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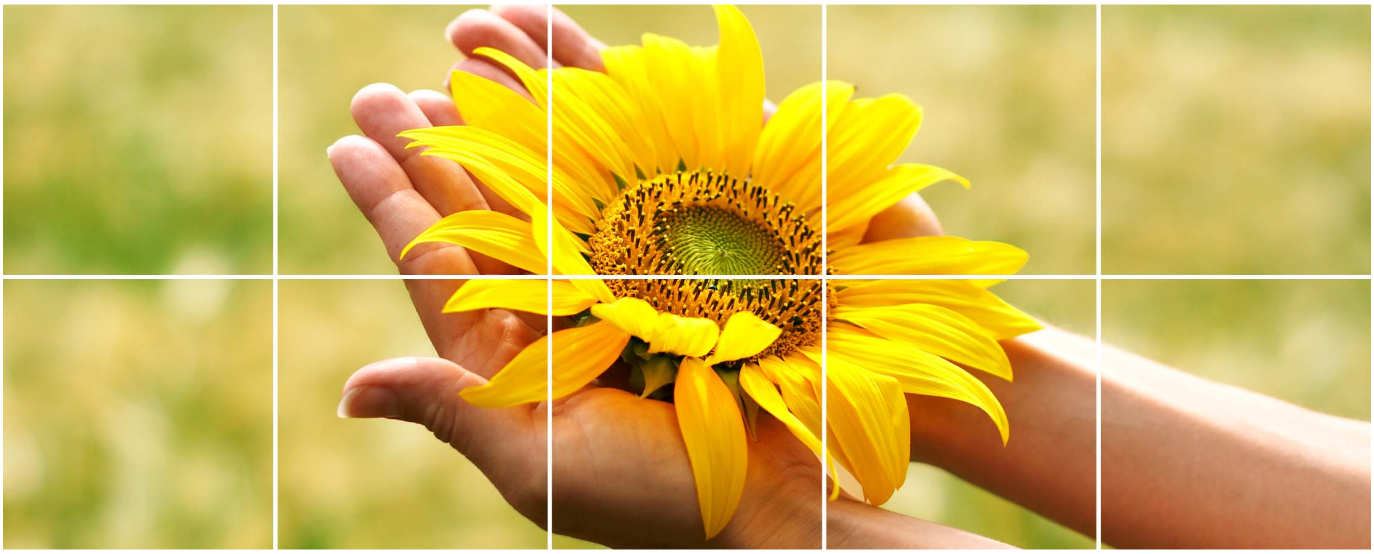

Adaptation to Climate Change in the Agricultural Sector AGRI-2006-G4-05

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1 Executive summary

1.1 Study context and scope

Climate change is already happening. Regardless of international progress to reduce emissions of the greenhouse gases that cause climate change, the climate system will continue to adjust for the next few decades to past and present emissions. This will bring unavoidable impacts on natural and human systems, presenting the challenge of a second response to climate change - adaptation - to prepare for and cope with these impacts.

Climate change is a real concern for the sustainable development of agriculture, both globally and within the EU. Although agriculture is a complex and highly evolved sector, it is still directly dependent on climate, since heat, sunlight and water are the main drivers of crop growth. While some aspects of climate change such as longer growing seasons and warmer temperatures may bring benefits, there will also be a range of adverse impacts, including reduced water availability and more frequent extreme weather. These impacts may put agricultural activities, certainly at the level of individual land managers and farm estates, at significant risk.

The European Commission has recently adopted a Green Paper entitled ‘Adapting to climate change in Europe – options for EU action’ (COM(2007) 354). This sets out options to help the adaptation process and focuses on four priority areas, including early action to avoid damage and reduce overall costs. Adaptation efforts need to be stepped up at all levels and in all sectors, and need to be coordinated across the EU. The Commission will publish a White Paper containing more concrete policy proposals in 2008.

Climate change will add to the many economic and social challenges already being faced by European agriculture, with crop yields, livestock management and location of production likely to be affected. Adjustments to the Common Agricultural Policy (CAP) and the ‘Health Check’ of 2008 could provide opportunities to examine how to integrate adaptation into agriculture support programmes. Consideration might be given to the extent to which the CAP can promote good farming practices that are compatible with changing climatic conditions.

This study on ‘Adaptation to Climate Change in the Agricultural Sector’ aims to provide the European Commission with an improved understanding of the potential implications of climate change and adaptation options for European agriculture, covering the EU 27 Member States. It also aims to assist policy makers as they take up the adaptation challenge and develop measures to reduce the vulnerability of the sector to climate change.

The full report provides comprehensive technical analyses, together with background information and details of the methodology, literature sources and stakeholder interactions used in the study. This shorter summary presents a synopsis of the methodology approach and conclusions.

1.2 Structure of the report

The report is structured in nine chapters. This executive summary (Chapter 1) synthesises the methods and the key results and conclusions of the study. The introductory chapter (Chapter 2) defines the scope of the assessment and the objectives of the report. The background knowledge related to climate change and its impacts on agriculture is included in Chapter 3. The methodology for the study is presented in Chapter 4. The results of the specific objectives of the study are presented in Chapters 5 to 8 as follows:

- An assessment of the impacts and risks of climate change on farming activities based on current scientific research and knowledge on the physical impacts of climate change (Chapter 5).
- The potential adaptation options to increase the resilience of the agriculture sector in view of the projected impacts of climate change (Chapter 6).
- Identification of whether and how CAP instruments work towards adaptation, and potential options on how climate change adaptation issues can be integrated into the CAP (Chapter 7).

The results of the study were evaluated in a workshop and information on the evaluation is provided in Annex J. Finally, the conclusions of the study are presented in Chapter 8. The complete list of scientific and technical studies that provide background information, contribute to the discussion and support the evaluation provided in this report is included in Chapter 9. Ten Annexes (Annex A to Annex J) contain additional information to complement the results provided in the main chapters of the report.

1.3 Methodology

The study comprised a series of tasks representing a logical progression from an assessment of climate change impacts, through an analysis of risks and opportunities, and identification of adaptation options, to potential integration into the CAP.

1.3.1 Assessment of climate impacts, risks and opportunities

A wide-ranging review of the available literature covering climate change projections, agricultural modelling and impacts assessments, and other material relevant to European agriculture in the 21st Century (such as socio-economic, policy and other sectoral drivers) formed the basis of the assessment of climate impacts. From reports published since 1995, 271 relevant recent studies were selected and impacts data categorised into groups according to key issues, risks and regions. Risks and opportunities were identified in relation to projected impacts. Climate change and socio-economic projections were used to define a number of European agro-climatic zones, which served to distinguish the priority risks and opportunities (and later, adaptation options).

By prioritising the risks and opportunities arising from climate change impacts, the approach identified those that need be addressed most urgently and provided a rationale for focusing the adaptation assessment on key issues. This prioritisation was carried out in a three-stage process. First, the risks and opportunities were categorised according to agro-climatic zones. Then a semi-quantitative approach was used to assess the magnitude and likelihood of risks and opportunities. Finally, risks and opportunities were prioritised according to their combined magnitude-likelihood scores. The analysis provides some indication of the overall impact of climate change on farming across agro-climatic zones. It does not, however, provide a means for identifying the risks/opportunities that affect the most vulnerable farmers; as in many cases the literature did not provide sufficiently detailed information.

The analysis refers to a time-frame of 2050 to 2080, therefore the suggested adaptation options are relevant to projected risks and opportunities within this period. Nevertheless, due to the lack of quantified information on uncertainty in climate change scenarios, a detailed time-frame analysis is not considered in this study.

1.3.2 Evaluation of adaptation measures

The process of identifying potential adaptation measures involved three main stages:

- Analysis of relevant literature and ongoing studies to characterise adaptation measures relating to the risks and opportunities identified in the impacts assessment.
- A review of national adaptation frameworks to highlight ongoing work across the EU-27 to prepare national adaptation strategies.
- A stakeholder consultation exercise to obtain practical information on adaptation measures; this took the form of a questionnaire targeted at representatives in each of the EU-27 Member States.

For the priority risks identified at sector and farm level in the assessment of impacts, a number of possible adaptation responses (at both sector/policy level and farm level) were evaluated with respect to the following issues: technical feasibility, potential costs of implementation, cost-effectiveness, ancillary benefits, and cross-sectoral implications (e.g. water, tourism, energy). Adaptation measures were further categorised as technical (e.g. introduction of new cultivars), management (e.g. changes in cropping patterns, soil, landscape, water), or infrastructural (e.g. changes in drainage, irrigation systems, access, buildings).

1.3.3 Examination of the role of CAP

This section aimed to analyse the potential contribution (and constraints) of the Common Agricultural Policy (CAP) and to identify policy measures that can support farmers and rural communities to tackle and facilitate adaptation. A SWOT analysis (Strengths/Weaknesses, Opportunities/Threats) was carried out on the main CAP instruments covering both direct income support payments and Rural Development measures.

1.4 Impacts, risks and opportunities of climate change on agriculture in Europe

1.4.1 Evolution of climate

- Temperatures will rise across Europe, especially during winter.
- Annual total precipitation may increase, but so will inter-season variability and evapo-transpiration. Summer rainfall is likely to be lower throughout much of Europe, with periods of intense rainfall becoming more common and less winter precipitation falling as snow.
- Although difficult to forecast, the incidences of extreme weather events is likely to rise in a warmer climate. This will mean more flooding, higher winds, destructive precipitation events and longer periods of drought.
- Sea level is predicted to rise by as much as 5m. One effect of this is likely to be the salinisation of water resources in coastal areas.
- Atmospheric levels of CO_2 and ozone will rise.

1.4.2 Evaluation of climate change impacts and risks: general trends

The combination of long-term changes and the greater frequency of extreme weather events is likely to have adverse impacts on the agricultural sector. Changes in hydrological regimes will directly impact agricultural production and production methods. Reductions in crop yield and quality as the result of reduced water availability and precipitation variability could result in a loss of rural income. This loss of income will be further exacerbated by the need for increased spending as a result of damage caused by extreme weather events.

Too much water

Heavier winter rain and the decreased proportion of winter precipitation falling and being stored as snow will increase the occurrence of floods, damaging crops at vulnerable stages of development and disrupting farm activity.

Excessively wet years may cause declining yields as a result of waterlogging and increased pest and disease problems.

Intense rain and hail-storms can affect yield and quality of vulnerable crops, such as soft fruits.

Sea level rise will directly impact some agricultural land, contribute to greater pressures via changes to land use around urban areas and increase the salinity of some water resources.

Too little water

Reduced water availability may lead to insufficient water available for irrigation, crops suffering from heat and drought stress, and increased competition for water resources may result in higher prices and regulatory pressure.

Increased manure and fertiliser applications (as a response to reduced nutrient uptake), may lead to a reduction in water quality as nutrients and other leachates are not sufficiently diluted by rainfall.

Drought will lead to soil degradation, which is a major threat to the sustainability of Europe's land resources and may impair the ability of European agriculture to successfully adapt to climate change.

Increased salinity may result in land abandonment as it becomes unsuitable for cropping.

The challenge to adapt

Varying seasonality and inter-annual variability will affect crop cycles and farm management, affecting yields and rural economies.

Temperatures are expected to rise beyond the optimum growing conditions for many common crop species.

Increased concentrations of tropospheric ozone are expected to reduce crop yields.

The delineation of agro-climatic zones is likely to change, leading to the loss of some indigenous crop varieties, regional shifts in farming practices and to shifts in optimal conditions for pest species and disease types.

Potential advantages

In some regions a positive relationship between temperature and crop yield is forecast, with higher temperatures and increased CO_2 concentrations producing greater yields. However, an insufficient supply of water or nutrients, coupled with increased weed competition is expected to frequently negate the fertilizing impact of higher CO_2 levels.

New crops such as soya could be grown in future conditions to produce livestock feed. However, warmer and drier climatic conditions may also reduce forage production leading to changes in optimal farming systems and a loss of income in areas dependent on grazing agriculture.

1.4.3 Risks and opportunities in Europe's agro-climatic zones

In the **Alpine**, **Boreal**, **Atlantic north** and **central** and **Continental north** zones, risks relate mainly to potential changes in precipitation patterns, with projected increases in winter rainfall and decreases in water availability in summer. Hence strategies are needed to reduce the effects of winter flooding, water logging and reduced water quality, while implementing measures for capturing and storing water to ensure adequate supply during the summer.

Mountain **Alpine** regions are particularly vulnerable as temperature increases are expected to be above average and other climate change impacts, such as decreased snow cover and glacial retreat, may have further impacts on hydrological cycles in many river basins.

In the **Alpine**, **Boreal**, **Atlantic**, and **Continental north** agro-climatic zones, a lengthened growing season and an extension of the frost-free period may increase the productivity of some crops and enhance the suitability of these zones for the growth of other crops. However, these changes will only be possible if there is sufficient water available.

Rising sea levels are a particular risk in the **Atlantic central** zone, requiring either improved defences or the abandonment of land due to inundation and saline intrusion. Hard defences are extremely expensive and not necessarily cost-effective, so farm-level measures should be considered in the context of wider Integrated Coastal Zone Management plans.

Whilst influxes of new pests and diseases present a high risk in the **Boreal**, **Atlantic central**, and **Continental north** zones, there is likely to be considerable opportunity in these zones for increased agricultural production. The yields of current crops are set to increase, together with the area of potentially productive land. There are also opportunities for the introduction of new crops types, and may be potential for increased livestock production in some zones. However, there is also a possibility that optimal growing conditions may shift from areas that have a large proportion of fertile soils towards those where soils are less fertile and, therefore, less able to produce higher yields.

In the **Atlantic south**, **Continental south** and **Mediterranean** zones, the greatest risks could derive from reduced crop yields and conflicts over reduced water supply. Strategies need to be developed to adopt cultivars or crops better suited to water- and heat-stress. Problems from new pests and diseases are also considered a high risk in these zones. There are few opportunities, although in parts of the **Continental south** zone (for example, Hungary or Romania), there may be some scope for the introduction of new crops.

Climatic changes, in general, are likely to shift the zones of optimal production areas for specific crops in the EU and altered carbon and nitrogen cycles may have significant implications for soil erosion and water quality in all zones. Temperature increases tend to speed the maturation of annual crops, therefore reducing their total yield potential. In turn, such changes in productivity and zonation may affect the total agricultural output of the EU and its share of international commodity trading.

Table A below summarises the risks and opportunities according to the current distribution of the defined agro-climatic zones.

Table A. Summary of risk and opportunity prioritisation by agro-climatic zone

Description	**Bor**	**Atl N**	**Atl C**	**Atl S**	**Cnt N**	**Cnt S**	**Alp**	**Md N**	**Md S**
Risks									
Crop area changes due to decrease in optimal farming conditions		M	M	M	M	M	M	M	H
Crop productivity decrease		M	M	M	M	M	M	M	M
Increased risk of agricultural pests, diseases, weeds	H	M	H	H	H	H	M	H	H
Crop quality decrease			M	M	M	M		M	H
Increased risk of floods	H		H		H		H		
Increased risk of drought and water scarcity		H	H	H	H	H	H	H	H
Increased irrigation requirements				M		H		H	H
Water quality deterioration	H	H	H		H		H		
Soil erosion, salinisation, desertification	H			M		H	H	H	H
Loss of glaziers and alteration of permafrost	M						H		
Deterioration of conditions for livestock production	H	H	H	L	H	L	H	L	M
Sea level rise	H	H	H	H	H			H	H
Opportunities									
Crop distribution changes leading to increase in optimal farming conditions	H	H	H	M	H	H	H	M	
Crop productivity increase	M	H	M	M	M		H		
Water availability	H	M	H	H	H		M		
Lower energy costs for glasshouses	M			M	M	M		M	
Improvement in livestock productivity	H	H	H		H		H		

H=High M=Medium L=Low

1.5 Options for adaptation in European agriculture

The different agro-climatic zones not only face different impacts, risks and opportunities, but will also have different adaptation options for the same risks because of inherent socio-economic constraints and adaptive capacity.

The review of national adaptation strategies highlights the current policy focus on reducing the risk of flooding, either from sea level rise or from increased runoff. There are also proposals, mainly from southern member states, to increase capture and storage of water to ensure adequate supplies. While some mention is made of such measures in northern states, it is important that these are promoted more widely as the prospect of drought may be viewed with some scepticism, particularly in those member states accustomed to receiving a large proportion of their annual precipitation in summer. However, as precipitation patterns change, limited capacity for water storage may need to be increased to capture a greater proportion of winter rainfall.

The stakeholder survey results revealed reasonable consistency across all nine agro-climatic zones. The responses differed in terms of projected impacts, however. For example, there is a higher likelihood of drought in the southern Mediterranean zone as opposed to the north, with a corresponding difference in the need for irrigation. In general, there was a greater awareness and greater adoption and/or consideration of adaptive measures in the southern agro-climatic zones than in the north. This reflects a greater likelihood of adverse impacts on crop production in these zones and hence a greater urgency to take adaptive action, insofar as is possible, or to seek alternative modes of production.

Despite the apparent lower appetite for adaptation in northern regions, measures clearly need to be implemented to lessen the negative impacts of climatic changes. Furthermore, there are likely to be opportunities for increased agricultural production. If these potential increases are to be realised, a more active approach to identifying and promoting adaptation measures may be needed.

1.6 Potential role for the Common Agricultural Policy in adaptation

The contribution of current CAP measures towards adaptation was evaluated in order to consider how existing policy instruments may be continued or extended to facilitate adaptation. The analysis also aimed to reveal where policies may present a barrier to adaptation or lead to ‘mal-adaptation’.

Using the CAP

Supplementing current **Statutory Management Requirements** with new legislation that addresses climate-related impacts would create stronger incentives for Single Payment Scheme claimants to adapt.

The flexibility that Member States can exercise in determining **Good Agricultural and Environmental Condition** standards allows for highly appropriate and localised management practices that assist with adaptation. The potential of GAEC’s would be maximised by requiring member states to identify major environmental pressures, which may include climate impacts, and justify the inclusion or exclusion of corresponding standards.

Member States should be required to make provision for training farmers on climate change issues, particularly new entrants such as young farmers. Developing the role and scope of the **Farm Advisory System** would be a feasible option for effective knowledge transfer.

The Rural Development Programmes have the potential to benefit further by guiding or placing an obligation on member states to meet or consider the impacts of future climate change across all axes.

- **Agri-environment schemes** have the potential to support many adaptation initiatives.
- To ensure investments made through Axis 1 and 3 bring benefits in terms of adaptation, **linking funding to cross compliance** should be explored

- Mitigation to climate change is explicitly mentioned throughout the Rural Development regulations. This could be expanded to include adaptation.
- Adaptation to climate change will be needed at all spatial levels. The Rural Development measures can do this through careful **co-ordination from the grassroots** Leader programme all the way up to integration with river basins through the Water Framework Directive.
- Adjusting the **criteria** for those eligible for rural development support for areas with high vulnerability to climate change may be an option to facilitate their adaptation.

In addition to existing CAP instruments, **insurance** needs to be considered and encouraged to allow farmers to increase their resilience to climate change. This may provide further incentives for farmers to adapt their business and buildings in order to reduce their premiums.

1.7 Conclusions

Summary of risks and opportunities across the agro-climatic regions

- In the Alpine, Boreal, Atlantic north and central, and Continental north zones, risks relate mainly to potential changes in precipitation patterns, with projected increases in winter rainfall and decreases in water availability in summer.

- Whilst influxes of new pests and diseases present a high risk in the Boreal, Atlantic central, and Continental north zones, there is likely to be considerable opportunity in these zones for increased agricultural production.

- In the Atlantic south, Continental south and Mediterranean zones, the greatest risks are reduced crop yields and conflicts over reduced water supply.

Adaptation options

Farmers have always adapted to changes in climate. The challenge now is to adapt within very short periods of time to potentially extreme impacts and new risks and opportunities. This will be achieved through a combination of managerial, infrastructural and technical measures.

In general, there seems to be greater awareness and greater adoption and/or consideration of adaptation measures in the southern agro-climatic zones than in the north, which is likely to be due to the higher prevalence of negative risks in southern areas.

Measures to adapt crop and livestock production, in particular to take advantage of the potential gains in productivity forecast for northern regions, need to be given greater attention. Simultaneously, there is a need for EU measures to help farmers cope with the forecasted loss of agricultural production in southern regions. While in a global economy it might be argued that the market should be left to resolve such issues, it must also be remembered that social and environmental issues are closely imbedded in this issue, which may falter without any support.

Many of the possible adaptation measures to address the risks and opportunities identified in the nine agro-climatic zones can be applied at farm level, with a significant proportion being management-related. However, before many of these adaptation initiatives can be implemented, short-term measures involving policy development, knowledge transfer, assessing adaptation costs and establishing relevant partnerships must first be put in place. Existing CAP mechanisms can be used to stimulate and facilitate adaptation and other mechanisms must also be utilised, such as insurance, capacity building, networks and partnerships.

2 Introduction

This chapter provides an overview of the realities of climate change and the challenges for the agricultural sector in Europe, using a common vocabulary to compare studies and results. Finally, the last section in this chapter defines the purpose and structure of the report.

2.1 The realities of climate change

In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change or IPCC (2007) documented, for the first time, the wide-ranging impacts of changes in the current European climate, including longer growing seasons, shifts in species ranges, heat stress and flooding. These observed changes are already posing challenges for many economic sectors and magnify the regional differences in Europe's natural resources and assets.

Climate change is a real concern for the sustainable development of agriculture, both globally and within the EU. Although agriculture is a complex and highly evolved sector, it is still dependent on heat, sunlight and water as the main drivers of crop growth. While aspects such as longer growing seasons and warmer temperatures may bring some benefits; there will also be a range of adverse impacts, including reduced water availability and more frequent extreme weather events.

The 2003 heat wave that affected much of Western Europe had serious adverse effects on water and agricultural resources; France was particularly badly hit. In 2007 extreme weather events once again affected many parts of Europe with record high temperatures recorded in southern Italy, Greece and in south-central Europe, adversely affecting agricultural production. Forest fires further exacerbated agricultural production in southern Italy, Greece and Spain, with fires in Greece engulfing large areas of olive groves and pasture. At the same time, torrential rains and extensive flooding affected many lowland areas of England with consequential damage to crops and infrastructure.

Agriculture has shown, throughout history, a great ability to adapt to changing conditions, with or without a conscious response by farmers. However, it is likely that the changes imposed by climate change in the future and as expressed above will and have exceeded the limits of autonomous adaptation, thereby requiring policies to support and enable farmers to cope with changes to farming systems and management.

2.2 Expected impacts of climate change on European agriculture- an overall view

There have been several thousand studies into the potential impacts of climate change with many different approaches (e.g. bio-physical modelling, econometric analysis) and definitions (e.g. impacts, vulnerability, risk, adaptation). Studies have focussed on particular issues (e.g. soil erosion, biodiversity, and farm income), time-frames (e.g. 2020s, 2050s, and 2100), scenarios (e.g. SRES) and spatial scales (with a focus on national and global scales). In consequence our knowledge of the potential impacts is diverse and fragmented. It is however agreed that all parts of Europe are to be negatively affected at some time in the next several decades, and the consistency shown with the IPCC's Fourth Assessment Report confirms a common direction.

