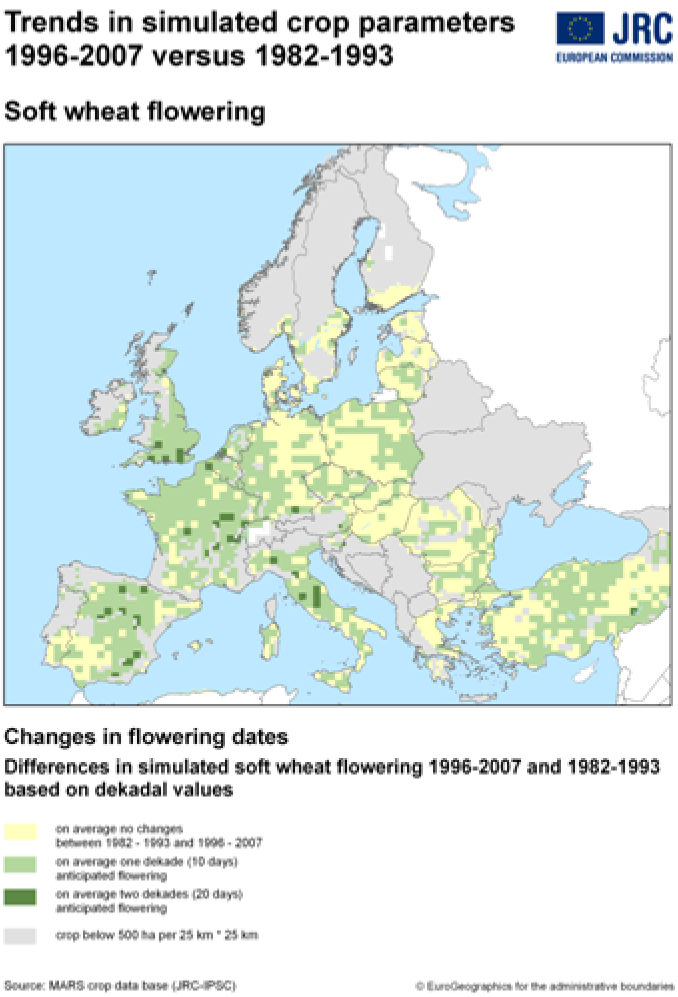
Source: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate – 2008 indicator-based based on JRC-MARS/STAT database.

Timing of the cycle of agricultural crops (agro-phenology)-modelled change of flowering dates for several arable crops

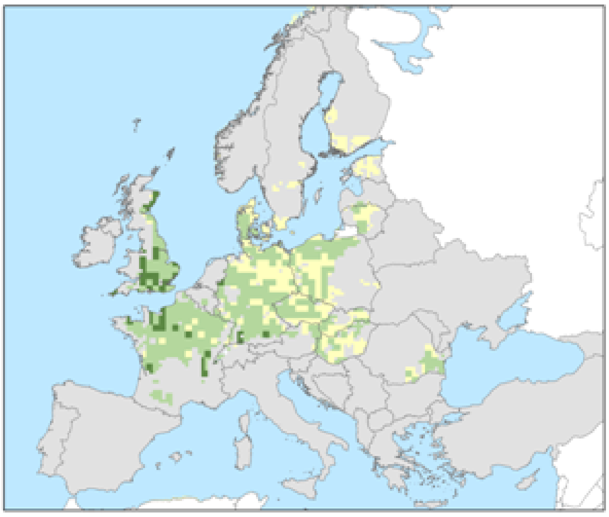
Over the last twenty-five years, there is evidence that the flowering and maturity of several crops in Europe now occurs two or three weeks earlier than in the past. Increasing temperatures accelerates the progression of a crop through its life cycle. The shortening of the phenological phases is expected to continue if temperatures continue to rise.

The simulated crop parameters shown in the maps below are an outcome of the EU MARS Crop Growth Monitoring System, carry out by the EU Joint Research Center (JRC). This system is able to monitor crop vegetation growth and include the short-term effects of meteorological events on crop productions. It is used operationally to provide early forecasts on European crop yields. The general anticipation in the flowering dates simulated for the period 1996 – 2007 is explained by the higher average daily temperatures which characterised the last ten years. However, the simulated result is probably showing a more pronounced situation than the reality, as a constant thermal sum to reach the flowering stage was used in the model for the two periods analysed. This implies the assumption that crop varieties have the same degree of precocity.