The effects of climate change and increased atmospheric carbon dioxide are expected to lead, overall, to small increases in European crop productivity at moderate warming. Yet within this macro scale, impacts on crop yields are expected to vary across Europe. In southern Europe, higher temperatures and droughts are projected to worsen conditions in a region already vulnerable to climate variability. Crop productivity will be negatively affected by reduced water supply and heat stress, and will be at risk from increased frequency of wildfires. In central and eastern Europe, summer rainfall is projected to decline leading to increased water stress. In northern Europe and Alpine regions, climate change is projected to bring mixed effects: initial benefits such as increased crop yields (at moderate levels of warming) are likely to be outweighed over time by more frequent flooding and increasing ground instability. Altered carbon and nitrogen cycles may affect soil erosion and water quality in all regions.

Some lowland crops that are currently grown in southern Europe will become viable further north or at higher altitudes. Energy crops (such as oilseed rape, maize, etc), solid bio-fuel crops (such as miscanthus and short rotation coppice), starch crops and barley show a northward expansion in potential cropping area, but a reduction in the south. Importantly, the potential benefits from climate change will only be possible if water requirements are met.

Rising temperatures are expected to increase the frequency of heat stress and the risk of disease in livestock. Severe heat stress will enhance the risk of mortality in intensive livestock systems, most notably for pigs and broiler chickens in northwest Europe. Warmer conditions will support the dispersal of disease-bearing insects (including new vectors currently limited by colder temperatures) and enhance the survival of viruses. The productivity of forage crops along the Atlantic coast may be reduced by drought such that availability is no longer sufficient for livestock feed at current demand.

The impacts of climate change and increased climate variability on agricultural production in Europe are closely associated with projected water resource availability and demand. Two variables are particularly critical for agriculture: future precipitation patterns and their distribution throughout the year, and the incidence of extreme weather events. The main consequences of changes in water resources for agricultural production include:

- Increased demand for water in all regions due to increases in crop evapotranspiration in response to increased temperatures.

- Increased water shortages, particularly in the spring and summer months, increasing the water requirement for irrigation, especially in southern and south-eastern Europe.

- Reduced water quality due to higher water temperatures and lower levels of runoff in some regions, particularly in summer, imposing further stress in irrigated areas.

- Increased risk of flooding due to the expected concentration of winter rainfall. The major flood events experienced in recent years (notably 2002 and 2007) demonstrate Europe's vulnerability to floods.

- Finally, the projected increases in sea level will also affect agricultural production in the low-lying coastal areas, unless measures to protect vulnerable land or other land management schemes are put in place.

2.3 Defining a common language

The IPCC defines climate change as a statistically significant variation in the state variables that define the climate of a region (such as temperature or precipitation) or in its variability persistent over an extended period of time (typically decades or longer periods).

The concepts of impacts, vulnerability, risk and adaptation are not defined in the United Nations Framework Convention on Climate Change (UNFCCC) nor in the Kyoto Protocol; the terms are used loosely by many scientific and policy communities and have a meaning in common usage. It has been observed that interpretation of some of these key terms by scientific groups or policy makers can be quite different, which may lead to varied or false expectations and responses (OECD, 2006).

According to the UNFCCC, there is a clear difference between **mitigation** (reduction of greenhouse gas emissions and carbon sequestration) and **adaptation** (ways and means of reducing the impacts of, and vulnerability to, climate change). Until recently, UNFCCC negotiations have focused primarily on mitigation; however, it is now clear that objectives of human well-being in the future should be addressed, stressing the importance of adaptation.

For the purposes of this study, the following terms are used:

Impacts are the consequences of climate change that are likely to affect agricultural activities. For example, a decrease in rainfall during summer is likely to impact grain filling of cereals.

Risk is the possible adverse outcome of a particular impact. From the example given above, there is a risk that summer droughts will reduce wheat yields.

Opportunity is the possible beneficial outcome of a particular impact. From the example given above, there is an opportunity that increased average temperatures will expand the potential areas for cultivation in northern European regions that are currently limited due to sub zero temperatures in the spring.

Adaptation is a measure, or measures, that can be taken to reduce the impact of a particular risk. From the example above, there are a number of means by which cereal growers could adapt to increased summer drought, such as using irrigation.

Further elaboration of adaptation concepts can be found in Chapter 6.1.

2.4 Purpose of the report and report structure

This study examines current evidence provided by earlier studies and research in order to provide the European Commission with an improved understanding of the potential implications of climate change for the European agricultural sector. It provides an overview of the options for adaptation in order to minimise potential negative effects, and supports the Commission's work to develop options for the Common Agricultural Policy (CAP) to reduce the vulnerability of the agricultural sector to climate change.

The report is divided into nine chapters. The executive summary (Chapter 1) summarises the objectives and methods and reports on the key results and conclusions of the study. Chapter 2 defines the scope of the assessment and the objectives of the report. Chapter 3 provides the background knowledge related to climate change and its impacts on agriculture, while the methodology for the study is presented in Chapter 4. The results of the specific objectives of the study are presented in Chapters 5 to 7 as follows:

- Assessment of the impacts and risks of climate change on farming activities based on current scientific research and knowledge (Chapter 5).

- Potential adaptation options for increasing resilience of the agriculture sector in view of the projected impacts of climate change (Chapter 6).

- Identification of whether and how CAP instruments facilitate adaptation, and potential options to integrate adaptation issues into the CAP (Chapter 7).

The results of the study were evaluated in a workshop, the conclusions of which are presented in Chapter 8. The complete list of scientific and technical studies that provide background information, contribute to the discussion and support the evaluation provided in this report is included in Chapter 9. Finally a glossary of terms and concepts is included in Chapter 10. In addition ten Annexes (Annex A to Annex J) include additional information to complement the results provided in the main chapters of the report.

3 Background

This chapter analyses the current knowledge of climate change and the projections of future scenarios, including the choice of socio-economic scenarios that determine the projected greenhouse gases emissions, and projected changes in precipitation and temperature. The chapter also presents how the climate change scenarios are linked to the evaluation of impacts, risk and opportunities and adaptations. Since the report will focus on territorial results, the European agro-climatic zones are defined. Finally, the chapter includes a brief discussion on the European policy context.

3.1 Current knowledge about observed climate change

3.1.1 The climate system

The climate system consists of a series of fluxes and transformations of energy (radiation, heat and momentum), as well as transports and changes in the state of matter (e.g. air, water, aerosols), with received solar radiation as its major energy source. The flows and transports occur between and within the main components of the system: the atmosphere, oceans, land, biota and cryosphere (the domain of ice and snow). The system regularly varies due to the shape of the earth's orbit - its angle and daily rotation; but also randomly as the atmosphere and the oceans are both fluid, subject to internal movements associated with random turbulence as energy is transported and transformed throughout the climate system. These latter variations result in climate extremes.

Climate is defined as the prevalent pattern of weather observed over a prolonged period of time. Climate variables (e.g. temperature, precipitation, wind speed) can be averaged on a daily, monthly, annual or longer basis. Associated with the variables' average states are indications of their oscillations about their mean values. The term climate change refers to an overall alteration of mean climate conditions, whereas the term climate variability refers to fluctuations about the mean. A changing climate is likely to bring about changes to patterns of climate variability.

Precipitation anomalies, for example, may occur with regard to the timing, quantity, intensity, seasonal and spatial distribution, and type (e.g. winter rain *vs.* snow). Greater temperature variation may be manifested, for example, in more prolonged heat waves and sudden cold snaps. Greater temporal and spatial variance of meteorological conditions and storms can all affect soil conditions, water availability, agricultural yields and susceptibility to pest and pathogen infestations.

3.1.2 Conclusions of the IPCC Fourth Assessment report

The climate system varies continuously. For example, the first two decades of the 20th Century were relatively cold, the 1920s and 1930s were hot, and the 1940s, 1950s and 1960s were colder than the previous decades. Yet from the 1970s to the present day, all decades have been hotter than the average of the previous 100 years. There is scientific consensus than the average global temperature (air temperature at the surface of the planet) has increased by 0.6º+/-0.2ºC over the last 100-year period and that the warmest five years on record have occurred in the last decade. At the same time, annual precipitation has also changed (about 0.5-1% per decade) in most medium to high latitude regions. Nevertheless, in many tropical and sub-tropical regions, precipitation has decreased in recent decades. In the Mediterranean region, temperature has increased more than in other European regions and precipitation has clearly been more variable between and within the year.

IPCC's Fourth Assessment Report (IPCC, 2007) clearly shows that the climatic variations over recent decades have had noticeable direct consequences in natural ecosystems, glaciers and agricultural systems in many regions. Many areas of the world are already struggling today with the adverse impacts of an increase in global average temperature.

The alarming number of extreme events that have occurred over the last five years further exacerbates these impacts. The scientific literature suggests that observed changes in climate have affected the frequency and intensity of these extremes (drought, floods, and heat waves).

3.2 Future climate change scenarios

A basic knowledge of the Earth's energy balance is sufficient to predict that an increase in greenhouse gases leads to a warming of the atmosphere. Nevertheless, the climate system is very complex and depends on interactions and feedbacks among multiple variables. Therefore, in order to describe the climate system accurately it is necessary to use numerical models that describe these complex processes.

A climate model is a set of equations that describe the energy balance and the transformation of momentum and energy transports between and within all components of the climate system (atmosphere, oceans, land, biota and cryosphere). Although very well developed and very complex, these climate models are obviously a simplification of the climate system. It is essential to note that temperature and precipitation projections are the numerical results of a given climate model. To reach these results, it is necessary to define a time horizon and the atmospheric concentrations of greenhouse gases; therefore, the results of a given climate model depend on the time frame and the social conditions that result in a certain concentration of greenhouse gases in the atmosphere. The main social conditions that determine these concentrations are population, economic development and land use. These conditions are defined in different socio-economic scenarios. Finally, regional models may be used to provide further spatial resolution to the results of a global climate model (this is called downscaling).

In summary, to define a climate change scenario, it is necessary to first define the atmospheric concentration of greenhouse gases, and secondly to introduce this concentration into a global climate model. In addition, it is useful to downscale the results by using a regional climate model in order to provide detailed geographic information. The climate scenarios are then used for subsequent evaluation of the consequences of change in different sectors.

3.3 The choice of socio economic scenarios

Socio-economic scenarios represent alternative ‘views’ of the future and are key to understanding potential vulnerability to different levels of climate change. The IPCC has defined a range of socio-economic scenarios in its Special Report on Emission Scenarios (IPCC SRES, 2001). These describe potential socio-economic futures that will determine concomitant levels of greenhouse gas emissions to the atmosphere (Box 1). Annex A summarises the A1, A2, B1 and B2 scenarios and the implications for climate impacts and adaptation.

There is considerable uncertainty surrounding future emissions and their underlying driving forces, as is reflected in the wide range of future emission forecasts in the literature. This uncertainty is increased when projecting from emissions to climate change, from climate change to possible impacts, and from impacts to adaptation and mitigation measures and policies. Since no single projection should be considered as an accurate prediction of the future, it is essential that more than one socio-economic scenario is used in any impact and adaptation assessment. This study uses the SRES A2 and B2 scenarios; these are used in many studies as they cover a wide range of realistic possibilities, but avoid the more extreme assumptions of the A1 and B1 scenarios in terms of population growth and economic development.

Box 1 Socio-economic projections for constructing climate scenarios (SRES)

The IPCC was set up by the United Nations in 1998 to produce assessments of the state of the Earth's climate system. The current state of scientific knowledge regarding climate change and its impacts was published early in 2007.

The IPCC uses global climate models and emission scenarios to estimate future changes in climate patterns. The scenarios cover a wide range of the main driving forces of future greenhouse gas emissions. The climate models, which represent the atmosphere and the oceans, involve conversions of projected emissions into atmospheric greenhouse gas concentrations and then variations in climatic variables.

The basic emission scenarios or SRES (A1, A2, B1, B2) represent storylines about possible world developments in economic growth, population increases, global approaches to sustainability and other sociological, technological and economic variables that could influence greenhouse gas emission trends.

In the scenario family A, economic development is the priority, while in the scenario family B, environmental sustainability considerations are important.

The "1" and "2" scenario groups differ in their technological development path: faster and more diverse in "1", and slower and more regionally fragmented in "2". Each scenario is identified as having low (B1), medium-low (B2), medium-high (A1) and high emissions (A2).

Table 1: Overview of main primary driving forces in 2020, 2050 and 2100 for the A1, A2, B1 and B2 scenarios

Scenario group	**A1**	**A2**	**B1**	**B2**
Population (billion) (1990 = 5.3)				
2020	7.6	8.2	7.6	7.6
2050	8.7	11.3	8.7	9.3
2100	7.0	15.1	7.0	10.4
World GDP (10 12 1990US$/ yr) (1990 = 21)				
2020	57	41	53	51
2050	187	82	136	110
2100	550	243	328	235
Per capita income ratio: developed countries and economies in transition (Kyoto Treaty Annex 1) to developed countries (Kyoto Treaty non-Annex 1) (1990 = 16.1)				
2020	6.2	9.4	8.4	7.7
2050	2.8	6.6	3.6	4.0
2100	1.6	4.2	1.8	3.0

Source: Adapted from the Special Report on Emission Scenarios

3.4 A review of the projections for global and European climate change

The IPCC provides detailed analyses of the simulations that have been conducted with available climate models and socio-economic scenarios. The results of these numerical simulations clearly point to a best estimation of global warming of 1.8ºC to 4ºC over the next century compared with 1990 levels (IPCC, 2007). This represents a three to six-fold increase in temperature since pre-industrial times.

The simulations also point to an increase in annual global precipitation (5 to 25%); this is to be expected, as a warmer atmosphere holds more moisture. The simulations' results further predict that globally:

- High latitudes and high elevations are likely to experience greater warming than the global mean, especially in winter.
- Winter and nocturnal temperatures (minimum temperatures) are projected to rise disproportionately.
- The hydrological cycle is likely to further intensify, bringing more floods and more droughts.
- More winter precipitation is projected to fall as rain, rather than snow, decreasing snow pack and spring runoff, potentially exacerbating spring and summer droughts.

In more than 10 global climate models (GCMs) being run globally, each gives different results for Europe (PRUDENCE Project, 2006). These include differences in temperature for the summer period in northern and southern Europe (Table 2). All models project increased annual precipitation in northern Europe, which is likely to cause more frequent and intense flooding. The models also commonly project decreased annual precipitation in southern Europe, with the consequent risk being that of increased drought.

Table 2 Summary changes of the summer mean temperature (June-August) and annual precipitation by 2071-2100 relative to 1961-1990 averaged over northern Europe (47.5 – 75.0°N; 15.0°W – 35.0°E) and southern Europe (35.0 – 47.5°N; 15.0°W – 35.0°E)

	Changes by 2071-2100 relative to 1961-1990	
	Average summer mean temperature change (June-August) (deg C)	Average annual precipitation change (mm/day)
Northern Europe (47.5 – 75.0°N; 15.0°W – 35.0°E)	1 to 4	+ 0.0 to + 0.3
Southern Europe (35.0 – 47.5°N; 15.0°W – 35.0°E)	2 to 8	+ 0.1 to - 0.5

Source: PRUDENCE project

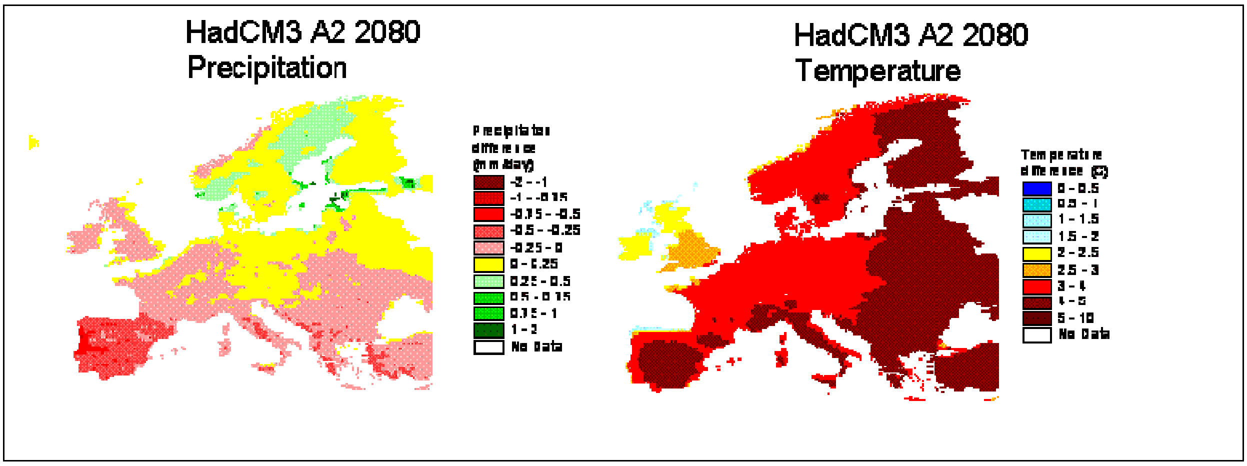
The PRUDENCE project provides data to develop regional (wide area) and local (a single point in space) climate change scenarios. In the PESETA project (PESETA, 2007), scenarios were constructed from a combination of global climate models (HadCM2 and ECHAM4) driven by the A2 and B2 socio-economic scenarios and downscaled for Europe with the HIRHAM and RCA3 regional models. The resulting high-resolution scenarios were then used to derive impacts of climate change to agricultural production (see below). The time frames considered are 2011-2040 and 2071-2100. In the time frame for 2011-2040, the socio-economic scenarios A2 and B2 are very similar and the resulting climate change scenarios are almost identical. Table 3 describes the scenarios and time frames, and Figures 1 to 4 show the annual changes in average temperature and precipitation resulting from the application of these scenarios over Europe.

Table 3 Summary of the five climate scenarios applied over Europe

Driving GCM	**RCM**	**SRES**	**Time frame**	**Change in average annual temperature in Europe (deg C)**	**Average CO_2 ppmv**
HadAM3H/HadCM3	DMI/HIRHAM	A2	2071-2100	3.1	709
HadAM3H/HadCM3	DMI/HIRHAM	B2	2071-2100	2.7	561
ECHAM4/OPYC3	SMHI/RCA	A2	2071-2100	3.9	709
ECHAM4/OPYC3	SMHI/RCA	B2	2071-2100	3.3	561
ECHAM4/OPYC3	SMHI/RCA3	A2	2011-2040	1.9	424

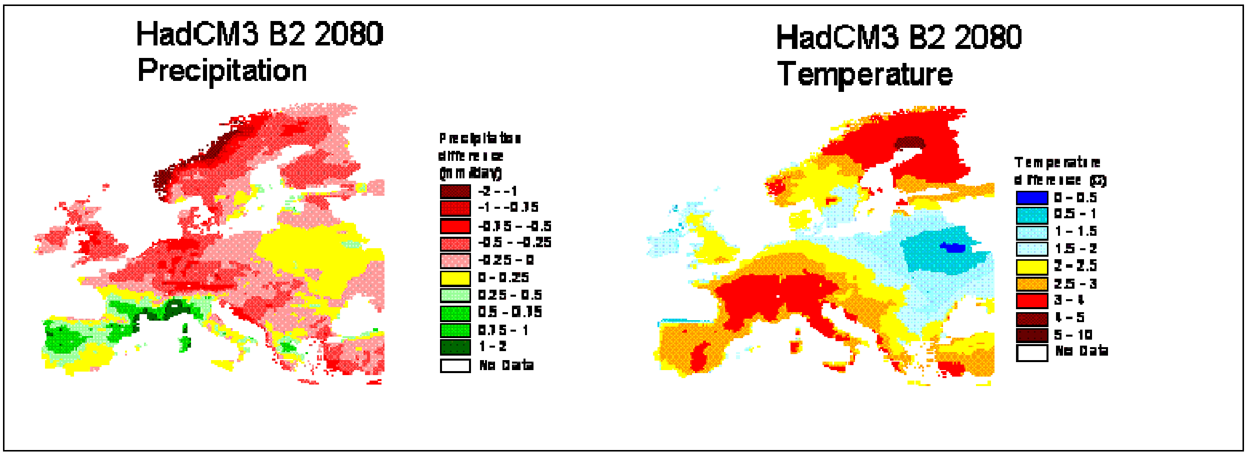
Source: PESETA - Agriculture

Figure 1 Changes in annual mean temperature and precipitation by 2071-2100 relative to 1961-1990 from the Prudence RCM nested in the HadCM3 GCM under the A2 scenario



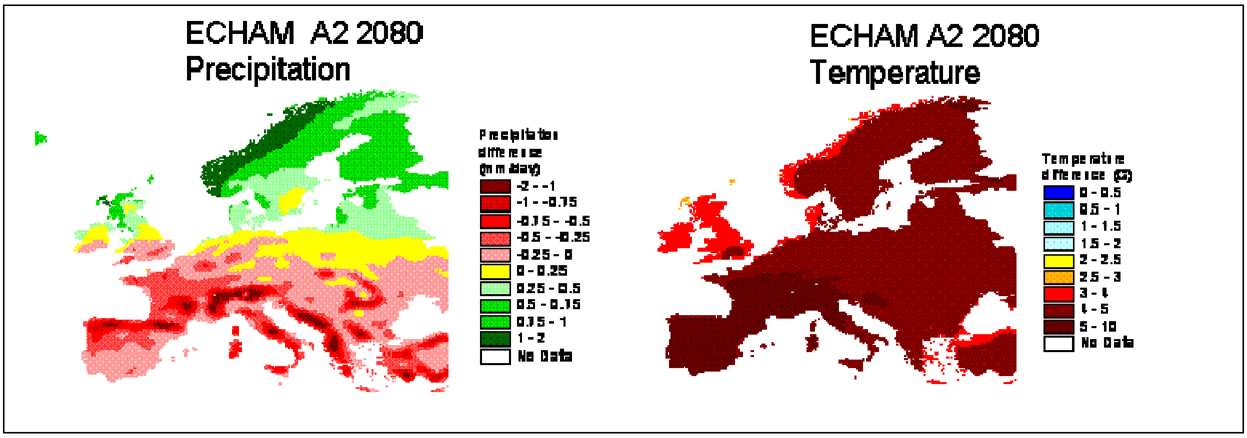
Source: PESETA - Agriculture

Figure 2 Changes in annual mean temperature and precipitation by 2071-2100 relative to 1961-1990 from the Prudence RCM nested in the HadCM3 GCM under the B2 scenario



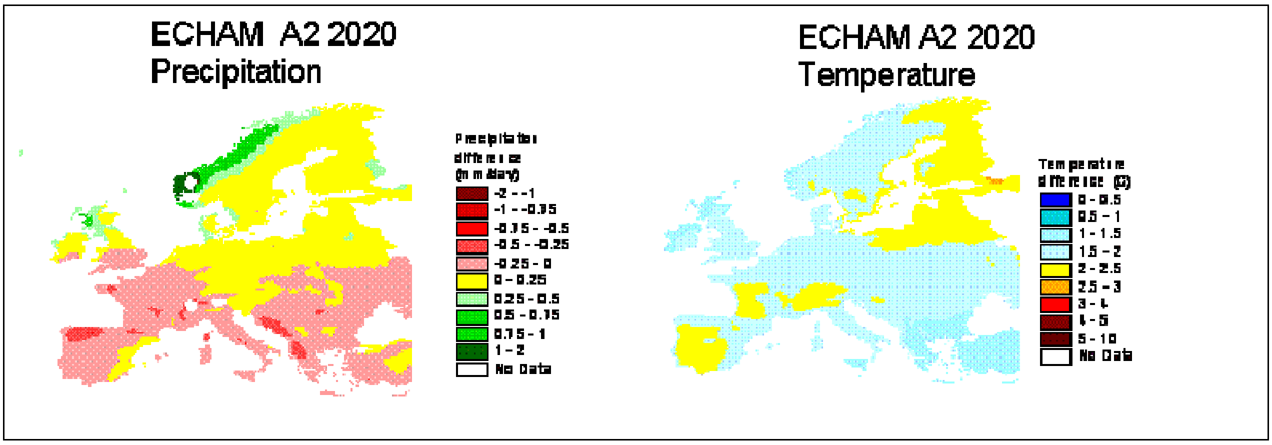
Source: PESETA - Agriculture

Figure 3 Changes in annual mean temperature and precipitation by 2071-2100 relative to 1961-1990 from the Prudence RCM nested in the ECHAM GCM under the A2 scenario



Source: PESETA - Agriculture

Figure 4 Changes in annual mean temperature and precipitation by 2011-2040 relative to 1961-1990 from the Prudence RCM nested in the ECHAM GCM under the A2 scenario



Source: PESETA - Agriculture

The two model forecasts for A2 2080 suggest similar changes in precipitation patterns across Europe, with decreases in southwest and southeast Europe, but increases in the total annual rainfall in the centre and north by the end of the century. The entirely different precipitation pattern projected by the Hadley model for the B2 scenario is due to the different consequences for greenhouse gas emissions from this scenario.

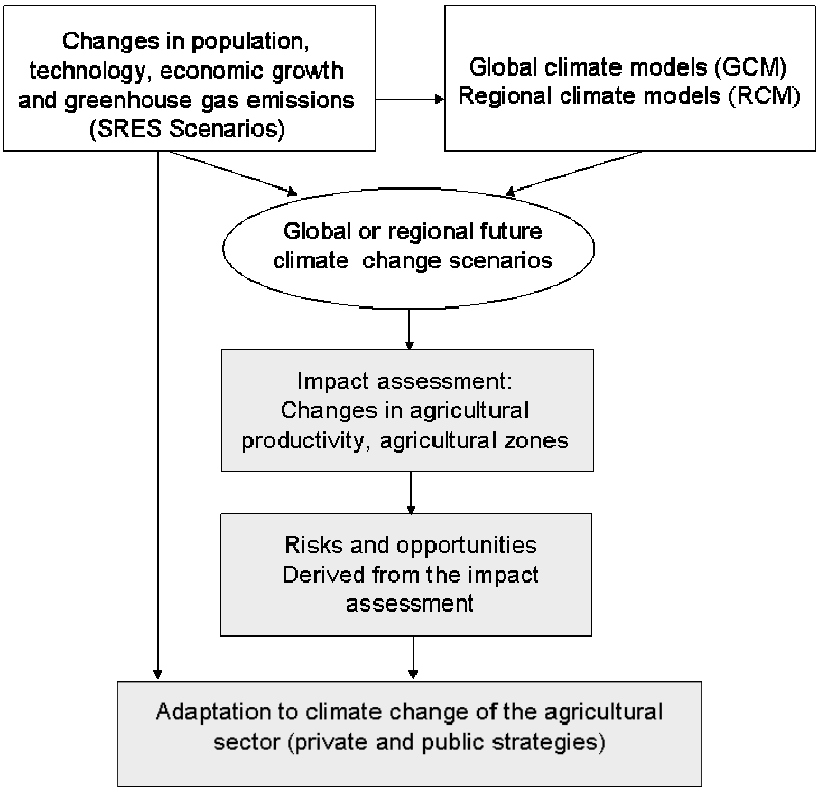
The two model outputs for the A2 scenario again project a similar pattern of change, with the greatest temperature increases in southern and eastern Europe.

The scenarios indicate a number of changes that can be expected with relatively high confidence. Average temperatures will rise; summers may become drier, particularly across southern Europe; winters may be wetter, with more heavy rain likely to bring an increase in flooding. Snowfall and snow cover will reduce everywhere and relative sea level will continue to rise.

3.5 Linking scenarios, impacts, risks and opportunities

Global or regional climate change scenarios are used to evaluate the possible impacts, risks and opportunities, and the potential for adaptation in a particular sector - in this study agriculture. Figure 5 shows the development of the climate change scenarios that drive this process. It is important to note that socio-economic conditions have a direct influence on the climate scenarios as they condition the amount of carbon dioxide and other greenhouse gases in the atmosphere. The socio-economic scenarios are also major determinants of possible adaptation options, since economic development is a driver of technological change, population defines demand and consumption, and land use change is influenced by policy.

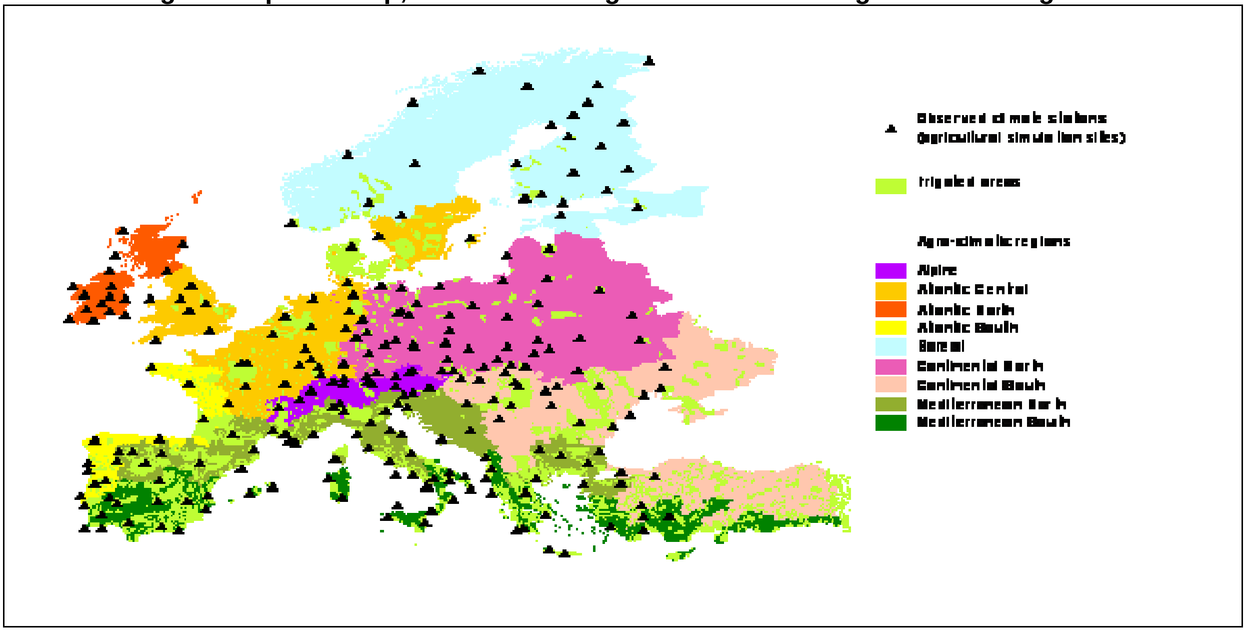
Figure 5 Linkages between climate models and scenarios for the evaluation of climate change impacts, risks and opportunities, and adaptation options in agriculture



3.6 European agro-climatic zones

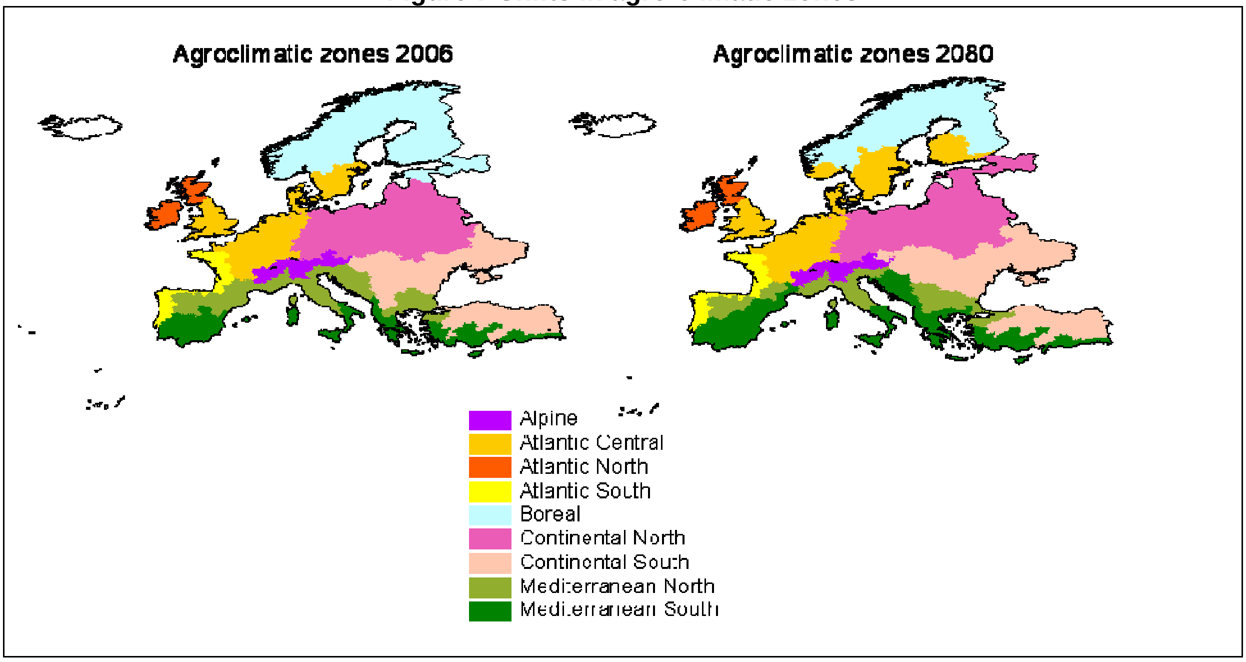
An agro-climatic characterisation of the EU has been used to differentiate estimated climate change impacts. The agro-climatic zones used for the analysis in this study were derived from the PESETA project. Nine agro-climatic zones were defined based on the K-mean cluster analysis of temperature and precipitation data from 247 meteorological stations, district crop yield data and irrigation data. The data used for the analysis are shown in Figure 6. Shifts in agro-climatic zones were considered for the application of the climate change scenarios, so the crop types simulated in the future are appropriate. The future zones were derived in the same way as the zones in the current climate, but the climate at each station was modified to take account of the changes forecast in the climate scenarios. The results are consistent with previous analysis (Metzger *et al.*, 2006; Rounsevell *et al.*, 2005). Figure 7 and Table 4 compare zones under the current climate and in 2080.

Figure 6 Spatial crop, climate and irrigation data define agro-climatic regions



Source: PESETA - Agriculture

Figure 7 Shifts in agro-climatic zones



Source: PESETA - Agriculture

(Enlarged (landscape) versions of Figures 6 and 7 are included in Annex B)

Table 4 Countries/regions within agro-climatic areas

Agro-climatic area	2006	2080
Boreal	EU: Sweden, Finland, Latvia, Estonia Other: Norway	EU: Sweden, Finland Other: Norway
Atlantic north	Ireland, Scotland	Ireland, Scotland
Atlantic central	England & Wales, Benelux, central and northern France, western Germany, Denmark, southern Sweden	England & Wales, Benelux, central and northern France, western Germany, Denmark, southern Sweden, southern Norway, Southern Finland
Atlantic south	Northern Portugal, Galicia, western France	Northern Portugal, Galicia, western France

Agro-climatic area	2006	2080
Continental north	EU: Eastern Germany, Poland, Lithuania, northern Ukraine, Czech republic, Slovakia, eastern Austria Other: Belarus	EU: Eastern Germany, Poland, Lithuania, Latvia, Estonia, northern Ukraine, Czech republic, Slovakia Other: Belarus
Continental south	EU: Hungary, Romania, Other: Serbia, Moldova, FYROM, southern Ukraine, north-eastern Turkey	EU: Hungary, Romania, eastern Austria Other: Serbia, Moldova, FYROM, southern Ukraine, north-eastern Turkey
Mediterranean north	EU: Northern Spain, southern France, Corsica, northern Italy, Bulgaria, the Macedonian region of Greece, Other: north-western Turkey, Croatia	EU: North-western Spain, southern France, Corsica, northern Italy, Bulgaria Other: north-western Turkey
Mediterranean south	EU: Southern Spain, southern Italy, Greece, southern Turkey	EU: Central Spain, southern France,
Alpine	EU:, western Austria, Slovenia Other: Switzerland	EU: western Austria, Slovenia Other: Switzerland

Source: PESETA - Agriculture

Farming systems determine the capacity to adapt to climate change and the optimal policy options. The farming systems are based on the EU typology of agricultural holdings: total specialised field crops, grazing livestock, horticulture and permanent crops. These were selected as they are recognised Europe-wide and represent the standard reporting format. The importance and structure of agriculture varies considerably between European agro-climatic zones. The general farming systems in the nine agro-climatic zones were used to provide a framework for the collection of information on risks and opportunities for each of the farming systems. Table 5 provides a summary of the main crops cultivated in the representative farming systems of the agro-climatic zones in this study. The identification of the farming systems assists in the discussion of the risks, opportunities and adaptation options in each zone.

Table 5 Summary of the main crops included in the representative farming systems in the agro-climatic zones

Agro-climatic Zone	% Utilized Agri Area in relation to Total Land Area	1st important share of the farming system	% in relation to Total Land Area	2nd most important share of the farming system	% in relation to Total Land Area	3rd most important share of the farming system
Boreal	11	field crops	8	grazing livestock	3	horticulture
Atlantic North	68	grazing livestock	58	field crops	9	horticulture
Atlantic Central	76	field crops	46	grazing livestock	29	permanent crops
Atlantic South	42	grazing livestock	25	field crops	9	permanent crops
Continental North	67	field crops	50	grazing livestock	15	permanent crops
Continental South	88	field crops	68	grazing livestock	18	permanent crops
Alpine	51	grazing livestock	25	field crops	25	permanent crops
Mediterranean Norht	54	field crops	34	grazing livestock	14	permanent crops
Mediterranean South	57	field crops	32	grazing livestock	16	permanent crops

Note: the area reported for each agro-climatic area only refers to the EU countries (EU-27).
Source: Eurostat 2005

3.7 European policy context

3.7.1 European climate change policy framework

Adaptation is not an alternative, but a necessary complement to mitigation; because of the slow response rate of the climate system to changes in greenhouse gas concentrations in the atmosphere. In recognition of this, the European Commission has adopted a Green Paper entitled ‘Adapting to climate change in Europe – options for EU action’ (COM(2007)354). This sets out options to help the adaptation process and focuses on four priority areas, including early action to avoid damage and reduce overall costs. Adaptation efforts need to be stepped up at all levels and in all sectors, and need to be coordinated across the EU. DG Agriculture is also looking at options for management of climate change risks and tools to aid adaptation. Land use research in the 7th Framework Programme will be more locally orientated and more focused on climate change.

3.7.2 EU agricultural policy

European agricultural policy faces some serious challenges in the coming decades – even without climate change. The most striking of these are the loss of comparative advantage in relation to international growers, competition for international markets, declining rural populations, land deterioration, competition for water resources, and rising costs due to environmental protection policies. Demographic changes are altering vulnerability to water shortages and agricultural production in many areas, with potentially serious consequences at local and regional levels. Population and land-use dynamics, and the overall policies for environmental protection, agriculture, and water resource management, are the key drivers for possible adaptation options to climate change.

The 2003 reforms of the CAP were a first step towards a framework for the sustainable development of EU agriculture. The central objective of the reforms was to promote an agricultural sector that was competitive and responsive to the market. This was founded on the principles of high standards for the environment, the public, animal and plant health, and animal welfare. Decoupling brought about greater market responsiveness, whereas higher standards were achieved through cross compliance.

The future direction of the CAP is likely to build on the 2003 reforms, with a continued shift from market intervention and further decoupling. Notably, the production of key commodities, including sugar, tobacco, olive oil, and fruit and vegetables, have been reformed since 2003, and negotiations between Member States on reform of the wine sector are underway.

To minimize the negative impacts of climate change on European agriculture, and to take advantage of the potential benefits, adaptation efforts will need to be introduced at all levels and may need to be coordinated across the EU. Changes at the level of an individual farmer, relating to tillage practice, cultivar variety, planting date and the use of external inputs have been widely studied and demonstrate that adaptation to climate impacts can occur autonomously to some degree with little or no external support (Easterling *et al.*, 2003). However, farm businesses are unlikely to be able to adapt to the extent, speed and severity of impacts of anticipated changing climatic patterns and extreme events, leaving European agriculture increasingly unstable and vulnerable. The issue is even more pertinent where ‘at risk’ regions and farm businesses are already economically marginal or at the edge of climate tolerance. Here overall rules for farm support, Rural Development policy and crisis management will play important roles in increasing agriculture’s resilience to climate change impacts.

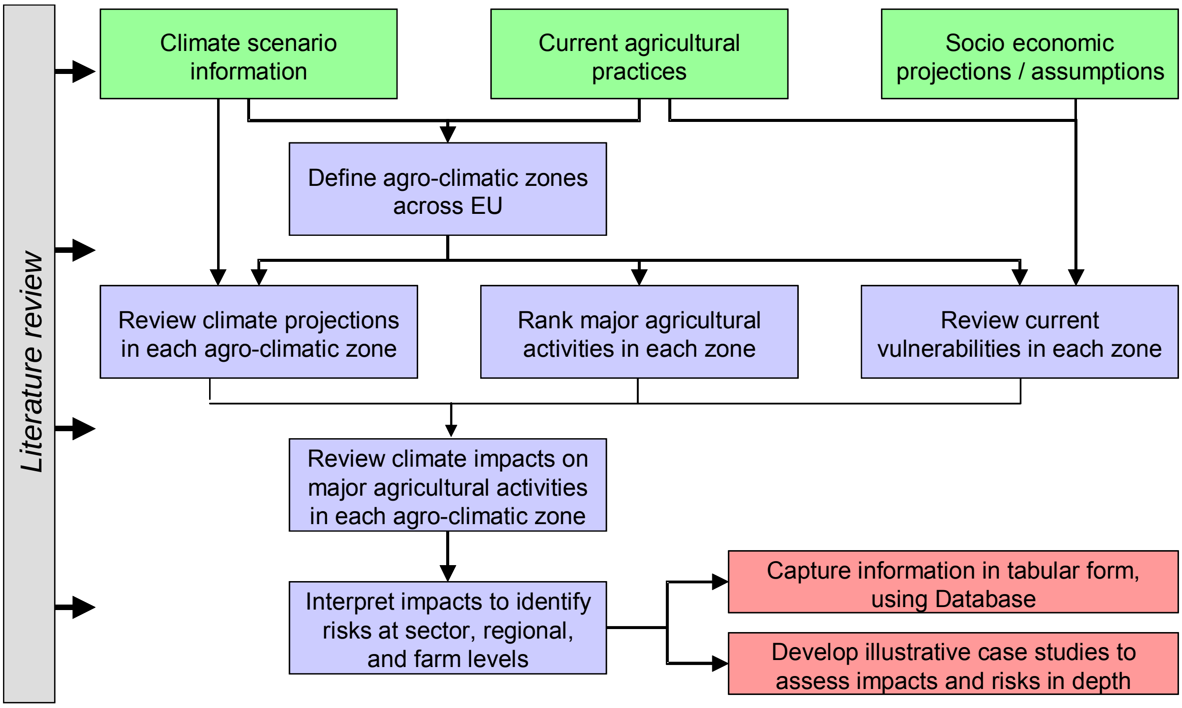
4 Methodology

This chapter defines the methodologies used to determine and categorise climate impacts covered in the literature, as well as the risks and opportunities arising from those impacts. The chapter then reports on the methods for evaluating adaptation measures and CAP measures that could facilitate adaptation.

4.1 Evaluating the potential impacts, risks and opportunities

This section describes the methods used for the evaluation of the potential impacts, risk and opportunities of climate change on agricultural systems and agro-climatic regions in Europe. Firstly, the climatic impacts are determined based on an extensive literature review. The existing sources of information are categorised according to the main determinants of climate change impacts and considering the methodological various approaches of the evaluations. The second step is to evaluate the risks and opportunities based on the projected impacts. The overall approach includes: (a) establishing priorities; (b) assessing the magnitude of risks and opportunities; and (c) estimating priorities. Figure 8 summarises the methodological approach.

Figure 8 Flow chart illustrating the elements involved in the assessment of the impacts of climate change



4.1.1 Sources of information for the assessment of potential impacts

The focus of the assessment is a review of the available literature covering climate change projections, agricultural modelling and impacts assessments, and other material relevant to understanding European agriculture in the 21st century (such as socio-economic, policy and other sector drivers). Starting with the IPCC Assessment Reports, and studies referenced therein, we have included other relevant policy and academic studies that touch on climate change impacts on European agriculture, including global studies, where appropriate, and work carried out at national and regional level in the EU. We have defined the climate scenarios in Europe (Peseta scenarios built from Prudence) and evaluated literature, particularly from the IPCC, EEA, Global projects (OECD, World Bank, FACE, etc), EU projects (Prudence, Peseta, Ateam, Ensembles, Circle, etc) and national initiatives (UK, DK, ES, etc).

271 relevant studies, published since 1995, were selected. The study analysed the impacts categorising the data in main groups according to key issues, risks and regions (Table 6). In each case, the study defines descriptive and quality criteria to categorise the results of the data analysed. These criteria include expected direction of change, potential impacts on agricultural production and food security, and the uncertainty level of the potential impact.

Table 6 Summary of the classification of the references used for the assessment of impacts

Category	Focus of the evaluation	Main factors included in the analysis	Number of scientific studies included in the assessment of impacts
Climate change and related variables relevant to agricultural production	Key issues	Atmospheric CO2 Atmospheric O3 Sea level rise Extreme events Precipitation intensity Temperature Heat stress	35 studies published in scientific journals, 4 reports of the EEA, IPCC
Effects of climate changes on main agricultural determinants	Risks	Water resources Irrigation requirements Forest productivity Forest wild fires activity Changes in agricultural pests and diseases Biodiversity loss Changes in soil fertility, salinity and erosion Changes in crop productivity Changes in crop growth conditions Changes in optimal conditions for livestock production Land use Changes in crop distribution Increased expenditure in emergency and remediation actions	35 studies published in scientific journals, 4 reports of the EEA, IPCC
Climate change impacts on agricultural regions in Europe	Regions	Alpine Atlantic Boreal Continental Mediterranean Europe-wide	35 studies published in scientific journals, 4 reports of the EEA, IPCC

It is important to note that the data used for the impact and risk analysis were obtained from a very broad range of studies developed using different methods. This broad analysis aims to decrease the uncertainty level of the results that arise from the different methods used. Nevertheless, in some cases it may be difficult to establish commonality across the studies in a particular region. Therefore this study considers data that may be contradictory.

A summary of the methods used to analyse the impacts in order to interpret the results can be seen below (Table 7). Each of these different methods yield information on different types of impacts. For example, simple agro-climatic indices can be used to analyse large-area shifts of cropping zones, whereas process-based crop growth models should be used to analyse changes in crop yields. Effects on income, livelihoods, and employment are assessed using economic and social forms of analysis.