For winter crops, i.e. soft wheat and winter rape seed, a clear pattern in the flowering dates between the two periods can be noticed. This pattern reflects the level of continentally within Europe. Where the advance in flowering dates is more evident (e.g. Ireland, United Kingdom, Spain, France, Italy, western Germany), the increase in temperatures observed in the same period is significantly higher in winter than in summer. The anticipation of flowering is much less evident for maize, although a general acceleration of development has also been simulated for this crop. In reality, farmers could have gradually sown cereal varieties with longer cycles, to allow the crop to maintain a constant length of the vegetative phase.



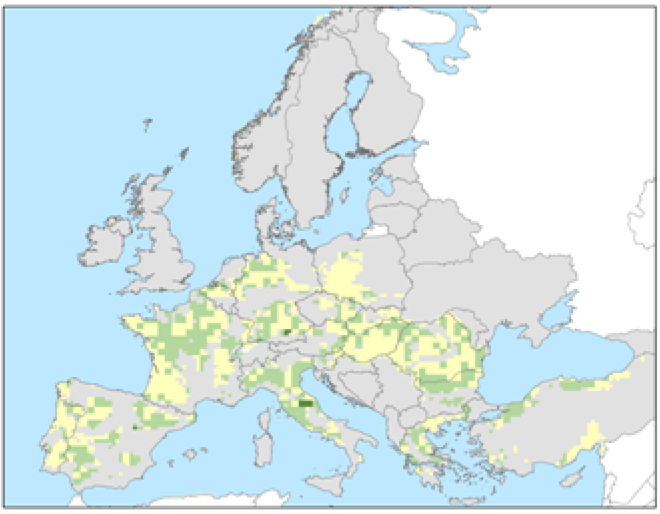
Rape seed flowering



Changes in flowering dates

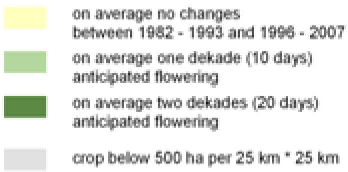
Differences in simulated rape seed flowering 1996-2007 and 1982-1993 based on dekadal values

Maize flowering



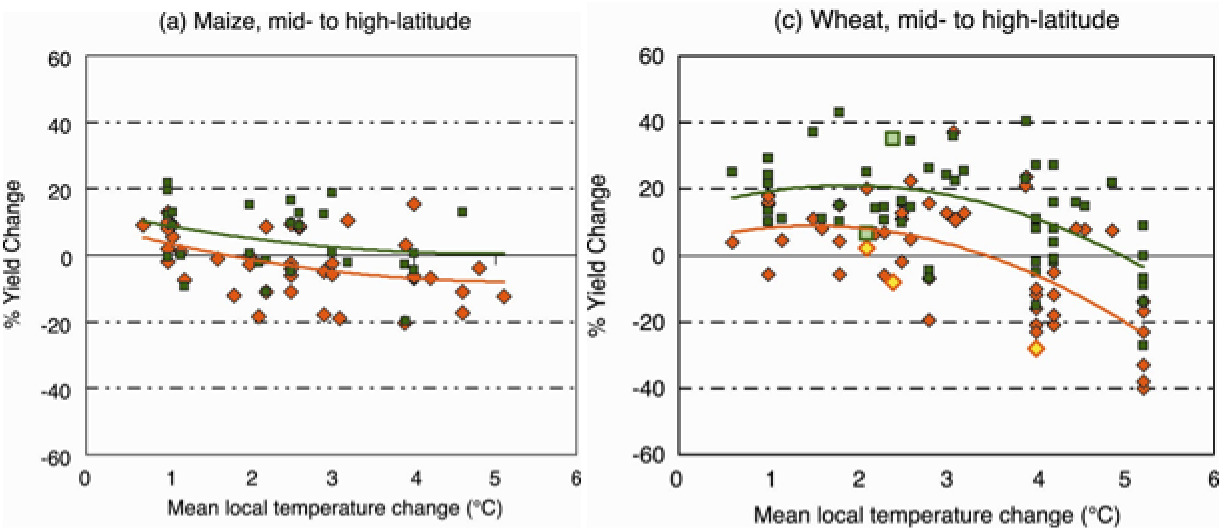
Changes in flowering dates

Differences in simulated maize flowering 1996-2007 and 1982-1993 based on dekadal values