Table 7 Approaches to derive impacts data in agriculture

Type of model	Description and use	Strengths	Weaknesses
Agro-climatic indices and GIS	Based on combinations of climate variables important for crops. Used in many agricultural planning studies. Useful for general audiences.	Simple calculation. Effective for comparing across regions or crops.	Climate based only, lacks management responses or consideration of CO2 fertilization.
Statistical models and yield functions	Based on the empirical relationship between observed climate and crop responses. Used in yield prediction for famine early warning and commodity markets.	Present-day crop and climatic variations are well described.	Do not explain causal mechanisms. May not capture future climate crop relationships or CO2 fertilization.
Process-based crop models	Calculate crop responses to factors that affect growth and yield (i.e., climate, soils, and management). Used by many agricultural scientists for research and development.	Process based, widely calibrated, and validated. Useful for testing a broad range of adaptations. Test mitigation and adaptation strategies simultaneously. Available for most major crops.	Requires detailed weather and management data for best results.
Economic tools	Calculate land values, commodity prices, and economic outcomes for farmers and consumers based on crop production data.	Useful for incorporating financial considerations and market-based adaptations.	Not all social systems, households, and individuals appropriately represented. Climate-induced alterations in availability of land and water not always taken into account. Focus on profit and utility-maximizing behaviour. Models are complex and require a lot of data.
Household and village models	Description of coping strategies for current conditions by household and village as the unit of response.	Useful in semi-commercial economies.	Not able to generalise; Do not capture future climate stresses if different from current.

4.1.2 Evaluation of risks and opportunities

Establishing priorities

Climate change will have many impacts on agriculture and this will lead to many risks and opportunities, of varying significance. By prioritising climate change risks and opportunities, we identify those that need addressing most urgently and provide a rationale for focusing the adaptation assessment on key issues.

Opportunities for farmers may also arise as a consequence of climate change. While climate change is often perceived as having negative consequences, there may be regions where increased average temperatures have the potential to increase the yield of current crops, the area over which those crops may be grown, or allow the cultivation of new crops. All of which could increase farm incomes. Hence, in some parts of the EU, farmers may benefit if they have access to capital or knowledge that will enable them to adapt their farming practices to take advantages of these potential opportunities. Moreover, such opportunities will not always take care of themselves – often they will need supporting action to translate into benefits, just as risks need action to mitigate their potential effects.

For the most vulnerable farming communities in Europe, the realisation of any opportunities that might arise could be critical to their economic survival. For this reason, we consider both risks and opportunities.

The prioritisation of climate change related risks and opportunities was carried out in a three-stage process which is described below. To begin, the risks and opportunities for the agricultural sector were categorised (Table 6) and agro-climatic zones described as in Annex B.

Assessing the magnitude of risks and opportunities

Secondly, a semi-quantitative approach was used to assess the magnitude and likelihood of risks and opportunities. The scores given are on a scale of high, medium or low.

The **magnitude** scores reflect the importance of the risk/opportunity across the whole agro-climatic zone, rather than risk/opportunity at the farm scale. The criteria used for assessing magnitude was the overall importance and structure of the agricultural sector taken from the size of area of farming type (field crops, grazing livestock, horticulture, permanent crops) to which the risk or opportunity relates in the agro-climatic zone in question (see Table 6 in Section 2.8 which gives the three most important farming systems in each agro-climatic zone by reporting the proportion of total land area in each agro-climatic zone (for the EU-27) that is occupied by those main farming systems. Thus a risk for type that is ranked “1” in an agro-climatic zone is scored “high”, whereas an opportunity for a type that is ranked “3” or less is scored “low”.

We have not factored the timing of the risks into the assessment of their magnitude as many of the identified risks may only have a significant impact in the distant future, such as the latter part of the current century. However, such risks should not be neglected. The Stern Review (2006) pointed to the need to take action now on future risks, in order to make future risk avoidance more affordable and to minimise the damage of climate impacts to society. For example, if decisions being made now, or in the near future, on agricultural infrastructure, (such as roads or buildings that have a life expectancy of 50 years or more), fail to take into account the adverse impacts of climate change, the results could be very costly in the long term. The timescale of impacts will be considered in the assessment of adaptation measures.

The **likelihood** (probability) of risks and opportunities were assessed using estimates of certainty of impacts provided in the literature (reported in Annex C). These vary in their comprehensiveness. In some circumstances, we have an estimate of certainty for the impact of climate change on farming activities; in other cases, we only have an uncertainty score for the general effects of climate change on a sector. We have used published information where possible.

The results of the risk/opportunity analysis are presented by agro-climatic zone as shown by Table 8.

Table 8 Example tabulation of risks and opportunities

Mediterranean South zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Risk 1 ...	LOW	MEDIUM	LOW
	Risk 2 ...	HIGH	LOW	MEDIUM
	Risk 3 ...	MEDIUM	HIGH	HIGH
Opportunity	Opportunity 1 ...	MEDIUM	MEDIUM	MEDIUM
	Opportunity 2 ...	LOW	LOW	LOW

In these estimates, the magnitude is derived from the area of farming practice within the agro-climatic zone as reported for the EU-27. This is a quantitative estimate, although for zones that lie partly outside the EU the magnitude will only reflect the importance of the farm type to EU countries. Likelihood is derived from the literature review.

Estimating priority

Thirdly, the risks/opportunities were prioritised from the weightings given to magnitude and likelihood. The prioritisation scoring we have used is described in Table 9.

Table 9 Deriving prioritisation scores from magnitude and likelihood

HIGH	MEDIUM	HIGH	HIGH
MEDIUM	LOW	MEDIUM	HIGH
LOW	LOW	LOW	MEDIUM
^ Magnitude Likelihood >	LOW	MEDIUM	HIGH

Limitations of the prioritisation methodology

The somewhat arbitrary nature of this scoring and weighting system is acknowledged. Due to uncertainties and inconsistencies in the model predictions and associated impacts, there is an unavoidable element of subjectivity in the process of prioritising potential risks and opportunities and in attempting to discriminate these risks between the agro-climatic zones, particularly given the incompleteness of the data. However, by basing the method upon reported crop areas, and using assessments of risk published in peer-reviewed literature, the method is both an informative and valid way of producing a preliminary assessment of agricultural risks/opportunities across the agro-climatic zones. In addition to giving some direction for the identification of adaptation measures, it also provides a means of highlighting the issues that need more detailed economic research.

The A2 and B2 socio-economic scenarios provide very limited information on the future socio-economic characteristics. Our assessment of risks takes account of the data provided for these scenarios. However, the scenarios do not consider technological change. The assumption that the current technological context will be valid in the future is clearly flawed. For example, air quality will be affected by a changing climate over the coming decades and could suffer. However, in the past, regulatory and technological changes have dwarfed the effects that climate change has had on air quality.

Inevitably therefore, some of the risks and opportunities listed here may become irrelevant in the future, and others not listed here will come into play. Even with extensive scenario planning, it is difficult to develop an evolving technological context that is sufficiently detailed for identification of specific climate change related risks/opportunities for agriculture, or indeed, for any sector.

Another drawback of focusing on climate change related risks alone is that we lose sight of the overall context in which agriculture will develop in the future. This may lead to overestimating the importance of climate change impacts when they are considered in isolation from, for example, issues relating to the CAP. Agriculture and rural areas may face many challenges in the future (such as further trade liberalisation, decline of population, maintenance of the economic fabric of rural areas) and climate change will make these challenges more difficult and costly.

The analysis does provide some indication of the overall projected impact of climate change on farmers across agro-climatic zones. It does not, however, provide a means for identifying the risks/opportunities that affect the most vulnerable farmers. In many cases, the literature that was reviewed did not provide enough information on vulnerable groups for a breakdown at this level to be possible. However, when the potential adaptations measures are considered, a range of practical, farm level adaptations will be identified that can help the vulnerable farming systems and sub-sectors deal with climate change impacts.

4.2 Evaluating the adaptation measures

The methodology for identifying and evaluating adaptation measures comprises three main components,

- Identify adaptation options
- Review national adaptation frameworks
- Consult stakeholders

4.2.1 Identification of adaptation measures

The aim of this part of the report is to characterise cost-effective and proportionate adaptation measures that are achievable and will make a real difference at farm level. The objective is to propose potential adaptation measures for each of the risks and opportunities identified in the assessment of risks and opportunities. This uses information provided by:

- Papers published in refereed journals and other reports
- The EC's report on 'Adaptation approaches, strategies, practices and technologies in the EU' for the UNFCCC Nairobi Work Programme on Adaptation (SBSTA, 2007)
- For some of the identified risks and opportunities, particularly in the case of opportunities, adaptation measures had not been proposed in the literature. In such cases, expert judgement was used to make proposals. Where this is so, the proposed measures are clearly indicated.

For the priority risks identified at sector and farm level in the assessment of impacts of climate change, a number of possible adaptation responses (at both sector/policy level and farm level) were reviewed with respect to the following issues:

- Technical feasibility
- Potential cost of implementation
- Cost effectiveness
- Additional benefits
- Cross-sectoral implications (e.g. for water, tourism, energy)

Additionally, the nature of the possible adaptation measures are described in three categories:

- Technical (e.g. introduction of new cultivars)
- Management (e.g. changes in cropping patterns)
- Infrastructural (e.g. changes in drainage)

4.2.2 Review of National adaptation frameworks

The characterisation of the adaptation frameworks was complemented by a review of the ongoing development of national adaptation strategies. Work is ongoing across the EU-27 to prepare national adaptation strategies, with most being in the early stages of development and a few completed.

The source of information analysed is from the report of the Subsidiary Body for Scientific and Technological Advice (SBSTA) on its twenty-fifth session, held at Nairobi from 6 to 14 November 2006. Only strategies and programmes of relevance to the agriculture sector have been cited in this report. Examples can be found in Annex E.

4.2.3 Stakeholder consultation by questionnaire

The aims of the questionnaire are:
- To collect information on existing and planned adaptive measures in the EU-27 relating to agriculture,
- To fill key knowledge gaps, particularly relating to improving adaptation facilitation in the CAP.

The role of the stakeholder consultation is detailed in Box 2 below.

Box 2 The role of Stakeholder consultation

A questionnaire was prepared for experts in all EU Member States to assess the extent to which the need for adaptation has been recognised and adaptation strategies devised and implemented. There is a large amount of information and knowledge already available on coping with climatic variability and climate change. Nevertheless there is presently no comprehensive overview available for all member states. This questionnaire was intended to complement the extensive consultation activities that have occurred during 2006 as part of the European Climate Change Programme Phase 2 (ECCP2).

The ECCP2 report concluded that most of the existing adaptation measures focus on flood defence, originated by the significant losses suffered from extreme weather events in recent years (e.g. 2002 floods and 2003 heat wave). Adaptation measures are either planned or taking place in the context of natural hazard prevention, environmental protection and sustainable resource management, which are also beneficial for adapting to climatic change. These measures are generally aimed more at reducing vulnerability to current climate variability, than at preventing the potentially more extreme weather conditions projected to take place in the future.

Implementation of long-term planned proactive adaptation measures and policies is still to be performed by most European countries. Furthermore some features such as the roles and responsibilities of the stakeholders in the adaptation process and the implications of non-climatic variables have not been fully developed or considered in most of the studies or initiatives undertaken to date, in spite of the common acknowledgment of their importance.

The Questionnaire has four sections:

- Section I: identifies the respondent so as to enable classification of the responses by stakeholder group and interest, especially with relation to the CAP (Questions 1 to 20);
- Section II: identifies potential adaptation measures (Questions 20 to 47);
- Section III: identifies further potential policy adaptations including any changes to the CAP (Questions 48 to 57);
- Section IV: provides the respondent with an opportunity to identify any additional adaptation options that were not included in the questionnaire (Question 58).

The questionnaire was designed in discussion with the Steering Group. The full text of the questionnaire is presented in Annex F.

Information from the questionnaire on national adaptation strategies has been used to identify any further possible adaptation measures in each agro-climatic zone, and where possible, to provide a qualitative ranking of preferred adaptation options within each zone.

The questionnaire was distributed as a web-based survey. This offered a number of advantages, including flexibility for the consultee to respond whenever convenient and the ability to link responses directly into a database (minimising data processing time). The web-based questionnaire format allowed a combination of multiple-choice and free comment questions and a mixture of compulsory and optional parts (so that the survey is automatically tailored to the individual consultee). The link to the questionnaire was sent in an explanatory email to the list of member state contacts. These contacts were identified by AEA and UPM and agreed with the Steering Group. Consultees were given a deadline by when they should respond, the responses were monitored and an email reminder sent out as appropriate.

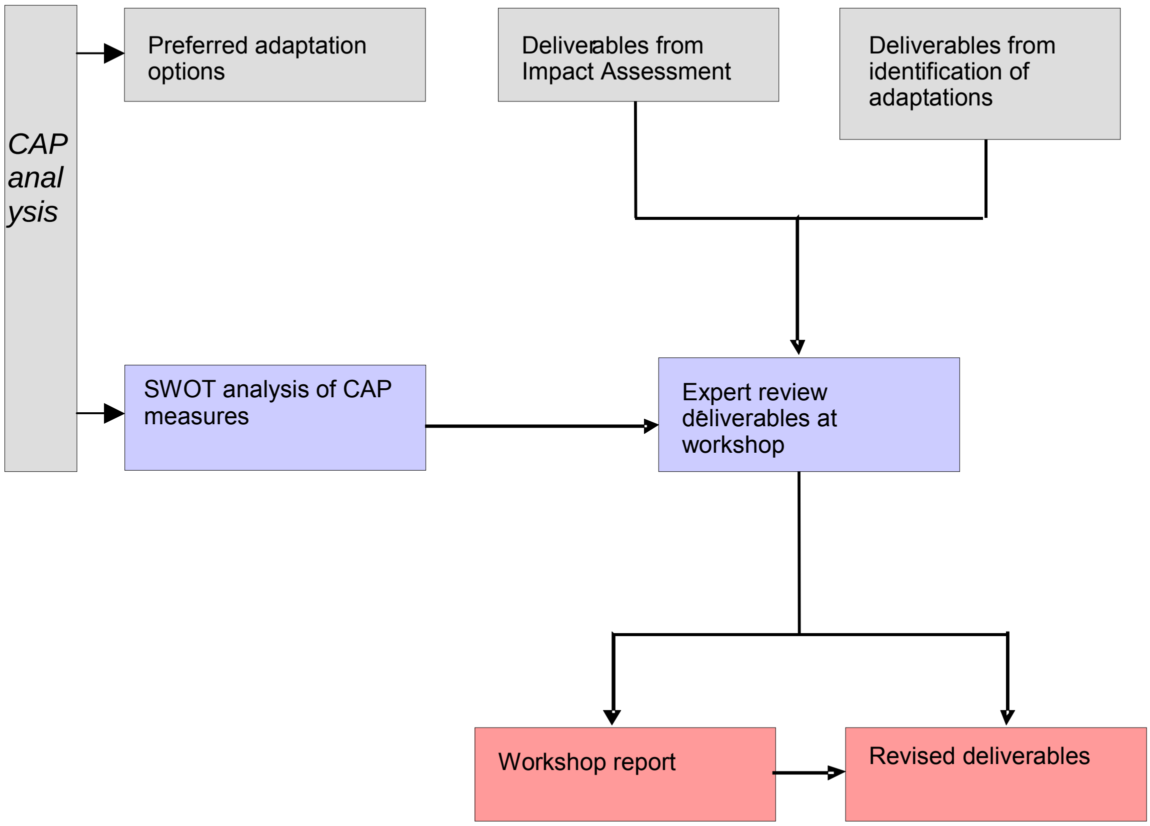
In section 6.9 we summarize the responses to the questionnaire and evaluate the extent to which priorities and potential measures identified in the assessment of impacts have been adopted or considered by member states.

4.3 Evaluating the CAP measures towards adaptation

The aim here is to provide an analysis of the potential contribution and constraints of the CAP (Figure 9), and to identify policy measures that can support farmers and rural communities to tackle and facilitate adaptation to climate change.

Based on the adaptive options discussed in Chapter 6, a SWOT (Strengths/Weaknesses, Opportunities/Threats) analysis was carried out on the CAP instruments covering both direct income support payments and rural development measures. Consideration of related legislation was also included where appropriate and the measures were grouped according to the type of adaptation option they would best support – management, infrastructure or technical.

Figure 9 Flow chart illustrating elements involved in the review of CAP



This initial analysis was then cross-referenced with the responses to the questionnaire so as to establish any correlations between the SWOT analysis and stakeholder experience. In some of the responses, it is difficult to understand the responder's motivation, as some information may have been lost in translation.

Both the SWOT analysis and the questionnaire's answers were then used for the basis of discussion at the expert workshop held in DG Agriculture in Brussels on the 4th October 2007.

4.4 Public review of the results

10 invited agriculture policy experts representing a cross-section of agro-climatic zones across the EU attended the workshop, in addition to members of the Project Team (AEA and UPM) and Steering Group (EC). The experts discussed and validated the conclusions and recommendations of the analysis of the impacts and risks, the assessment of adaptive measures, and the options for integration of adaptation measures into the CAP.

To ensure that the workshop was effectively organized and attended, the Project Team and Steering Group agreed in advance:

- the workshop objectives;
- a list of potential policy experts for invitation to the event;
- a detailed agenda, including presentations and mechanisms for input and feedback from the invited experts and;
- the content of briefing materials to be sent to delegates prior to the event.

The agenda, list of experts who attended and the minutes from the workshop can be found in Annex J.

5 Potential climate change impacts, risks and opportunities for EU agriculture

The results of the impacts assessment is structured in thee different ways to provide insights on the:

- Impacts of climate change on key variables relevant to agricultural production (Section 5.1);
- Impacts of climate change on factors that determine agricultural output (risks) (Section 5.2)
- Impacts of climate change on agricultural regions in Europe (Section 5.3)

The analysis incorporates an assessment of the sources of uncertainty (Section 5.4) or degree of confidence. The confidence level is defined as the "Degree of confidence in being correct" as derived from the agreement reported in studies of a specific impact. Here we simplify the IPCC degree of confidence scale to three levels:

- High confidence represents more than 8 out of 10 studies in agreement;
- Medium confidence represents 5 to 7 out of 10 studies in agreement and;
- Low confidence represents 1 to 4 out of 10 studies in agreement.

Finally, the chapter includes a summary overview of the impacts, risks and opportunities and their adaptation challenges, and the on-going adaptation options at the regional and national level with a territorial perspective (Section 5.5).

5.1 Impacts of key climate variables

This section outlines the direct climate changes that are relevant to agriculture, which are elaborated in Table 10.
These include:

- changes in precipitation amounts, intensity and seasonal distribution;
- changes in temperature, and the effects of heat stress;
- an increase in extreme and potentially damaging weather events;
- sea level rise and;
- changes in atmospheric CO_2 and atmospheric ozone (O_3) concentrations.

Table 10 Climate change and related factors relevant to agricultural production at the global scale (see Annex D for information sources)

Climate factor	Expected direction of change	Potential impacts on agricultural production and food security	Confidence level of the potential impact
Atmospheric CO_2	Increase	Increased biomass production and increased potential efficiency of physiological water use in crops and weeds. Modified hydrologic balance of soils due to C/N ratio modification. Changed weed ecology with potential for increased weed competition with crops.	Medium
		Agro-ecosystems modification.	High
		N cycle modification.	High
		Lower yield increase than expected.	Low
Atmospheric Ozone	Increase	Crop yield decrease.	Low
Sea level rise	Increase	Sea level intrusion in coastal agricultural areas and salinisation of water supply.	High
Extreme events	Poorly known, but significant	Crop failure. Yield decrease.	High

	increased temporal and spatial variability expected Increased frequency of floods and droughts	Competition for water.	
Precipitation intensity	Intensified hydrological cycle, but with regional variations	Changed patterns of erosion and accretion. Changed storm impacts. Changed occurrence of storm flooding and storm damage. Increased water logging. Increased pest damage.	High
Temperature	Increase	Modifications in crop suitability and productivity. Changes in weeds, crop pests and diseases. Changes in water requirements. Changes in crop quality.	High
	Differences in day-night temp	Modifications in crop productivity and quality.	Medium
Heat stress	Increases in heat waves	Damage to grain formation, increase in some pests.	High

Source: own elaboration

5.2 Impacts on agricultural determinants

This section analyses the main risks to agricultural production imposed by climate change. These include risks resulting from changes in:

- water resources and irrigation requirements;
- agricultural pests and diseases;
- soil fertility, salinity and erosion;
- crop growth conditions, crop productivity and in crop distribution;
- optimal conditions for livestock production;
- land use; and,
- increased expenditure in emergency and remediation actions.

The information is summarized in Table 11 with the information sources listed in Annex D.

Table 11 Effects of climate changes on main agricultural determinants and expected consequences for agro-ecosystems and rural areas.

Main agricultural determinant	Expected intensity of negative effects	Potential consequences for agro-ecosystems and rural areas	Confidence level of the potential agricultural impact
Water resources	Changes in hydrological regime. Differences in water needs. Increased water shortages.	Variations in hydrological regime. Decreased availability of water. Risks of water quality loss. Increased risk of soil salinisation. Conflicts among users.	High
		Groundwater abstraction, depletion and decrease in water quality.	High
Irrigation requirements	High in areas already vulnerable to water scarcity	Increased demand for irrigation Decreased yield of crops	High
Changes in	Changes in	Reduced water quality from increased	Medium

Main agricultural determinant	Expected intensity of negative effects	Potential consequences for agro-ecosystems and rural areas	Confidence level of the potential agricultural impact
agricultural pests and diseases	distribution, introduction of new varieties.	use of pesticides. Decreased yield and quality of crops. Increased economic risk. Loss of rural income.	
Changes in soil fertility, salinity and erosion	High for southern countries.	Decrease in water quality from nutrient leaching. Decreased crop yields. Land abandonment. Increased risk of desertification. Loss of rural income.	High
Changes in crop productivity	Imbalances between regions.	Decreased food security in areas with low economic development. Increased world food prices. Increased agricultural trade.	High
Changes in crop growth conditions	High for some crops and regions.	Pollution by nutrient leaching. Loss of indigenous crop varieties. Seed production and seedling recruitment.	High
Changes in optimal conditions for livestock production	Medium	Changes in optimal farming systems. Loss of rural income.	Low
Land use	Depends on region.	Shift in optimal conditions for farming. Deterioration of soils. Loss of rural income. Loss of cultural heritage. Land abandonment. Increased risk of desertification.	High
Changes in crop distribution	High for areas where current optimal farming systems are extensive.	Changes in crop and livestock production activities. Relocation of farm processing industry. Loss of rural income. Economic imbalances. Increased economic risk.	Medium
Increased expenditure in emergency and remediation actions	High for regions with low adaptation capacity.	Loss of rural income. Economic imbalances.	Medium
Biodiversity loss	High for vulnerable regions	Loss of natural adaptation options Modified interaction among species	Medium

5.2.1 Water resource and irrigation requirements

Changes in hydrological regimes will impact the use and distribution of water within agriculture. Decreased availability of water may lead to insufficient water being available for irrigation resulting in crops suffering moisture stress.

For crop production, a change in the seasonality of precipitation may be even more important than a change in the annual total. The water regime of crops is vulnerable to a rise in the rate and seasonal pattern of evapotranspiration, brought on by warmer temperatures, drier air, or windier conditions. Inter-annual variability of precipitation is a major cause of variation in crop yields and yield quality.

Crop yields are most likely to suffer if dry periods occur during critical developmental stages. In most grain crops, flowering, pollination, and grain-filling are especially sensitive to water stress.

By reducing vegetative cover, droughts exacerbate wind and water erosion, thus affecting future crop productivity. Increasing demand for water is likely to lead to increased groundwater abstraction and thus depletion of those resources. The likelihood of these risks occurring is reported as high.

Excessively wet years may also cause yield declines due to waterlogging and increased pest infestations. High soil moisture in humid areas can also hinder field operations. Intense bursts of rainfall may damage younger plants and promote lodging of standing crops with ripening grain.

5.2.2 Water quality, soil fertility, salinity and erosion

Lower levels of winter rainfall will mean that various leachates are not adequately diluted, leading to decreased water quality. Other climate-induced changes in crop growth, such as reduced yields and associated extra fertilizer and manure loading, will exacerbate the problem of water quality.

Increased salinity, as a result of drought or seal level rise, may lead to land becoming unsuitable for cropping and being abandoned. In extreme cases this may lead to desertification. The risk of these problems occurring is reported to be high.

Soil degradation is a major threat to the sustainability of Europe's land resources and may impair the ability of European agriculture to adapt successfully to climate change. European soils are currently experiencing a range of conservation problems, including high erosion rates (and erosion-derived agro-chemical pollution of waterways), declines in soil organic matter and vulnerability of soil organic carbon pools. These are linked to site factors and changing land management practices and are being exacerbated by climate change and the increasing incidence of extreme weather events.

Increased intensity of precipitation is likely to change patterns of erosion and accretion, increase the occurrence of storm flooding and storm damage and lead to greater incidences of waterlogging.

Soil erosion is a well-documented concern in southern Europe, usually exemplified by rills and gullies. However, high rates of soil loss through sheet erosion are now becoming more commonplace in northern Europe.

Reductions in soil organic matter are associated with decreases in mixed farming, in particular a reduction in grass leys and a separation of livestock production from arable farming. The addition of organic matter to improve soil properties continues to be the basis of much traditional and organic farming across Europe. Land use planning (e.g. set-aside policies, afforestation-reforestation), management practices (e.g. nitrogen fertilisation, irrigation, tillage) and the responses of plants to elevated CO_2 levels critically affect soil organic matter content.

5.2.3 Crop growth conditions, crop productivity and crop distribution

In some regions a positive relationship between temperature and crop yield is forecast with increased wheat and grass yields resulting from higher temperatures and increased CO_2 concentrations.

Greater concentrations of CO_2 in the atmosphere have the potential to increase biomass production and to increase the physiological efficiency of water use in crops and weeds. However, increases in CO_2 do not produce proportional increases in crop productivity; other factors play a significant role. While experiments with increased concentrations of CO_2 under controlled conditions have been shown to significantly increase yields of crops, these increases have occurred when other factors such as moisture supply, nutrients and pest and disease incidence have not been limiting. In practice, an insufficient supply of water or nutrients or greater pest/disease attack or competition from weeds is expected to frequently negate the fertilizing impact of increased CO_2 concentrations in the atmosphere. Since weed growth may also be enhanced by increased $CO_{2,}$ a changed weed ecology may emerge with the potential to increase weed competition with crops

Increased concentrations of tropospheric ozone will be expected to reduce crop yields. Ozone enters plant leaves through the stomatal openings in the leaf surface where it produces by-products that reduce the efficiency of photosynthesis.

When the optimum temperature range for a crop is exceeded, plant growth tends to be reduced. The optimum temperature varies between species, yet most crops are sensitive to episodes of high temperature. Air temperatures between 45 and 55°C that continue for at least 30 minutes damage crop leaves in most environments; even lower temperatures (35 to 40°C) can be damaging if they persist. The vulnerability of crops to temperature damage varies with developmental stage. High temperatures during reproductive development are particularly injurious – for example, to corn at tasseling, to soybean at flowering, and to wheat at grain-filling. Soybean is one crop that seems to be able to recover from heat stress.

Heat stress and drought stress often occur simultaneously, with one contributing to the other. They are often accompanied by high solar irradiance and high winds. When crops are subjected to drought stress, their stomata close. Such closure reduces transpiration and, consequently, raises plant temperatures.

The delineation of agro-climatic regions is likely to change. There may be losses of indigenous crop varieties, in particular traditional top and soft fruit varieties. The risks associated with these problems are considered high for some crops and regions. Episodes of high relative humidity, frost, and hail can also affect yield and quality of fruit and vegetables.

5.2.4 Livestock production

A warmer and drier climate may reduce forage production leading to changes in optimal farming systems and a loss of rural income in areas dependent on grazing agriculture. In some northern areas, a warmer climate and therefore extended growing season, has the potential to increase forage production. However, such areas are also forecast to have increased winter rainfall and so it may be difficult to fully utilise the increased potential. In other parts of Europe, new crops such as soya could be grown to produce livestock feed. However, a switch away from grazed forages and increasing heat stress, both leading to an increased requirement for livestock housing, will increase costs and, by increasing manure production, may lead to a decrease in water quality if manure spreading leads to contamination. However, the risk associated with these problems is regarded as low.

5.2.5 Land use

A shift in the location of optimal conditions for specific crop or livestock production systems may lead to a loss of rural income and soil deterioration in the areas where those modes of production can no longer be maintained. Such losses of established farming practices may lead to a loss of cultural heritage, land abandonment and increased risk of desertification. There is a high risk of these problems occurring during the 21st century.

Rising sea levels may also lead to significant land use changes. An indirect effect on agriculture may occur if rising sea levels make population centres uninhabitable. The displaced populations will need to be housed and at least some of the housing is likely to be built on agricultural land.

5.2.6 Agricultural pests and diseases

Crop yield and quality may decrease, risking loss of rural income due to the incidence of new, or more intense problems of pests and disease. Actions taken to mitigate these risks may lead to a decrease in water quality from increased use of pesticides. The risk of these problems has been assessed as medium.

5.2.7 Expenditure in emergency and remediation actions

The need for increased spending as a result of damage caused by extreme weather events will lead to a loss of rural income and economic imbalances between the more and less prosperous parts of Europe, especially since insurance cover tends to increase with higher income. The risk of this is regarded as high for regions with low adaptive capacity, but medium for other regions of Europe.

5.2.8 Consequences of agricultural changes for biodiversity

Climate change is likely to lead to changes in the distribution of species. The great speed at which climate is forecast to change is likely to lead to a loss of natural adaptation options and a loss of diversity, especially in Mediterranean species. Changes in land use due to climate change may lead to ecosystem disturbances and fragmented populations. These risks are regarded as medium.

5.3 Territorial climate impacts

This section summarizes the projected impact of climate change in the main European agro-climatic areas (Table 12) based on state-of-the art knowledge. A detailed regional analysis of the risks and opportunities for the farming sector arising from these expected impacts in each area is presented in the following section.

Table 12 Agro-climatic zones in Europe

Agroclimatic zone	Countries or areas of the countries within the region
Boreal	Norway, northern Sweden, Finland, Latvia, Estonia
Atlantic North	Scotland and Ireland
Atlantic Central	England and Wales, The Netherlands, Belgium, Luxemburg, northern France, western Germany, Denmark and southern Sweden
Atlantic South	Portugal, north-west Spain, western France
Continental North	Eastern Germany, Poland, Lithuania, Belarus, Czech republic, Slovakia, northern Ukraine and eastern Austria
Continental South	Hungary, Serbia, Romania, Moldova, FYROM, southern Ukraine and north-eastern Turkey
Alpine	Switzerland, western Austria, Slovenia
Mediterranean North	Northern Spain, southern France, Corsica, northern Italy, Croatia, Bulgaria, the Macedonian region of Greece, north-western Turkey
Mediterranean South	Southern Spain, Sardinia, southern Italy, Albania, Greece (except Macedonia), south-western Turkey

Source: own elaboration

5.3.1 Boreal

Important changes in temperature and precipitation are expected. Temperature will increase considerably in these northern latitudes, especially in Finland, with very significant increases in yearly precipitation. Winters are projected to be much wetter increasing the risks of winter floods and flash floods. Intense precipitation and severe storms are also expected to become more frequent. There will be potential for cultivating new areas and crops due to much longer growing seasons. Yields could increase by 40%, under limited warming but agriculture could suffer from new pests and diseases. The warmer climate could aggravate the problems of water quality in the Baltic Sea. Permafrost changes due to warming will also be of particular concern for soils.

5.3.2 Atlantic North

Temperature increases by 2080 are expected to be moderate at 1.5 - 2.5 °C, while total annual rainfall is expected to decrease slightly in the summer, but with an increased risk of flooding in winter (Reynard *et al.,* 2001). There will be potential for increasing yields of forage crops due to longer growing seasons and for increasing the area sown to barley and potatoes (Holden *et al.,* 2003). Impacts on crop yields due to warming may vary according to crop type but new pests and diseases may be introduced.

5.3.3 Atlantic Central

Temperature increases of 2.5 to 4 °C are forecast. Precipitation is expected to decrease in total, but with increased proportion of rainfall falling over winter. This greater intensity of winter precipitation and warmer temperatures are expected to increase the frequency of storms and flooding, especially as in this zone there are the confluences of several large rivers. Summers are projected to become dryer and hotter. The longer growing season is forecast to increase yields of wheat. There is also likely to be an increase in the northern range over which crops such as soya and sunflowers may be grown. The greatest problem to be faced by agriculture in this zone may be rising sea level which may affect 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. Reduced water resources during summer may lead to conflicting demands between agriculture and other users.

5.3.4 Atlantic South

Temperature increases of 3 to 4 °C are forecast, while yearly rainfall is expected to decrease, especially in the southern part of the zone. Water resources may be a problem leading to conflict with other users. A greater risk of forest fires has been identified in this area, and this may have impacts on adjacent areas of permanent crops. Despite the decrease on total water availability, winter flooding is predicted to increase (De Cunha *et al.,* 2002). Crop yields are predicted to decrease by c. 14%.

5.3.5 Continental North

Annual mean temperature increases are forecast to be in the order of 3 to 4 °C. Total annual rainfall is expected to increase, with precipitation increases in the winter while reduction in summer could occur in several areas. The increased rainfall is predicted to lead to a greater number of intense rainfall events and to increase the risk of flooding, which may be particularly severe as this area has large areas of low-lying land vulnerable to flooding from rivers. A warmer climate may lead to an increase in the northern range over which crops such as soya, sunflowers may be grown and potential increases in yield from the longer growing season.

5.3.6 Continental South

Significant temperature increases of 3 to 5 °C are forecast, while total annual rainfall is expected to decrease. Reduced precipitation is predicted to reduce yields of wheat and maize. However, yields of crops with a greater requirement for heat are forecast to increase. Reduced precipitation and the encroachment of agriculture are expected to lead to a reduction in the area of wetlands. Extreme weather events may increase in frequency.

5.3.7 Alpine

Increases in extreme weather events will affect vulnerable mountain areas while any intensification of the hydrological cycle is likely to increase erosion, floods, and glacier retreat. An accelerated rate of glacier retreat has been observed in the last decade. This zone is vulnerable to accelerated permafrost thaw, which may lead to destabilization of soils and landslides. Increased temperatures are forecast to decrease the depth of snow cover and reduce biodiversity. The distribution of land use will change due as the distribution of species in mountainous areas may shift upwards.

5.3.8 Mediterranean North

Decreases in crop yields up to 40% under current management conditions are forecast for much of this zone. In addition yield variability is also forecast to increase. A decrease in water availability is predicted together with an increase in water demand. Decreasing water resources in some areas may affect soil structure while reduced soil drainage may lead to increased salinity. However, an increase in frequency and intensity of floods is predicted in some areas where significant winter rainfall is likely. These changes are expected to reduce the diversity of Mediterranean species.

5.3.9 Mediterranean South

Decreases in crop yields are also forecast for this zone, together with greater yield variability. A significant reduction in water availability is predicted together with an increase in water demand, leading to potential conflict between users. Decreasing water resources are likely to damage soil structure while reduced soil drainage may lead to increased salinity. These changes are expected to reduce the diversity of Mediterranean species. Box 3 summarises the results of several impact studies in the region.

Box 3 Assessment impacts in the Mediterranean region

Source: Bindi *et al.,* 2000, 2005; Iglesias *et al.,* 2000; 2003; Salinari *et al.,* 2006; Tubiello *et al.,* 2000, 2002.

Background: Agriculture in the Mediterranean is highly subsidized. Irrigation accounts for over 60% of the total water abstraction, is used on about ten percent of the agricultural area, and gives rise to about 90% of the total value of crop production. Water resources vary greatly among basins.

Problem: The studies focus on the evaluation of the potential impact of a change in climate on the potential crop production and irrigation demand. The aims also examine the potential increase in irrigation demand in areas already vulnerable to water use conflicts.

Methods: Several methods including process-based agronomic models were used to estimate crop yields and crop water requirements at site and regional levels. Crop yield and irrigation demand functions were derived form the validated site results to evaluate spatial water demand and potential change in irrigation areas.
Each of the models used in the study was validated against local data.

Scenarios: The current baseline adopted for the socio-economic projections is 1990 and the climatic baseline, 1951-1980. Scenarios of climate change were projected for the 2050s with several global climate models driven by a range of socio-economic conditions.

Impacts: Under climate change irrigation demand is expected to increase in all southern Mediterranean regions, especially the ones with the largest current irrigation areas.

Adaptive responses: Improvements in water delivery systems are able to supply the demand for increases in irrigation supply and the projected increase in the irrigated area in the northern half of the region, but do not achieve the same results in the south-eastern part of the region.

5.3.10 Summary of the territorial impacts

Table 13 summarises the climate change impacts on the agro-climatic zones of Europe.

Table 13 Climate change impacts on agro-climatic zones in Europe[1].

Agro-climatic area	Impact described	Direction of change	Confidence level
Boreal	CO_2, O_3 increases	Reduced productivity.	Medium
	Suitability of spring wheat	Increase in crop suitability.	Medium
	Evaluation of regional yields	Positive relationship between yield and temperature.	Medium
	Permafrost thaw, forests	Destabilization of soils, landslides, negative effects on forests.	High
	Terrestrial ecosystems	Changes in population distributions, biodiversity loss.	Low
	Pest distribution changes	Increase in pest populations and distribution with increased temperature.	Medium
	Weather extremes and forests	Increased susceptibility of trees to extremes and pests.	Medium
	Glaciers response to CO_2	Glaciers retreat with increased CO2 and temperature.	Medium

[1] NOTE: Since most of the socio-economic studies explicitly include some level of adaptation, those are not included in this evaluation and will be included in the second report. Source: own elaboration

Agro-climatic area	Impact described	Direction of change	Confidence level
	Boreal forests insects	Increase in pest populations and distribution with increased temperature.	Medium
	Short rotation forestry	Decrease in productivity of short rotation forests.	Low
Atlantic	Glacier mass balance	Accelerated rate of glacier mass loss, secondary impacts on economy	High
	Barley and potato changes in cropping areas	Definition of agro-climatic regions, observed changes in distribution.	Medium
	Water resources	Decreased available water resources. Increased floods.	Medium
	Forest fires	Increased frequency and intensity.	High
	Increased wheat yield	Increased wheat yield with higher temperatures.	Medium
	Livestock conditions	Changes in health, nutrition, productivity.	High
	Changing ecosystems	Land use change, ecosystem disturbances and fragmented populations.	Medium
	Floods and land use	Increased flood frequency.	High
	Soil degradation	Soil erosion	High
Continental	Snow cover melting	Increased rate of melting	High
	Wheat and maize yield decrease	Decrease in precipitation leading to reduced yields.	Medium
	Flood frequency	Increase in frequency and intensity.	High
	Snow parameters	Glacier retreat and snow depth decrease.	High
	Wetlands/agriculture	Disappearance of wetlands, encroachment of agriculture.	Medium
	Forest structure and functions	Modification of forest structure and functions, decreased productivity.	Medium
	Hydrological regimes	Intensification of cycles, more extreme events, need for management.	High
	Crop production	Increase in crop production with increasing temperature, pests too.	High
	Wheat and soybean yield different effects	Increase in yields especially in mineral soil.	Medium
	Agriculture	Changes in crop productivity and distributions.	Medium
	Water resources	Increased frequency of extreme events.	High
	Summer flash flood frequency and intensity	Increased frequency and intensity of floods.	High
	Forestry	Increased mortality of trees.	Medium
	Mean monthly runoff	Decrease in runoff of up to 50% in mountain areas.	High
	Snow trends	Snow cover early-melting.	High
Alpine	Snow melt increase	Intensification of hydrological cycle (increased erosion, floods and glacier retreat).	High
	Extreme climate events	Increase in extreme climate events affecting vulnerable areas like mountains.	Medium
	Differences in temperature	General increase, greater differences between day and night temperatures.	Medium
	Increased speed of snow melt	Secondary effects of glacier retreat on tourism economy.	Medium
	Plant species distribution	Distribution of species in mountainous areas may shift upwards.	Medium
	Permafrost thaw	Accelerated permafrost thaw, destabilization of soils, landslides.	High

Agro-climatic area	Impact described	Direction of change	Confidence level
	Snow cover depth	Observations of decreased depth, with differences among regions.	High
	Temperature increase	Higher than average temperature increase. Decrease of snow cover depth and loss of biodiversity	High
	Glacier retreat	Accelerated rate of glacier mass loss in the last decade.	High
	Effects on biodiversity	Observed changes in the inventory of biodiversity and species distribution.	Medium
	Impacts on vegetation	Vegetation is quite stable but land use change is highly possible.	Medium
	Pastureland changes as response to temperature and CO_2	Distribution of land use will change due to changing conditions	Medium
Mediterranean	Hydrological impacts	Increase in frequency and intensity of floods.	High
	Maize yield changes	Decrease in yields.	Medium
	Grapevine yield	General increase in yields.	Medium
	Effects on cropping systems	Decrease of yields up to 40% under current management conditions.	High
	Yields and irrigation needs	General decrease in yields and increase in irrigation requirements.	Medium
	Crop yields variations		Medium
	Increased production risk	Increased variability of yields and associated risk.	Medium
	Water availability	Decrease in water availability and increase in water demand.	High
	Modifications in vegetation	Decreased productivity, changes in distribution.	Medium
	Reduced diversity of seedlings	Loss of diversity in Mediterranean species.	Medium
	Wheat cropping systems	Changes in drainage of soils leading to increased salinity.	Low
	Desertification	Water resources deficit, affected soil structure.	Medium

5.4 Sources of uncertainty of the projections

This section contains an analysis of the different sources of uncertainty of the impact data. There are various sources of uncertainty surrounding the impacts of climate change on agriculture. However, these relate more to the magnitude of projected impacts than to the direction.

Socio-economic projections

The limitations for projecting socio-economic changes not only affect the SRES scenarios but also the potential adaptive capacity of the system. For example, there will be uncertainties over future population (density, distribution, migration), gross domestic product and technology and these factors will determine and limit the potential adaptation strategies.

Climate change scenarios

Climate change scenarios are derived from GCMs driven by changes in the atmospheric composition that in turn are derived from socio-economic scenarios. In all regions expected changes result in uncertainties with respect to the magnitude of the impacts on agriculture.

For example, in some regions projections of rainfall, a key variable for crop production, may be positive or negative depending on the climate scenario used. The uncertainty derived from the climate model is related to the limitations of current models to represent all atmospheric processes and interactions of the climate system. The limitation of projecting the socio-economic development pathways is an additional source of uncertainty.

Climate variability

Regional climates naturally fluctuate about the long-term mean. For example, rainfall varies with regard to the timing and amount, affecting agriculture each year. It is clear that changes have occurred in the past and will continue to occur, and climate change modifies these variability patterns, for example resulting in more droughts and floods. Nevertheless, there are a lot of uncertainties, especially for future rainfall scenarios.

Water availability

Climate change, population dynamics, and economic development are likely to affect the future availability of water resources for agriculture in different regions. The demand for, and the supply of, water for irrigation will be influenced not only by changing hydrological regimes (through changes in precipitation, potential and actual evaporation, and runoff at the watershed and river basin scales), but by concomitant increases in future competition for water with non-agricultural users due to population and economic growth.

Effect of CO_2 on crops

The assimilation of atmospheric CO_2 by photosynthesis is required for biomass production. The opening of plant stomata is regulated by the concentration of CO_2 and therefore atmospheric CO_2 concentrations affect plant transpiration. As result, in theory, plants growing in increased CO_2 conditions will produce more biomass and consume less water. Experiments under controlled conditions confirm this effect. Nevertheless, due to the interactions of physiological processes, increases in biomass accumulation tend to be smaller than those theoretically possible. In field conditions, the increases are even smaller. Most of the crop models used for climate change evaluations include an option to simulate the effects of CO_2 increase on crop yield and water use (see Rosenzweig *et al.,* 2001). It is difficult to validate the crop model results since there are only a very limited number of these experiments worldwide, hence the uncertainty in the model outputs.

Agricultural models

The agricultural models contain many simple, empirically derived relationships that do not completely represent actual plant processes. When models are adequately tested against observed data (calibration and validation process), the results reproduce agricultural output under current climate conditions. Nevertheless, the simplifications of the crop models are a source of uncertainty of the results. For example, agricultural models in general assume that weeds, diseases, and insect pests are controlled; there are no problem soil conditions such as high salinity or acidity; and there are no catastrophic weather events such as heavy storms. The agricultural models simulate the current range of agricultural technologies available around the world; they do not include potential improvements in such technology, but may be used to test the effects of some potential improvements, such as improved varieties and irrigation schedules. Provided that the limitations are carefully evaluated, a range of agricultural models are used widely by scientists, technical extension services, commercial farmers, and resource managers to evaluate agricultural alternatives in a given location under different conditions (i.e., drought years, changes in policy for application of agro-chemicals, changes in water input, among others).

The Impacts of temperature on soil carbon fluxes and loss of soil organic matter

The results reported by Bellamy *et al*., (2005) of a decrease in UK soil carbon stocks between 1980 and 1996, raise concerns that increasing temperatures across the EU region will lead to significant decreases in soil organic matter (SOM) and hence soil structure and fertility. However, Bellamy *et al*., (2005) reported that significant losses of carbon were from soils containing > 5.0 Corg.

The majority of soils in long-term arable use will contain less than 5.0% Corg. Hence, while the decreases in Corg reported are disturbing, in that they provide evidence of a positive feedback mechanism which may exacerbate climate change, the results do not suggest there will be a significant impairment of agricultural soils.

There is, however, another aspect of soil sustainability that needs to be addressed. While climate change has the potential to increase cereal yields in Scandinavia and the Eastern Baltic, the preponderance of leached sandy soils in those regions make it unlikely that, without greatly improved varieties or husbandry, yields comparable to those currently reported from the main cereal growing areas of Europe can be achieved. This project is not tasked with carrying out an appraisal of soil suitability across EU, but such a study could usefully be carried out to further assess the extent to which the potential for adaptation may be limited by differences in inherent soil characteristics across the EU.

Thresholds and unexpected risks

Risk can be evaluated when the probability of occurrence of an event is known, but in impact evaluation, the associated probabilities to a particular scenario are generally not known. Therefore, the inclusion of uncertainty (i.e., when the event is known but the probabilities that will occur are not known) into climate change impact methods is very important and recent studies are now beginning to include explicit methods to deal with it. Earlier studies have often used best estimate scenarios that represent the mid-point of predictions. The inclusion of a range of scenarios representing upper and lower bounds of the predicted effects is more realistic and allows for the propagation of uncertainty throughout a model system. Further, probability distributions of different events may be defined, with contrasts between the low probability of catastrophic events and the greater probability of gradual changes in climate.