Sensitivity of maize and wheat yields to climate change

Figures below show 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 in the atmosphere, and vary in how they represent future changes in climate variability. It is expected that with a limited increase in mean annual temperature (below 3°C), cereal yields increase, partly because of the fertilisation effect of the increase in CO2 (more important for wheat and other cool-cereals than for maize). However, as temperature increase and the crop cycle gets shorter the CO2 effect will not compensate for the resulting loss of yield. 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.



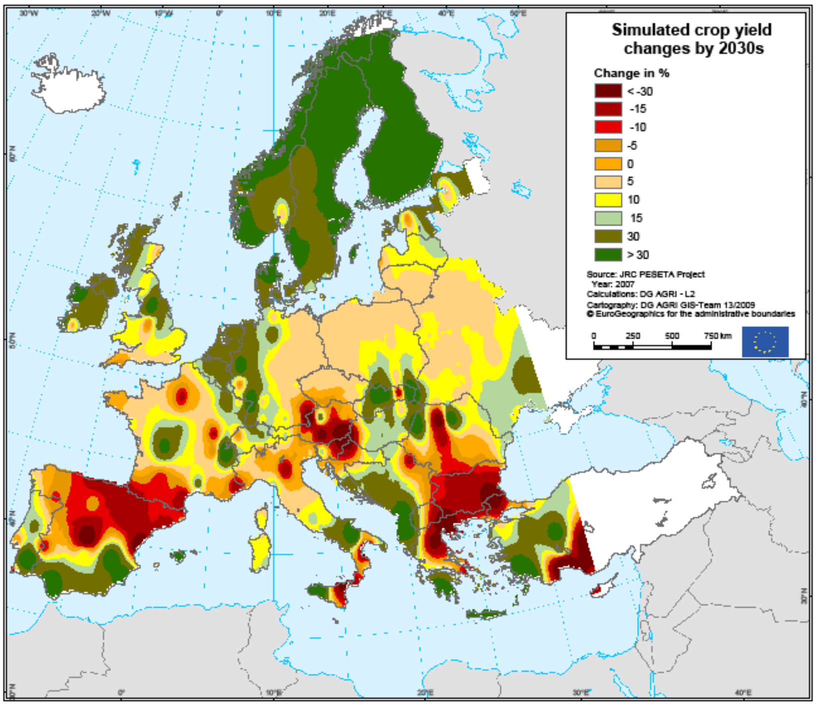
Note: A small increase in temperature has a positive impact on cereals yield, while a high increase (3–5 °C) has a negative impact. Lines are best-fit polynomials and are used here to summarise results across studies rather than as a predictive tool.

Source: Joint EEA, JRC and WHO report – Impacts of Europe's changing climate – 2008 indicator-based (based on Eastering et al., 2007. Published with permission of the Intergovernmental Panel on Climate Change).

Projected spatial effects of climate change on crop yields

The PESETA study projects potential regional yield changes for arable crops for several time horizons in Europe, by using several climate models and socio-economic scenarios. By the 2030s southern European regions could experience a 5–10% decrease in yields compared to current levels, mainly because of shortening of the growing season. The extent of yield losses will depend on seasonal patterns of rainfall, which remain very uncertain, and ultimately on water policy. Productivity improvements in Northern countries of about 5 to 10% are forecast because of lengthened growing season, higher minimum winter temperatures, and extension of the frost-free period.

Projected crop yield changes between the 2030s and the reference period 1961–1990



Source: Based on the results of PESETA project (results from ECHAM4/RCA3 A2 and B2 scenarios for the "2030s", average of 2011–2040 time horizon)

Projected crop yield changes between the 2080s and the reference period 1961–1990