5.5 Risks and opportunities: a territorial perspective

In this section we summarise, for each agro-climatic zone in turn, the risks and opportunities for agriculture that climate change is expected to bring. The numbers in the subsequent tables allow the reader to cross-reference the risks and opportunities described with a fuller elaboration provided in Annex D.

The risks and opportunities reported in this section were based on the literature review and methodology described in Chapter 4, including an assessment of risks and opportunities for each of the agro-climatic zones. The results presented in this section were developed from information in Annexes B to D. Here the definition and prioritisation of risks and opportunities in the European Agro-climatic zones is summarised.

The assessment of risks and opportunities do not only refer to specialist farms. The risks mainly relate to the types of production/sub-sectors, such as arable crops, permanent crops and livestock, independent of whether the farms are specialised or diversified. The number of specialised farms has been used earlier to give an idea of the importance of the production in each area but it does not mean that they are the only or most severely affected.

There may at times appear to be contradictions within the results presented below. In some cases this is because climate change has the potential to increase agricultural production through longer growing seasons and increased atmospheric CO_2 concentrations, but that potential may not be realised if moisture is limited during critical growth periods. The overall impact of complex interactions between many factors is difficult to forecast. There are also cases where published studies come to different conclusions. In this study we have decided to report literature results fully in order to illustrate where the greatest uncertainties occur.

5.5.1 Boreal

Risks and opportunities

The current Boreal agro-climatic zone is the region where forecasted climate change may provide the greatest opportunities for agriculture. However, the impacts to agriculture will be limited due to the small proportion (11%) of agricultural land of the total land area. Output from a number of scenarios run as part of the PESETA project suggested crop yields could increase by c. 40 % (range 34-54%). These increases were forecast to arise mainly as a result of the increase in the northern range over which the major agricultural crops may be grown and potential yield increases from the longer growing season, together with increased temperatures and increased concentrations of CO_2 in the atmosphere (Saarikko, 2000).

By 2080, according to model projections, southern Norway, parts of south-central Sweden and south-western Finland will no longer be part of the Boreal agro-climatic region but will experience weather patterns currently found in the Central Atlantic zone. Estonia will become part of the northern continental agro-climatic zone. As well as an increased potential for growing arable crops, increased livestock production may also be possible. The longer growing season will increase grass yields, while increased temperatures will increase the potential for growing forage legumes. The longer growing season should also reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

There is, however, a need to consider the soil resources in this region in order to properly assess the extent to which potential crop yield increases can be realised. Preliminary assessment indicates that the majority of soils in the region, where the greatest potential opportunities may arise, are podsols and leptosols of limited fertility and hence these inherently infertile soils may limit the potential for increased crop growth.

Any benefits could be counteracted by risks, such as rising sea levels inundating some low-lying land. Although this will only affect a small proportion of the land area, some of the vulnerable land includes population centres such as Stockholm and Riga and the inhabitants of those cities may need re-location, reducing the land area available for agriculture.

Intensification of hydrological cycles, leading to more extreme events may cause flooding, storm damage to crops, yield decreases and even crop failure (Schylter *et al.,* 2006). However, by their nature, the impacts of extreme weather events and their consequences are particularly difficult to forecast. The impacts on water quality are potentially complex and difficult to summarize. However with the warmer climate the Baltic Sea could be increasingly affected by increased pollution risks such as eutrophication. Increased episodes of heavy rainfall during which the infiltration capacity of the soil is exceeded are likely to increase the incidence of point source pollution, particularly in livestock production areas where manure is applied to land. However, increases in hydrologically-effective rainfall (HER) may reduce the impact of diffuse pollution by, by increasing the volumes of water draining through the soil thereby diluting the pollutant's concentration.

A particular problem of the boreal region is likely to be permafrost thaw (Haeberli *et al.,* 2002) leading to destabilization of soils and landslides, but these negative effects will impact mainly on woodlands. Warmer temperatures will lead to new pest and disease risks and increased use of pesticides in reaction (Rafoss *et al.,* 2003). The exact nature of the risks and measures taken to mitigate them may also have consequences for water quality.

Table 14 outlines the risks and opportunities and their priority in the Boreal region. Only an abbreviated explanation of the risk is given in this, and other tables. The full explanation of each risk, together with the literature source, is given in Annex D.

Table 14 Priority Risks and Opportunities for the Boreal zone

Boreal zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Increased risk of floods	HIGH	HIGH	HIGH
	Water quality deterioration	HIGH	HIGH	HIGH
	Soil erosion, salinisation, desertification	HIGH	MEDIUM	HIGH
	Loss of glaziers and alteration of permafrost	MEDIUM	MEDIUM	MEDIUM
	Deterioration of conditions for livestock production	HIGH	HIGH	HIGH
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	HIGH	HIGH
	Crop productivity increase	HIGH	HIGH	MEDIUM
	Water availability	MEDIUM	HIGH	HIGH
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM
	Improvement in livestock productivity	MEDIUM	HIGH	HIGH

Prioritisation of risks and opportunities

For the Boreal zone six out of the seven risks are considered to be high priority. The risks for attention concern the consequences of excess precipitation. Hence strategies need to be considered to reduce the risks of flooding, water quality, waterlogging and stock health. Although these risks will arise from the same root cause, different strategies will need to be adopted to deal with the full range of risks. Improved infrastructure will be needed to reduce the risk/severity of flooding affecting farmland. However, with respect to water quality, advice will need to be given on how to reduce the risks of point source pollution, e.g. following the spreading of livestock manures, and also to reduce the risks of soil erosion.

Of the opportunities three were considered high priority and these mainly relate to the potential for increased production of arable crops, either as a result of the increased yield potential of current crops, the greater area of land over which crops might be grown or due to the introduction of new crops. Given the concerns expressed in Section 5.1.1 above over the availability of soils suitable to achieve increases in crop production, a key factor in appraising the adaptive capacity of this region is to undertake a review of the soil resources.

Summary

This zone is one in which increased temperatures may increase both the cultivable area and crop yields within the entire zone, as well as provide opportunities for increased livestock production. However, the soil types in this zone may limit the potential for increased agricultural production. In addition, increased rainfall may lead to increased waterlogging, flooding risk and perhaps also a decrease in water quality.

5.5.2 Atlantic North

Risks and opportunities

The current Atlantic north agro-climatic zone, which covers Ireland and Scotland, is another region where forecasted climate change may provide opportunities for agriculture. Output from the PESETA report predicted increases in crop yields of c. 10% by 2080 (range -5 to 22%), mainly as a result of the increase in the northern range over which the major agricultural crops may be grown and potential increases in yield due to a longer growing season, increased temperatures and increased concentrations of CO_2 in the atmosphere (Holden *et al.,* 2003). Both countries will remain part of the Atlantic north agro-climatic region. As well as an increased potential for growing arable crops, there may also be benefits for livestock production. The longer growing season will increase grass yields, while increased temperatures will increase the potential for growing forage legumes. The longer growing season should also reduce the costs of housing livestock. There may be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

There is a need to consider the soil resources in this region in order to properly assess the extent to which potential crop yield increases can be realised. Preliminary assessment indicates a range of soils in Ireland, including Cambisols and Luvisols, which are potentially high yielding, although Scotland is dominated by podsols and histosols of limited fertility. Thus, particularly in Scotland, soil limitations may restrict the potential opportunities arising from climate change.

Several risks are also expected in this region. Rising sea levels will inundate some low-lying land, although to limited effect. Of greater concern will be increased winter rainfall leading to increased risks of flash flooding, waterlogging - which could have adverse effects on stock health on over-wintered on pastures, and perhaps also to water quality. Increased episodes of heavy rainfall may increase the incidence of point source pollution, particularly in livestock production areas where manure is applied to land. However, increases in HER may reduce the impact of diffuse pollution by diluting the pollutant concentration.

There is an apparent contradiction in our findings for this zone. While there is potential for cereal yields to increase due to increased average annual temperatures (e.g. Atkinson *et al.,* 2005), allowing earlier drilling and hence greater potential for yield, there is a risk that if rainfall is reduced or if temperatures are too great during the critical grain filling period, this yield potential may not be achieved. This is reflected in the results of the simulations run under PESETA which forecast a range of yield changes of range -5 to +22%. However, the current assessment is that the risk to cereal yields is low. Similar considerations apply to forage crops in that a longer growing season has the potential to increase yields while there is a high risk that warmer and drier summers may reduce forage yields during the summer, increasing the need for supplementary feeding.

Warmer temperatures will lead to new pest and disease risks and increased use of pesticides to deal with these risks. The exact nature of the risks and measures taken to mitigate them may also have consequences for water quality.

Table 15 outlines the priority of the risks and opportunities of the Atlantic North Zone.

Table 15 Priority Risks and Opportunities for the Atlantic North zone

Atlantic North zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	MEDIUM	MEDIUM	MEDIUM
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Water quality deterioration	HIGH	MEDIUM	HIGH
	Deterioration of conditions for livestock production	HIGH	HIGH	HIGH
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	HIGH	HIGH
	Crop productivity increase	HIGH	MEDIUM	HIGH
	Forest productivity increase	MEDIUM	LOW	LOW
	Water availability	MEDIUM	MEDIUM	MEDIUM
	Improvement in livestock productivity	HIGH	HIGH	HIGH

Prioritisation of risks and opportunities

For the Atlantic north zone four of the risks are considered to be high priority. Two of the risks for attention concern the consequences of potential changes in the precipitation pattern, with increased rainfall in winter and decreased water availability in summer, which is forecast to become hotter and drier. While the reduction in water availability during summer might not be severe enough to be defined as drought, countries like the British Isles, which currently receive more rainfall in summer than in winter, may not be fully prepared for decreased summer rainfall. Hence water storage for irrigation in summer is limited and farmers will need to adapt to hotter and drier summers.

Due to the forecast of wetter winters, strategies need to be considered to minimise the risks of reduced water quality and waterlogging while conserving that winter rainfall to ensure supply during the summer. Such an approach may require a dramatic change in approach to water resources in this zone as it is accustomed to having significant rainfall throughout the summer.

Of the opportunities three were considered high priority. These relate to the potential for increased livestock production, either as a result of the increased yield potential of grassland or due to the introduction of forage legumes. Again this may appear to contradict Section 5.2.1, but increases in forage yields in autumn and early spring may be difficult to utilise if the soils are too wet for grazing. Reduced growth in summer, due to water stress, may reduce the potential for silage making and hence reduce the amount of feed available during the winter housing period. Given the concerns expressed in above over the availability of soils suitable to achieve increases in crop production.

Summary

There is also potential in this zone for increased agricultural production, especially in the livestock sector, but soil type may limit this potential. Measures need to be introduced to enable adaptation to drier summers, as currently summer rainfall usually enables unrestricted growth of crops and forage.

5.5.3 Atlantic Central

Risks and opportunities

The forecasted changes in climate may provide benefits for agriculture in this zone. Output from the scenarios run in PESETA forecast average increases in cereal yields of c. 12% by 2080 (range 5-19%), with potential increases in yield from the longer growing season, increased temperatures and increased concentrations of CO_2 in the atmosphere (Atkinson *et al.,* 2005). There is also likely to be an increase in the northern range over which crops such as soya and sunflower may be cultivated. This region has some of the most productive agricultural areas in Europe and the extension of these agro-climatic conditions into southern Norway, part of south-central Sweden and south-western Finland may potentially increase food production in Europe.

Livestock production may also be favoured. The longer growing season will increase grass yields, while warmer temperatures will increase the potential for growing forage legumes. The longer growing season should also reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

However, this area may also face significant risks from projected climatic conditions. Rising sea levels will inundate large areas of low-lying land in eastern England and the north-sea coasts of Belgium, the Netherlands and Germany. Moreover, these areas represent some of the most productive agricultural areas in those countries. In addition, rising sea levels may also flood important population centres such as Antwerp, Rotterdam, Amsterdam, Bremen and Hamburg and the inhabitants of those cities may need re-location reducing the land area available for agriculture. Due to a greater proportion of precipitation falling in winter, the risk of flooding will also increase (Reynard *et al.,* 2001) and this may lead to severe problems in areas where large areas of low lying land surround large rivers. Extreme weather events are also likely to become more frequent.

The annual distribution of rainfall is expected to change with a greater proportion falling in winter and reduced in summer. Increased episodes of heavy rainfall during which the infiltration capacity of the soil is exceeded are likely to increase the incidence of point source pollution, particularly in livestock production areas where manure is applied to land. However, increases in HER, may reduce the impact on water quality by diluting the pollutant concentration.

As reported for the Atlantic north zone, there is a risk that if rainfall is reduced, or if temperatures are too high during the critical grain filling period, crops may not reach their yield potential. In addition, this zone covers quite a large area, and it is to be expected that the response to climate change will not be entirely consistent across the region, depending on location and soil type. Hence in some parts of the zone the risk of yield reduction may be a greater likelihood than yield increase, counteracting the potential for yield increases outlined above. Warmer and drier summers will also have different impacts on different crops. Potatoes and sugarbeet, which are spring-sown and sensitive to dry soil conditions, already often require irrigation to fulfil their yield potential in this zone. In future, the demand for irrigation will increase. Hence even if the yields of autumn-sown cereals increase, which are less sensitive to water stress, productivity of sugarbeet and potatoes may decrease.

Warmer temperatures could lead to outbreaks of new pest and disease risks and increased use of pesticides to deal with these risks. The exact nature of the risks and measures taken to mitigate them may also have consequences for water quality. The soil resources in this region include a large proportion of cambisols and luvisols and may withstand drought stress better than shallow or coarse-textured soils. However, if drought stress becomes severe these soils may fail to achieve their yield potential. There is also the possibility that reduced water resources during the summer may lead to conflicting demands between agriculture and other users. Some traditional fruit crops may become difficult to cultivate. The production of apples and pears, for example, which mature during the summer, may be reduced by hot, dry summers.

Table 16 reports the assessment of the importance of the risk or opportunity for Atlantic Central zone.

Table 16 Priority Risks and Opportunities for the Atlantic Central zone

Atlantic Central zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of floods	HIGH	HIGH	HIGH
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Water quality deterioration	HIGH	MEDIUM	HIGH
	Deterioration of conditions for livestock production	MEDIUM	HIGH	HIGH
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	MEDIUM	HIGH
	Crop productivity increase	MEDIUM	MEDIUM	MEDIUM
	Forest productivity increase	LOW	MEDIUM	LOW
	Water availability	HIGH	MEDIUM	HIGH
	Improvement in livestock productivity	MEDIUM	HIGH	HIGH

Prioritisation of risks and opportunities

For the Atlantic central zone six of the risks are considered to be high priority. The risks for attention concern the consequences of potential changes in the precipitation pattern. Hence strategies need to be considered to reduce the risks of reduced water quality and waterlogging in the winter and ensure supply during the summer. Such an approach may require a dramatic change in approach in this zone which is accustomed to having significant rainfall throughout the summer. While rising sea levels were considered a high level risk in most zones, the much greater area of low-lying coastal land, together with the considerable numbers of people at risk of being displaced, mean that this risk needs particular attention in the Central Atlantic zone.

Of the opportunities, three were considered high priority and relate either to the potential for increased crop production or increased livestock production, either as a result of the increased yield potentials, the greater area of land over which new crops might be grown or due to the introduction of forage legumes. However, high temperatures or water stress during the critical growing periods may mean that the opportunities for increased yield presented by other factors may not be realised. In order to address these conflicts attention will need to be given to water supply, soil suitability and introduction of appropriate crop cultivars.

Summary

This zone is particularly vulnerable to flooding from rising sea levels and attention needs to be given to measures that will reduce this risk. Some increases in agricultural production are possible from increased yields of cereals and the introduction of new crops. However, it may be difficult to maintain the yields of more moisture- or temperature-sensitive crops if summer rainfall decreases and insufficient water is available for irrigation.

5.5.4 Atlantic South

Risks and opportunities

In this agro-climatic zone climate change many not offer many opportunities for agriculture, despite potential increases in yield from the longer growing season and increased concentrations of CO_2 in the atmosphere as reported above. The scenarios run in the PESETA project suggested crop yields may decrease by c. 14% (range -7 to -26%) by 2080. The longer growing season could, however, reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

However, increased summer temperatures and drought risk can make it difficult to achieve the potential yield increases from a longer growing season and increased CO_2 can threaten the achievement of current yield levels. Water resources may be a problem leading to conflict with other users (De Cunha *et al.,* 2002). There may also be problems arising from the introduction of new pests and diseases. A large proportion of soils in this agro-climatic zone are leptosols, a soil type prone to drought stress.

Table 17 outlines the priority of the risks and opportunities of the Atlantic South zone.

Table 17 Priority Risks and Opportunities for the Atlantic South zone

Atlantic South zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	MEDIUM	MEDIUM	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	MEDIUM	HIGH	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Increased irrigation requirements	MEDIUM	MEDIUM	MEDIUM
	Soil erosion, salinisation, desertification	MEDIUM	MEDIUM	MEDIUM
	Deterioration of conditions for livestock production	MEDIUM	LOW	LOW
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	MEDIUM	MEDIUM	MEDIUM
	Crop productivity increase	MEDIUM	MEDIUM	MEDIUM
	Water availability	MEDIUM	HIGH	HIGH
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM

Prioritisation of risks and opportunities

For the Atlantic south zone three of the risks are considered to be high priority. In contrast to the other Atlantic zones, here the risks for attention concern the consequences of decreased water supply and increased heat stress. Hence strategies need to be considered to conserve as much water as possible over winter to maintain supply during the summer.

The attendant risk of reduced yields was also assessed as high risk and strategies need to be developed to adopt cultivars or crops better suited to reduced water availability and heat stress.

Of the opportunities only one was considered high priority and these related either to the potential for increased production of some crops, either as a result of the increased yield potentials under the new climatic regimes or an increase in the area over which new crops might be grown. Hence attention needs to be given to the promotion of crops that have the potential to flourish in the changed conditions.

Summary

The priority in this zone will be to conserve water to reduce the risk of decreases in crop yields and to avoid conflict with other water users. There may also be opportunities to grow crops more tolerant of heat and drought and this possibility needs to be thoroughly evaluated.

5.5.5 Continental North

Risks and opportunities

The current Continental north agro-climatic zone is another region where forecast climate change may provide opportunities for agriculture, mainly as a result of the increase in the northern range over which crops such as soya or sunflowers may be grown and potential increases in yield from the longer growing season, increased temperatures and increased concentrations of CO_2 in the atmosphere (Stuczyinski *et al*., 2000).

The climatic conditions of this central European area are forecast to extend into Estonia and the area of the Russian Federation bordering on the Baltic and this may potentially increase food production in Europe. As well as an increased potential for growing arable crops, there may also be opportunities for increased livestock production. The longer growing season will increase grass yields, while increased temperatures will increase the potential for growing forage legumes. The longer growing season should also reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

However, there will be significant risks alongside the expected benefits in those central parts of the EU. Rising sea levels will be of only limited importance, mainly in the areas around Szczecin and Gdansk, but flooding is forecast to be a problem in areas of the confluence of major rivers (Lapin *et al.,* 2003; Middlekoop *et al.,* 2001; De Roo *et al.,* 2003), due to the increased frequency of extreme weather events such as heavy rains and storms (Middlekoop *et al.,* 2001).

The distribution of rainfall is expected to change with a greater proportion falling in winter with decreases in summer.

Increased temperatures and reduced summer rainfall may lead to drought and decreases in yields of arable crops such as sugarbeet and potatoes. Warmer temperatures will lead to new pest and disease risks and increased use of pesticides to deal with these risks. The exact nature of the risks and measures taken to mitigate them may also have consequences for water quality. The soil resources in this region include a large proportion of cambisols and luvisols and may withstand drought stress better than shallow or coarse-textured soils. However, if drought stress becomes severe these soils may fail to achieve their yield potential. There is also the possibility that reduced water resources during summer may lead to conflicting demands between agriculture and other users.

Increased episodes of heavy rainfall during which the infiltration capacity of the soil is exceeded are likely to increase the incidence of point source pollution, particularly in livestock production areas where manures are applied to land. However, increases in HER, by increasing the volumes of water draining through the soil, may reduce the impact of diffuse pollution by diluting the pollutant concentration and thus improving water quality.

Table 18 reports the assessment of the importance of the risk or opportunity.

Table 18 Risks and Opportunities for the Continental North zone

Continental North zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of floods	HIGH	HIGH	HIGH
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Water quality deterioration	HIGH	MEDIUM	HIGH
	Deterioration of conditions for livestock production	MEDIUM	HIGH	HIGH
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	MEDIUM	HIGH
	Crop productivity increase	MEDIUM	MEDIUM	MEDIUM
	Forest productivity increase	MEDIUM	LOW	LOW
	Water availability	HIGH	HIGH	HIGH
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM
	Improvement in livestock productivity	MEDIUM	HIGH	HIGH

Prioritisation of risks and opportunities

For the Continental north zone six of the risks are considered to be high priority. The risks for attention concern the consequences of decreases water supply and heat stress. Such an approach may require less adjustment than in the Atlantic zones, as over much of the continental zone annual precipitation is only c. 600 mm and so the farmers in this region are more accustomed to managing water resources.

Of the opportunities three were considered high priority and these related either to the potential for increased crop production, or increased livestock production, either as a result of the increased yield potentials, the greater area of land over which new crops might be grown or due to the introduction of forage legumes. However, given the identified risks of water supply and heat stress, careful consideration would need to be given over how the potential yield increases may be obtained.

Summary

The increase in the northern range of crops and longer growing season offers the potential for increased crop and livestock production. However water stress in summer and infertile soils may limit this potential. Flooding is also a serious risk. Priority needs to be given to manage water supplies to reduce the risk of flooding and to conserve water to increase availability for agriculture.

5.5.6 Continental South

Risks and opportunities

In this agro-climatic zone that includes two EU countries, Hungary and Romania, there may be some opportunities for agriculture, mainly as a result of potential increases in yield from the longer growing season, increased temperatures and increased concentrations of CO_2 in the atmosphere (Corobov, 2002). The longer growing season will potentially increase grass yields, while increased temperatures will increase the potential for growing forage legumes. Output from the model runs carried out as part of the PESETA project predicted an increase of c. 24% by 2080 (range 11-33%). The longer growing season should also reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

However, in this zone most of the impacts would be adverse. Increased summer temperatures and drought risk could make it difficult to achieve the potential yield increases from increased concentrations of CO_2 (Alexandrov *et al.,* 2000) and perhaps threaten current productivity levels. Some crops will be more vulnerable to hotter and drier summers. Yields of sugarbeet and potatoes, both of which are frequently irrigated under current conditions, are likely to be reduced more than the yield of cereals. The summer growth of forage crops also appears likely to be reduced. An increased frequency of extreme weather events may also lead to crop damage or failure (Cuculeanu *et al.,* 2002). There may also be problems arising from the introduction of new pests and diseases.

Rising sea levels are likely to reduce the available area of agricultural land in the southern Ukraine. A large proportion of soils in this agro-climatic zone are cambisols and luvisols, both fertile soils that should be relatively resistant to drought stress. However, in the east of the zone, there is a large proportion of Chernozems. These soils have large organic matter content and breakdown of SOM is likely to increase with warmer temperatures. While this breakdown will increase soil fertility in the short term (via release of nutrients) in the longer-term soil fertility is likely to be reduced.

Table 19 outlines the priority of the risks and opportunities in the Continental South zone.

Table 19 Priority Risks and Opportunities for the Continental South zone

Continental South zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Increased irrigation requirements	HIGH	HIGH	HIGH
	Soil erosion, salinisation, desertification	HIGH	HIGH	HIGH
	Deterioration of conditions for livestock production	MEDIUM	LOW	LOW
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	MEDIUM	HIGH
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM

Prioritisation of risks and opportunities

For the Continental south zone four of the risks are considered to be high priority. Three of the risks for attention concern the consequences of potential changes in the precipitation pattern, with increased rainfall in winter and decreased water availability in summer. Hence strategies need to be considered to conserve as much water as possible over winter to maintain supply during the summer. The attendant risk of reduced yields was also assessed as high and strategies need to be developed to adopt cultivars or crops better suited to reduced water availability and heat stress.

Of the two opportunities one was considered high priority and this relates to the potential for increased production of some crops, either as a result of the increased yield potentials under the new climatic regimes or an increase in the area over which new crops might be grown. Hence attention needs to be given to the promotion of crops that have the potential to flourish in the changed conditions.

Summary

Agriculture in this zone is likely to be adversely affected by hotter drier summers with yields of crops such as potatoes, sugarbeet and forage crops most likely to be reduced. Priority needs to be given to ensuring water supplies for agriculture and also promoting the growth of crops, such as soya, that could replace vulnerable crops.

5.5.7 Alpine

Risks and opportunities

The Alpine zone is a region where forecast climate change may provide opportunities for agriculture, mainly as a result of the potential increases in yield of traditional crops from the longer growing season, increased temperatures and increased concentrations of CO_2 in the atmosphere. Crop yields were predicted to increase by c. 20% (range 20-23%) in the scenarios carried out as part of the PESETA project. As well as an increased potential for growing arable crops, livestock production may also benefit. The longer growing season will increase grass yields, while increased temperatures will increase the potential for growing forage legumes (Riedo *et al.,* 2001). The longer growing season should also reduce the costs of housing livestock. There may also be benefits for horticulture, both with respect to reducing costs of indoor production and increasing the range of horticultural crops that can be grown outdoors.

However, there will be significant risks that could negate these benefits. The distribution of rainfall is expected to change with a greater proportion falling in winter with decreases in summer. Increased episodes of heavy rainfall during which the infiltration capacity of the soil is exceeded are likely to increase the incidence of point source pollution, particularly in livestock production areas where manures are applied to land. However, increases in HER may reduce the impact on water quality. There is also a forecast increase in extreme climate events affecting vulnerable areas like mountain pastures (Beniston, 2000; 2003; 2004). Increased temperatures and reduced summer rainfall may lead to drought and decreases in yields of arable crops. Warmer temperatures will lead to new pest and disease risks and increased use of pesticides to deal with these risks. The exact nature of the risks and measures taken to mitigate them may also have consequences for water quality. The soil resources in this region include a large proportion of leptosols which are prone to drought stress hence, if drought stress becomes severe, these soils may fail to achieve their yield potential. There is also the possibility that reduced water resources during summer may lead to conflicting demands between agriculture and other users.

Table 20 outlines the risks and opportunities of the Alpine zone and their priorities.

Table 20 Risks and opportunities in the Alpine zone

Alpine zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	MEDIUM	MEDIUM	MEDIUM
	Increased risk of floods	MEDIUM	HIGH	HIGH
	Increased risk of drought and water scarcity	MEDIUM	HIGH	HIGH
	Water quality deterioration	HIGH	MEDIUM	HIGH
	Soil erosion, salinisation, desertification	HIGH	HIGH	HIGH
	Loss of glaziers and alteration of permafrost	HIGH	HIGH	HIGH
	Deterioration of conditions for livestock production	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	HIGH	MEDIUM	HIGH

	Crop productivity increase	HIGH	MEDIUM	HIGH
	Water availability	MEDIUM	MEDIUM	MEDIUM
	Improvement in livestock productivity	HIGH	HIGH	HIGH

Prioritisation of risks and opportunities

For the Alpine zone six of the risks are considered to be high priority. The risks for attention concern the consequences of potential changes in the precipitation pattern, with increased rainfall in winter and decreased water availability in summer. Hence strategies need to be considered to reduce the risks of water quality and waterlogging over winter while conserving that winter rainfall to ensure supply during the summer.

Of the opportunities three were considered high priority and these related to the potential for increased livestock production, either as a result of the increased yield potentials, the greater area of land over which new crops might be grown or due to the introduction of forage legumes.

Summary

Changes in precipitation pattern and increased frequency of extreme events appear to pose the greatest risks ion this zone. There may be opportunities for increased production of both crops and livestock but the realisation of these opportunities will depend upon the continued availability of water at critical periods of crop growth.

Changes in precipitation pose some of the greatest risks in this zone, together with an increased risk of extreme weather events. There may be benefits from a longer growing season and the ability to grow some crops at greater altitudes, but this potential may not be realised due to soil limitations.

5.5.8 Mediterranean North

Risks and opportunities

In this agro-climatic zone, there appear to be few opportunities for agriculture, only some reduction in the costs of indoor production and perhaps the introduction of some new crops such as Soya. The expected impacts of future changes in climate conditions are also driven by the importance of agriculture in this zone, which represents c. 54% of the total surface.

One of the predominant impacts consistently forecast is the decrease in yearly rainfall (Alcamo *et al.,* 2001; Eisenreich, 2005) which in turn is projected to substantially reduce summer river flows. This would lead to an increase of water demand by agriculture for irrigation and increase the risks of conflicts over water resources between agriculture and other sectors of society.

Crop yields are likely to be reduced by increased summer temperatures and drought risk (Kapetanaki *et al.,* 1997; Tubiello *et al.,* 2000, 2002), and a mean decrease of 10% was predicted from the scenarios run in the PESETA project (range 0 to -22%). There may also be problems arising from the introduction of new pests and diseases.

The livestock sector is likely to be adversely affected by reduced yields of forage crops and perhaps also heat stress to the animals. Moreover, one of the most productive areas within this agro-climatic zone, the Po valley, will be vulnerable to rising sea levels.

Table 21 reports the assessment of the importance of the risk or opportunity of the Mediterranean North zone.

Table 21 Priority Risks and Opportunities for the Mediterranean North zone

Mediterranean North zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	LOW	HIGH	MEDIUM
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	LOW	HIGH	MEDIUM
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Increased irrigation requirements	HIGH	HIGH	HIGH
	Soil erosion, salinisation, desertification	HIGH	HIGH	HIGH
	Deterioration of conditions for livestock production	MEDIUM	LOW	LOW
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	Crop distribution changes leading to increase in optimal farming conditions	LOW	HIGH	MEDIUM
	Lower energy costs for glasshouses	LOW	HIGH	MEDIUM

Prioritisation of risks and opportunities

For the Mediterranean north zone six of the risks are considered to be high priority. The risks for attention concern the consequences of potential changes in the precipitation pattern, with increased rainfall in winter and decreased water availability in summer. Hence strategies need to be considered to conserve as much water as possible over winter to maintain supply during the summer. The attendant risk of reduced yields was also assessed as high and strategies need to be developed to adopt cultivars or crops better suited to reduced water availability and heat stress. None of the opportunities were considered high priority, as this region is not well placed to benefit from the forecast changes in climate.

Summary

In this zone the forecast risks greatly outweigh any potential benefits. Forecast decreases in total annual rainfall make water conservation a priority and careful attention needs to be given to avoiding conflicts over water use.

5.5.9 Mediterranean South

Risks and opportunities

In this agro-climatic zone there appear to be few opportunities for agriculture from changing climatic conditions, with crop yields forecast to decrease by c. 8% (range +5 to -27%) from the PESETA scenarios. As for the northern parts of Mediterranean, the impacts of future changes in climate conditions may be expected to be important as agricultural area accounts for nearly half of the total surface of the south-Mediterranean regions.

Since some crops are currently grown under protection in this zone there may be some reduction in the costs of indoor production and perhaps the introduction of some new crops. For example, the crop Jatropha which is grown for use as a biofuel feedstock may be grown on degraded land. However, these possibilities aside, insufficient opportunities have been identified.

A decrease in total annual rainfall is forecast (Alcamo *et al.,* 2001; Eisenreich, 2005) which is projected to substantially reduce summer river flows and increase the risks of conflicts over water resources between agriculture and other sectors of society (Iglesias *et al*., 2003). Crop yields are likely to be reduced by increased summer temperatures and drought risk (Guereña *et al*., 2001; Iglesias *et* *al.,* 1997, 2000). There may also be problems arising from the introduction of new pests and diseases. The livestock sector is likely to be adversely affected by reduced yields of forage crops and perhaps also heat stress to the animals. Reduced rainfall and consequent changes in drainage of soils may lead to increased soil salinity (Van Ittersum *et al.,* 2003) and damage to soil structure leading to desertification (Karas, 1997).

Table 22 outlines the risks and opportunity priorities of the Mediterranean South region.

Table 22 Risks and Opportunities for the Mediterranean South zone

Mediterranean South zone	Detail of risk/ opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	HIGH	HIGH	HIGH
	Crop productivity decrease	LOW	HIGH	MEDIUM
	Increased risk of agricultural pests, diseases, weeds	HIGH	MEDIUM	HIGH
	Crop quality decrease	MEDIUM	HIGH	HIGH
	Increased risk of drought and water scarcity	HIGH	HIGH	HIGH
	Increased irrigation requirements	HIGH	HIGH	HIGH
	Soil erosion, salinisation, desertification	HIGH	HIGH	HIGH
	Deterioration of conditions for livestock production	MEDIUM	MEDIUM	MEDIUM
	Sea level rise	HIGH	HIGH	HIGH
Opportunity	n/a	n/a	n/a	n/a

Prioritisation of risks and opportunities

For the Mediterranean south zone eight of the risks are considered to be high priority. The risks for attention directly concern the consequences of potential reductions in total precipitation. Hence strategies need to be considered to conserve as much water as possible over winter to maintain supply during the summer. The attendant risk of reduced yields was also assessed as high and strategies need to be developed to adopt cultivars or crops better suited to reduced water availability and heat stress. No significant opportunities were identified in this zone, which is not well placed to benefit from the forecast changes in climate. The impacts of climate change are forecast to be so serious that land may be no longer in agricultural use.

Summary

Priority needs to be given to water resources and to identify any possible opportunities, such as Jatropha cultivation, to prevent land being abandoned.

5.5.10 Summary risk matrix

Table 23 below summarises the risks and opportunities according to the current distribution of the defined agro-climatic zones.

Table 23 Summary of risk and opportunity prioritisation by agro-climatic zone

Description	Bor	Atl N	Atl C	Atl S	Cnt N	Cnt S	Alp	Md N	Md S
Risks									
Crop area changes due to decrease in optimal farming conditions		M	M	M	M	M	M	M	H
Crop productivity decrease		M	M	M	M	M	M	M	M
Increased risk of agricultural pests, diseases, weeds	H	M	H	H	H	H	M	H	H

Description	**Bor**	**Atl N**	**Atl C**	**Atl S**	**Cnt N**	**Cnt S**	**Alp**	**Md N**	**Md S**
Crop quality decrease			M	M	M	M		M	H
Increased risk of floods	H		H		H		H		
Increased risk of drought and water scarcity		H	H	H	H	H	H	H	H
Increased irrigation requirements				M		H		H	H
Water quality deterioration	H	H	H		H		H		
Soil erosion, salinisation, desertification	H			M		H	H	H	H
Loss of glaziers and alteration of permafrost	M						H		
Deterioration of conditions for livestock production	H	H	H	L	H	L	H	L	M
Sea level rise	H	H	H	H	H			H	H
Opportunities									
Crop distribution changes leading to increase in optimal farming conditions	H	H	H	M	H	H	H	M	
Crop productivity increase	M	H	M	M	M		H		
Water availability	H	M	H	H	H		M		
Lower energy costs for glasshouses	M			M	M	M		M	
Improvement in livestock productivity	H	H	H		H		H		

6 Adaptation measures for EU Agriculture

This chapter initially provides an overview of the adaptation concept, types of adaptation measures and the key issues of risk and uncertainty when adapting to climate change in the agricultural sector. Thereafter, the focus shifts to the national adaptation strategies and an EU-wide evaluation of the adaptation measures. A territorial summary of the impacts, risks, opportunities and adaptation measures is included to assist in the interpretation of the overall results of the study.

Recognising that stakeholders play a determinant role in the potential definition and realisation of the adaptation measures, the chapter includes a discussion on the stakeholder consultation. Finally, the chapter discusses the challenges European agriculture faces in adapting to climate change.

6.1 The concept of adaptation

A proposed definition of **adaptation** is: “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation”. Adaptation refers to all those responses to climate change that may be used to reduce vulnerability or to actions designed to take advantage of new opportunities that may arise as a result of climate change (Burton *et al.*, 1996). The focus of these actions is on managing risk. Investments in risk-based actions are fundamental to reducing the environmental, social and economic costs of climate change.

In its Fourth Assessment Report, the IPCC (2007) recognises that some adaptation is occurring, but on a very limited basis, and affirms the need for extensive adaptation across nations and economic sectors to address impacts and reduce vulnerability. **Vulnerability** to climate change may be defined as “The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”.

Various types of adaptation can be distinguished, including **anticipatory** and **reactive** adaptation, **private** and **public** adaptation, and **autonomous adaptation** and **policy-driven adaptation**. Autonomous adaptation describes actions “taken ‘naturally’ by private actors, such as individuals, households, businesses in response to actual or expected climate change, without the active intervention of policy”. It may be that the agricultural sector is one in which autonomous adaptation is a particularly important category because farmers have traditionally adapted their methods in response to felt changes. In contrast, policy driven adaptation is “the result of a deliberate policy decision”. Policy-driven adaptation is therefore associated with public agencies, either in that they set policies to encourage and inform adaptation or they take direct action themselves, such as public investment (Stern, 2006).

In this study, a common categorisation of planned adaptations into two main groups has been followed (HM Government UK, 2006), classified here as “building adaptive capacity” and “taking adaptive action” (Table 24). These are complementary forms of action, with adaptive actions usually following later in time after adaptive capacity has been built up.

The term “**adaptive capacity**”, used in this definition of vulnerability, has also been widely cited in the literature, often with reference to human groups (from individuals to communities to institutions) that could adapt to climate change. However, the definition extends beyond human activities. “Adaptive capacity is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (IPCC, 2001).

Building adaptive capacity involves ensuring that the scientific, technical and socio-economic evidence, the skills, the governmental and non-governmental partnerships, the policies and the resources are in place to enable adaptation to be undertaken. An example is the UK Government’s Climate Change Impacts and Adaptation (Agriculture) R & D Programme (Defra, 2005) which has considered: the implications of drought risk and increased winter rainfall for crop performance; the impacts of climate change on grassland systems, nutrient pollution and soil function; identification and costing of agricultural adaptive responses; and knowledge transfer issues. In many cases, efforts to build adaptive capacity may be best made at a sectoral level, but even within individual organisations, or for an individual farmer, a certain amount of capacity building (e.g. awareness-raising, education) is initially required as the foundation for the next step of taking actual adaptive action.

Taking adaptive action involves increasing the resilience of systems, structures and people to climate risks by reducing their vulnerability and optimising their ability to accommodate and adapt to change. An example from northwest Europe is the management of flood meadows to accommodate increased rainfall and the development of water storage facilities for use in summer irrigation. Anticipatory adaptation, as opposed to reactive adaptation, is important for sustaining existing and future assets with long life spans. Efforts to take adaptive action will necessarily be location and context specific, as they require a deliberate change of practice, whether in management, process or infrastructure.

Adaptation strategies are put in place to deliver adaptations. An adaptation strategy is a broad plan of action that is implemented through policies and measures. Adaptation strategies are not only reactions to posed threats of climate change, but can comprise at the same time a large number of technical, social, economic and environmental challenges (Iglesias *et al.*, 2007a; Olesen and Bindi, 2002).

Table 24 Summary of approaches to adaptation

Type of adaptation	Characteristics	Examples
Building adaptive capacity	Creating the information and conditions (regulatory, institutional, and managerial) that enable adaptation actions to be undertaken.	Climate change impacts research funded by agriculture advisory services. Awareness-raising among farmers. Genetic resources for breeding programmes. Policy support tools.
Taking adaptive action	Taking actions that will help reduce vulnerability to climate risks or exploit opportunities.	Creating water collection and storage facilities on farms for use in irrigation. Introducing new crop varieties. Diversification. Resource management tools and infrastructure.
Autonomous or unassisted adaptation	Adaptation that occurs naturally or arises not as a conscious response to changing climate.	Natural responses of agricultural crops to seasonal changes (e.g. earlier springs). Autonomous farming practices evolution (e.g. treatments and sowing dates).

6.2 Types of adaptation measures

Farmers have always carried out adaptive changes to their businesses based on the weather and respond in the short-term by altering cropping patterns and management practices. However, this is unlikely be enough to ensure that livelihoods can be sustained in the face of climate change. Historically, new techniques have diffused through the industry, with innovative farmers being the first to introduce new techniques, and others adopting these approaches as they are seen to be successful. The changing climate will impact upon such a breadth of agricultural enterprises and associated sectors, and some of these changes may be extreme and relatively rapid, so that even the innovators may not be sufficiently responsive to adapt successfully without support. Therefore, some studies have considered that larger-scale, more permanent and structured proactive adaptations may be needed. For example, there may be a need for state-funded research to help drive change in breeding and cropping programmes, while the installation of new infrastructure may require financial support.

However, with a move away from agricultural support, the cost of most adaptive measures may have to be borne by farmers themselves. Those farming on marginal land, where incomes are low, are at greatest risk. The risks are not just long-term; in the short-term, extreme weather events could cause major loss of income or increase in costs and lead, in turn, to more rapid abandonment of land. There is a danger that these areas, which may account for only a small proportion of national gross domestic product, could be neglected. Adaptation is, therefore, a major issue for maintaining incomes across rural communities. Furthermore, the proportion of farms on limited incomes is highest in the southern regions of the EU – regions that are projected to face the greatest risks and have the fewest opportunities (from climate change). The northern regions, where opportunities are greatest, are those that have the highest proportion of large farms. These typically generate reasonable incomes and have the potential to invest in adaptation.

Adaptation is, at least in part, a policy-driven process and information on options may reflect differing perceptions about the long-term future of the environment, economies and society. The capacity to adapt to environmental change is also implicit in the concept of sustainable development. While some adaptation options may initially seem costly, projections of the potential environmental and economic damages from climate change indicate the importance of investing in adaptation.

We have categorised three types of adaptation options in the agriculture sector: management, technical/equipment and infrastructural. The type of measure will largely determine the extent to which farmers can adopt them without additional assistance. Farmers should be able to carry out some changes in management measures without support. This will also be true, to a large extent, for technical measures, while infrastructural measures are likely to require significant capital investment. Some examples of this simple classification are given below, together with some caveats to its use.

Management measures

The choice of crop variety and pesticide are management decisions which farmers make every year. These decisions are based on information taken from a number of sources: agrochemical industry publications and representatives, government extension service advisers, discussions with other farmers and articles in the farming press; larger farmers may employ professional consultants to provide guidance. To a large extent, the market forces that have driven historic innovation and adaptation may continue to drive the adoption of new measures.

Technical/equipment measures

The distinction between these and management measures are somewhat arbitrary, as technical understanding is needed to implement the management decisions outlined above. However, the introduction of new crops or livestock, together with the agrochemicals needed, may be considered technical since the husbandry requirements may be new to the farming community. The introduction of improved irrigation equipment may also be regarded as a technical measure. Advice may be needed from government agencies, as commercial firms may be slow to develop products in these areas, waiting instead to see if markets can be established before committing resources to product development and promulgation. Extensive breeding and testing programmes may be necessary to identify cultivars and breeds appropriate to changing local conditions.

Infrastructural measures

Infrastructural measures will vary greatly in scale and expense, but all will require an element of capital investment. The introduction of on-farm harvesting and storage of rainwater is one example of such a measure. While the necessary capital outlay may appear modest (e.g. adding guttering to the roofs of farm buildings and collecting water in an earth-banked reservoir), farm incomes and profits in many parts of the EU are not currently sufficient to finance such a measure. A second example is the encouragement of farmers to effectively manage flood plains. This is likely to need public support investment to provide incentives for them to relinquish current practices in riparian zones and adopt protective measures. The re-creation of water meadows may require a farm currently devoted to arable production to invest in the establishment of a livestock enterprise.

The full list of measures and their evaluation is given in Table 27.

6.3 Taking unexpected risk and uncertainty into account

There is already considerable knowledge of the likely impacts of climate change on agriculture. From this knowledge, potential risks and measures to enable adaptation may be identified. However at present, methods to effectively plan adaptation or evaluate policies and measures including costs have not been developed. There are a number of reasons for this.

Impacts occur at different scales (farm, community, region, country). However, assessments of climate impacts, and modelling of agricultural productivity, are usually at regional, national or global scales. The application of information from coarse-scale impact studies to devise farm-level adaptation measures is fraught with difficulties.

Knowledge transfer between scientists, political decision makers and the people directly affected by climate change is currently weak, and existing information is poorly used. One of the difficulties is the number and range of stakeholders involved in adaptation. Another challenge is the inherent **uncertainty** in climate science and impacts projections; uncertainty can lead to confused messages and inertia if it is not communicated in the right way.

Wider influences on farmers' behaviour, such as changes in demand and market prices, must be considered alongside climate change. It is important to consider whether adaptations are sustainable, or rendered irrelevant by other sectoral drivers. This holistic approach should also ensure that adaptation decisions and investments are both cost-effective and proportionate to the risks or benefits that may be incurred.

Farming involves not only the production of crops and livestock, but also the management of people, supply chains, markets, building and transport infrastructures, insurance, etc. The indirect impacts of climate change in these other areas may be more significant than changes in crop productivity at farm level.

The development of adaptation measures must take into account future socio-economic scenarios, as well as future climate change scenarios. Practitioners need to understand the relevance of a future climate to a future society, rather than to society today. Credible socio-economic scenarios are required to provide a framework for adaptation decision-making for practitioners.

The sectoral approach to impacts and adaptation has provided a pragmatic solution to a wide-ranging problem. However, adaptations often involve combined effort across many sectors. Agriculture is sensitive to the responses in other sectors, particularly water, tourism and biodiversity conservation. Adaptation measures for agriculture should take account of policies in other sectors.

Adaptation is unlikely to be facilitated through the introduction of new and separate policies, but rather by the revision of existing policies that undermine adaptation and the strengthening of policies that enhance it. If adaptation is to become "mainstreamed", it will be necessary for relevant polices, such as the Common Agricultural Policy and the Water Framework Directive, to address the issue more directly. Existing agreements also have a part to play. For example, the Convention on the Protection of the Alps (1991) may need to be reconsidered in the light of climate change.

6.4 Summary of national adaptation strategies

Table 25 summarises the status of national adaptation strategies. These strategies have the potential to be strong drivers of adaptation in the agriculture sector in Europe. A broad range of adaptation actions has been designed/planned at different government levels and in various sectors. From these efforts, both theoretical and practical knowledge has resulted in a wide range of possible options to adapt to projected climate changes impacts.

Many member states have carried out assessments of climate change impacts, including within the agriculture sector, but progress on implementing adaptation actions has been slow, due in part to the long-term nature of climate change effects or respective perceptions by policy makers and the sector alongside the complexity of the information required for decision-making and in part to the number of stakeholders involved. The focus of much of the effort made to date has been on management of flood risk. Adaptation strategies covering the agriculture sector are being developed in a number of countries. Immediate attention has focused on raising awareness and research activities, and these roles are often facilitated and complemented by organisations that are outside national governments, such as universities or trade and professional bodies (for example, the National Farmers' Union in the UK). National policies on adaptation in agriculture have not yet been clearly articulated.

Table 25 Summary of the National adaptation strategies in the EU-27 and other European countries

Status of the National Adaptation Strategies	Countries
Developed	Finland (published in 2005 by the Ministry of Agriculture and Forestry of Finland) Spain (PNACC is ongoing) France (National Adaptation Strategy) published in 2007 Sweden (National Adaptation Strategy) published in 2007
Under preparation, to be published in the near future (EU-27)	Netherlands (most developed in the water sector) UK (Adaptation Policy Framework is already in progress, under the guidance of the Department for Environment Food and Rural Affairs, Defra)
Under preparation, to be published in the near future (other European countries)	Norway (currently in the process of developing adequate response strategies to the impacts of climate change, both sector by sector and as an overall strategy)
First steps in including climate change adaptation within the framework of their National Climate Policy in addition and complementarily to mitigation	Rest of the countries

The following section highlights the country specific National Adaptation Strategies, their predominant focus and main national actions.

6.4.1 Cyprus

Cyprus is introducing adaptation strategies to combat water shortages, including increased use of treated and desalinated water, severe restrictions on domestic and agriculture water supplies as well as implementing irrigation programs according to crop irrigation needs. Desalination plants and new and improved irrigation systems are being built.

6.4.2 Finland

According to Finland's National Strategy for Adaptation to Climate Change (Anon., 2005a), recent experiences of extreme weather are not necessarily caused by climate change, but the impacts of climate change can be estimated on the basis of the extremes of the current climate. In summer 2004, for example, exceptionally high precipitation in Finland caused floods that led to nutrients and organic wastes from arable land entering watercourses, causing fish population mortality and crop damage.

The impacts of drought caused by climate change can also be assessed from current climate extremes. For example, prolonged drought in 2002/3 caused estimated losses of 100 million euros compared with normal years. Hydropower producers did not suffer any losses, but buildings, agriculture and water supply were affected and suffered damage, more than 1,400 farms suffered from drought. Water had to be transported by tanker to more than 1,100 farms. (Anon., 2005)

Finland's Adaptation Strategy is part of the National Energy and Climate Strategy that was forwarded to the Parliament in November 2005. Its objective is to reinforce and increase the capacity of society to adapt to climate change. Adaptation may involve minimising the adverse impacts of climate change, or taking advantage of its benefits. While the National Energy and Climate Strategy focuses on mitigation measures to be taken in the near future, the scope of the Adaptation Strategy extends as far as 2080. The Adaptation Strategy gives a detailed account of the expected impacts of climate change and presents adaptation measures to be taken in sectors including agriculture and food production, forestry, fisheries, reindeer husbandry, game management, water resources, biodiversity, industry, energy, transport and communication, land use and planning, building, health, tourism and recreation, and insurance. Priorities identified for increasing adaptation capacities for the next 5 to 10 years include: (i) mainstreaming climate change impacts and adaptation into sectoral policies; (ii) targeting long-term investments; (iii) coping with extreme weather events; (iv) improving monitoring systems; (v) strengthening research and development; and (vi) international cooperation. The research programme on adaptation was initiated in 2006. The National Strategy also identified sector-specific adaptation measures as important priorities for 2006 - 2015.

For the agriculture sector, Finland's national strategy indicates that the common agricultural policy of the EU will continue to steer agriculture and its regional orientation in Finland in the near future. Possible measures will include taking changing climatic conditions into account in future agricultural policy. Incentives could be used to improve more flexible land use and the regional distribution of cultivation so that any potential benefits of climate change can be utilised. It could be necessary to support the adoption of new technologies and cultivation methods and the diversification of agriculture. Minor changes may be required in the monitoring systems for animal diseases. The means for water protection must be assessed because of the likelihood of increased leaching of nutrients from agriculture. The need to develop risk management measures, as well as the compensation systems for crop damage and storm damage, may need to be assessed.

The following table (Table 26) is taken from Finland's National Adaptation Strategy and contains possible adaptation actions at a variety of timescales.

Table 26 Finland's National Adaptation Strategy

Time scales: *Immediate: 2005–2010, **short-term: 2010–2030, ***long-term: 2030–2080

Sector		Anticipatory	Reactive
Public	Administration and planning	Attention to production methods adaptable to climate change, production structure and locations in support policy Development of animal disease monitoring systems Development of plant disease and pest monitoring systems	
	Research and information	Development of new technologies and cultivation methods and providing information of them Conceptualisation of climate change and its risks	
	Economic-technical measures	Integration of changed climate conditions and plant protection requirements into plant improvement programmers	Minimising the disadvantages of the potentially increasing use of pesticides**
	Normative framework	Assessment of the revisions to water protection guidelines	
Private		Introduction of new cultivation methods, cultivated crops and technology	Extending the farm animal grazing period Increasing the control f pests and diseases

6.4.3 France

The National Adaptation Strategy has been presented in 2007. Following the strategy, France is currently in the process of preparing an Action Plan. Meanwhile, there are adaptation initiatives ongoing, particularly in relation to flood risk, soil management and sustainable water management. Recommendation 30 is concerned with agriculture. It highlights the need to modify the use of soils and water as a consequence of climate change. It also states that the impacts of climate warming should be included in agricultural policy and in future policy and operational programmes for rural development. The creation of a forum for information exchange between Government and agriculture professionals is proposed; this would consider climate change and its consequences, and its amelioration through adaptation.

Climate change is expected to bring more intense winter and spring flooding hazards, as well as low-water periods (from June/July to October/November). Occasionally the effects of such disturbances in the ecological cycle could combine with more frequent and intense flooding (as occurred in 2001 when an inundation swamped the department of the Somme while ground water was saturated (French Fourth National Communication to the UNFCCC, 2006)). The heat wave that affected France in 2003 led to droughts that affected almost the whole of country in 2003 and 2005.

6.4.4 Italy

In Italy plans are ongoing to address potential water crises, providing both technical and financial emergency measures. A National Plan for irrigation is ongoing and specific funds are allocated to alleviate the effects of extreme events (including droughts). The Rural Development Plan component of the National Strategic Plan includes specific measures for water resource protection especially with respect to 'Improvement of agricultural sector and forestry competitiveness' and 'Environmental and rural areas improvement. The programme CLIMAGRI, climate change and agriculture, ran from 2001 to 2004 with the aim of improving knowledge of linkages between agriculture and climate change (Annex E). The main focus was on climate change impacts, but with a view to support implementation of response measures, and draw recommendations for adaptation.

6.4.5 Malta

Among the EU projects being implemented in Malta are Inwaterman, and Interreg III A, which involves cooperation between Italy and Malta 2004-2010 (Annex E). The overall objective of the INWATERMAN project is the sustainable management of conventional and non-conventional water resources in arid and semi-arid insular settings. The government is planning a major flood relief project which will involve the catchment of storm water, its storage in galleries and its use for irrigation. This would mean that less water would be extracted from the aquifer, giving it time to recharge itself in volume and quality.

6.4.6 The Netherlands

The greatest concern in the Netherlands is flooding or breaching of water-retaining structures in the coastal areas of the rivers Rhine and Meuse or in the IJsselmeer lake region. Drought is also a perceived problem and can result in significant economic loss by agriculture as well as other industries. During the heat wave in 2003, for example, a dyke broke because of dried out embankments, endangering agricultural crops (Anon., 2005b).

Adaptation is most developed in the water sector (Coastal and riverine areas management, with e.g. the current Water Policy in the 21st century by the Ministry of Transport, Public Works and water Management, 2000). Adaptation measures also exist for ecosystem management (nature, biodiversity), agriculture, and spatial planning. Cost evaluation of adaptation measures is still limited.

6.4.7 Romania

The National Action Plan on Climate Change (2005) highlights the need for an Action Plan on Adaptation by 2007 (Annex E). A National Research Program is under consideration, which would assess the Romanian agro-climatic potential and establish the potential of the current major crops in order to initiate a sustainable management system, according current climate and climate change scenarios. New agro-climatic mapping could be created, containing a new regionalisation and classification of vulnerable areas to extreme events.

6.4.8 Spain

The Climate Change National Adaptation Plan, formally adopted by the Ministerial cabinet on 6 November 2006, is a reference framework for the coordination of public administrations in relation to the evaluation of impacts, vulnerability and adaptation to climate change in Spain. The Plan is based on knowledge development, public participation and information dissemination. The knowledge strategy ranges from the scenario development to sectoral impact evaluations. The adaptation component is not explicitly addressed. The plan establishes a complex institutional structure based in the Ministry of the Environment and coordinated by the Spanish National Office for Climate change that coordinates the Inter-ministerial Commission, the Coordination Commission for Climate Change Policies and the National Council for Climate.

6.4.9 United Kingdom

High and extreme rainfall and river flow are predicted. “Sensitivity analysis of river flood alleviation schemes should take account of potential increases of up to 20% in peak flows over the next 50 years” (MAFF, 2001). West and Gawith (2005), report that river flooding is expected to increase in winter across the UK.

A study of future drought risk by the Environment Agency’s Southern Region showed that a small increase in moderate drought conditions might be detectable as early as the 2020s, even under the Low Emissions scenario (Wade, 2004). Further work is required to demonstrate whether the projected change in drought conditions is beyond the limits of natural variability. Nonetheless, the study showed that by the 2080s, such conditions could be more frequent with the frequency of short (6 month) serious droughts, such as that experienced in 1995, increasing from 1 in 9 years (present) to 2 in 15 years (under the Low Emissions scenario) or 1 in 3 years (under the High Emissions scenario). (West and Gawith, 2005).

Action to prepare the UK for climate change has already begun (see Box 4 for a summary of the potential policy objectives). A climate change perspective is incorporated into many areas of Government policy, including flood management, water resources, planning, building regulations, health, agriculture and international development. Government funds the UK Climate Impacts Programme (UKCIP, www.ukcip.org.uk) to improve the knowledge base on climate impacts and to assist stakeholders (including those in the agriculture sector) to adapt.

The UK’s first Adaptation Policy Framework is under development, driven by the Department for Environment Food and Rural Affairs (Defra). The recognized key priorities for adaptation for the UK over the next 30 to 50 years are:

- water resource management;
- coastal and river flood defence;
- enhanced resilience of buildings and infrastructure;
- management of wildlife, forestry and agriculture;
- co-ordinated approaches to planning.

Box 4 Potential Adaptation Policy Objectives for Agriculture in the UK

A recent study funded by the UK Department for Environment, Food and Rural Affairs (Defra) suggested methods for developing adaptation policies, together with some possible policy objectives in priority sectors, including agriculture.

The objectives for agriculture, below, focus on clusters within the sector rather than on individual risks to crops or livestock. These broad objectives could encompass solutions to specific risks such as adapting management of livestock feed because of changes in the availability of autumn grazing; investing in irrigation and on-farm reservoirs to allow for drier summers or investing in new housing for livestock to avoid higher summer temperatures.

- Enable farmers and markets to take advantages of new opportunities and manage changes in climate resources and risks
- Anticipate climate change and ensure national strategy of adaptation is incorporated into agri-environment schemes and regulations
- To develop regional specific plans and anticipate new regional agro-processing needs due to shifts in regional suitability of agricultural activity/ crop.
- To anticipate new requirements for crops from plant breeding programmes particularly because of increases in temperature and summer drought conditions.

(Defra, 2005a)

6.5 Characterisation and evaluation of adaptation measures – EU-wide analysis

In this section we present potential adaptation measures for European agriculture. Adaptation options are directly linked to the risks and opportunities from climate change that have been identified in the previous chapter. To begin, the measures applicable to each of the risks and opportunities were identified, then further information on some key risks and opportunities is presented followed by examples for each agro-climatic zone. The obstacles and barriers to adaptation in each agro-climatic zone are also taken into account. Barriers may occur at any scale, from individual behavioural inertia to EU policy level. In particular, key current and future EU policies that affect the agricultural sector (e.g. Water Framework Directive) are considered, together with how responses to climate change in other sectors (e.g. tourism, nature conservation, water) may present a conflict or synergy with adaptation in agriculture.

Table 27 provides an assessment of the potential consequences for agricultural production of the identified risks and opportunities, adaptation options, option category and level of implementation. Additional information is provided in Annex D. We have considered timescales for action in the short-term (within the next five years), medium-term (within 5 to 10 years' time) or long-term (beyond 10 years). While these timeframes seem short in comparison with the timescales for climate change, they are used because they correspond to normal timescales for agricultural business planning and policy development. As the felt impacts of climate change intensify over the coming decades, many of the activities started in this first phase of adaptation will need to be stepped up or rolled out across wider areas.

There are a number of factors that determine the timescale or urgency with which an adaptation action is considered. Many adaptations may be carried out relatively quickly by individual farmers in response to events, for example bringing forward dates of planting, or sowing new varieties of current crops (if such varieties already exist). In these cases, timescale for action is likely to be governed mainly by the cost and technical feasibility of making such a change. However, some adaptations will require sector-wide co-operation (such as research to breed new crop varieties), or policy changes, or large-scale infrastructure investment, or development of a new habitat. In such cases, adaptation will require a long lead time of perhaps many years. Adaptations that can be addressed in a short timescale are those that can be rapidly implemented at a low cost, or those that need to be considered soon as their implementation is time consuming. One other reason for a short-term response is where there is a high level of uncertainty surrounding an impact or potential adaptation: in this case, further research may be needed as soon as possible to build greater knowledge so that a robust decision may be made about the nature and urgency of appropriate adaptation.

In some cases, the expertise for certain adaptations may not exist in some member states, agro-climatic zones or sectors. In this case communication and knowledge transfer is a key issue. While some may implement adaptation rapidly, it may take longer for others to build sufficient capacity.

Another factor that may need consideration in the assessment of "timeframe" and "importance" of adaptation actions is the cross-sectoral implications of particular decisions.

Table 27 Potential consequences for agricultural production of the identified risks and opportunities, adaptation options, option category and level of implementation.
* T: Technical / M: Management / I: Infrastructural / E: Equipment
** F: Farm level / S: Sector level

Consequences for agricultural production	Agricultural adaptation	Category *	Level **
Risks			
1. Crop area changes due to decrease in optimal farming conditions			
Main climatic causes of risk Changes in monthly precipitation distribution Increased temperatures in critical periods Increased erosion Loss of soil water retention capacity			

Consequences for agricultural production	Agricultural adaptation	Category *	Level **
Farming optimal conditions altered resulting in increased risk to rural income	Livelihood diversification	M	S
	Strengthen local capacity to reduce sensitivity	M	S
	Conversion of ambient storage to refrigerated stores	E	F
	Irrigation	I	F
	Changing cultivation practices	M	F
	Additional aphicide application	M	F
	Increased need for cutworm control	M	F
	Increased irrigation of maincrop potatoes	M	F
	Extra aphicide application in winter	M	F
	Fewer aphicide applications in summer	M	F
	Industry level: Movement of wheat to more favourable areas	M	S
	Change of cropping mix	M	F
	Switching to alternative crops	T	F
	Industry level: Loss of early potato production advantage and shift to alternative crop	T	F
	Industry level: Increase in wheat breeding investment	T	S
Loss of indigenous species	Climate change resilient crops	T	F
	Insurance	M	F
Soils deterioration due to land use changes	Extensification: enhance carbon management and zero tillage	M	F
	Precision agriculture: improve soil and crop management	M	F
Land abandonment due to very large changes in optimal conditions	Intensify research efforts and an enhanced training	T	S
	Livelihood diversification	M	S
2. Decreased crop productivity			
Main climatic causes of risk Changes in monthly precipitation distribution Increased temperatures in critical periods (heat stress) Loss of soil water retention capacity			
Crop productivity decrease	Change in crops and cropping patterns	M	F
	Industry research	T	S
	Increased input of agro-chemicals to maintain	M	F
	yields (as fertilizers rates)	M	F
	Irrigation	M	F
	Advisory services for farmers on adapted farming practices, new crops	M	S
Crop productivity variability risk increased	Agricultural insurance	M	F
	Crop planting diversification	M	F
Land abandonment	Design of regional adaptation plans	M	S
	Livelihood diversification	M	S
Agricultural trade intensification	Strengthen local capacity to reduce sensitivity	M	S
3. Increased risk of agricultural pests, diseases, weeds			
Main climatic causes of risk Increased water logging Increased average temperatures			
Pest populations increase and distribution with increased temp, boreal forest	Use new pest resistant varieties	M	F
	Use of thermostats and rapid cooling to reduce pest and disease infestation	E	F
	Develop sustainable integrated pesticides strategy	M	S
	Use of natural predators	M	F
	Vaccinate livestock	M	F
	Monitoring of pests/diseases patterns to prevent damages		

Consequences for agricultural production	**Agricultural adaptation**	**Category ***	**Level ****
Pollution by increased use of pesticides	Develop sustainable integrated pesticides strategy Advisory support for farmers	M M	S M
4. Crop quality decrease			
Main climatic causes of risk Heat stress Changes in annual and seasonal precipitation distribution			
Crop quality reduction in fruits and vegetables	Thermal screens Temperature control Use of thermostats and rapid cooling	E E E	F F F
Damage to grain formation due to heat stress	Thermal screens Temperature control Use of thermostats and rapid cooling	E E E	F F F
5. Increased risk of floods			
Main climatic causes of risk Increase of extreme events frequency Loss of soil water retention capacity			
Increased expenditure in emergency and remediation actions	Develop contingency plans Create/restore wetlands Enhance flood plain management Hard defences	M M M I	F F F S
Flash flood frequency and intensity increase	Increase rainfall interception capacity Move towards farmers as 'custodians' of floodplain lands with appropriate compensation Reduce grazing pressures to protect against soil erosion from flash flooding	M M M	F S F
Flooding and storm damage increase	Increase rainfall interception capacity/soil management Contour ploughing Increase drainage Addition of organic material into clay soils (difficult to work in wetter conditions) Insurance for farm infrastructure	M M I M M	F F F F F
6. Increased risk of drought and water scarcity			
Main climatic causes of risk Decreased annual and/ or seasonal precipitation Increase in the frequency of extreme conditions (droughts and heat waves)			
Conflicts among water users due to drought and water scarcity	Shift crops from areas that are vulnerable to drought Set clear water use priorities Increase water use efficiency	M M M	F S F

Consequences for agricultural production	Agricultural adaptation	Category *	Level **
Water supply reduced	Increase rainfall interception capacity (techniques for conserving soil moisture)	M	F
	Improve field drainage and soil absorption capacity	I	F
	Reduced run-off via contoured hedgerows and buffers	M	F
	Introduce forage crops into arable rotations	M	F
	Altering crop rotations to introduce crops more tolerant to heat/drought	M	F
	Woodland planting	M	F
	Use of precision farming: tillage and timing of operations	I	F
	Small-scale reservoirs and methods to collect water	M	F
	Water management	M	F
	Water audits	M	F
	Re-negotiation of water abstraction agreements	M	S
	Water charging/tradable permit schemes to promote efficient use of prescribed (reduced) sources	M	S
	Insurance (or other risk protection tools)	I	S
Groundwater abstraction, depletion and pollution	Re-negotiation of water abstraction agreements	M	F
Damage to wetlands	Installation of small-scale water reservoirs on farmland	I	F
	Recreate wetlands	M	F
7. Increased irrigation requirements			
Main climatic causes of risk Increased average and extreme temperature Increase of drought and heat stress conditions frequency Decreased precipitation			
Water availability decrease Water shortage in irrigated areas	Invest in irrigation equipment that helps reduce the severity and collects rain water	E	F
	Technical improvements in advanced irrigation equipment	T	S
	Trickle irrigation	E	F
	Irrigation during the night	M	F
	Separation of clean and dirty water	E	F
	Installation of small-scale water reservoirs on farmland	I	F
8. Water quality deterioration			
Main climatic causes of risk Increased precipitations extremes, flood and drought frequency			
Water quality loss due to the higher leaching and run-off	Aerating ploughing equipment	T	F
	Industry research	T	S
	Develop less polluting inputs	T	S
	Timed input of N inputs	M	F
	Reduce N outputs from soil through enhanced efficiency of fertiliser use	M	F
9. Soil erosion, salinisation, desertification			
Main climatic causes of risk Increased temperature Sea level rise Decreased precipitation Extreme conditions (heavy precipitations, drought) Melting of permafrost soils			

Consequences for agricultural production	Agricultural adaptation	Category *	Level **
Desertification due to water resources deficit, loss of soil structure, land abandonment	Livelihood diversification Strengthen local capacity to reduce sensitivity Intensify research efforts and an enhanced training	M M T	S S S
Soil salinisation increases	Change in cropping Allocate fields prone to flooding from sea level rise as set-aside	M M	F S
Erosion and accretion increase	Change fallow and mulching practices to retain moisture and organic matter Use intercropping to maximise use of moisture	M M	F F
Soil drainage changes leading to increased salinity	Change fallow and mulching practices to retain moisture and organic matter	M	F
Water logging increases	Invest in machinery or development and disseminate good practices that minimise the adverse effects of water logging	E	S
Loss of rural income	Change fallow and mulching practices to retain moisture and organic matter Livelihood diversification Strengthen local capacity to reduce sensitivity	M M M	F S S
10. Loss of glaciers and alteration of permafrost			
Main climatic causes of risk Increased temperature			
Glacier retreat and snow depth decrease	Compensatory water capture and storage systems	I	F
Permafrost thaw acceleration, destabilisation of soils, landslides	Repair, maintenance and structural underpinning of buildings and infrastructure.	I	F
11. Deterioration of conditions for livestock production			
Main climatic causes of risk Increased temperature and variability (heat stress) Appearance of new pests and diseases Change of optimal crop areas			
Livestock changes: health, nutrition, productivity and heat stress	Decline in number of native breed livestock and introduction of more heat tolerant species/breeds Move herds from waterlogged fields Increase shelter for animals Windbreak planting to provide shelter for animals from extreme weather Increase amount of wallows for outdoor pigs to protect them from the sun Change breeding and shearing patterns for sheep production Supplemental feeding	T M I I I M M	S F F F F F F
Loss in forage quantity and quality and grazing behaviour	Balance of grazing and cutting Use extended grazing or changes in the grazing regime Increase use of legumes Change of seed mixture Change the time of operations Match stocking densities to forage production	M M M M M M	F F F F F S
12. Sea level rise			
Main climatic causes of risk Increased sea temperature and accompanying thermal expansion of sea water			

Consequences for agricultural production	Agricultural adaptation	Category *	Level **
Sea level intrusion in coastal agricultural areas and salination of water supply	Hard defences Alternative drainage systems Set aside of land for buffer zones Alternative crops Livelihood diversification Research into other options for management of salt water intrusion	I I M M M T	S F F F F S
Opportunities			
1. Crop distribution changes leading to increase in optimal farming conditions			
Main climatic causes of opportunity Increased availability of CO_2 Increased temperatures			
Crop suitability increase	Introduce more productive varieties Increase range of crops (annual and permanent) Grow quicker maturing varieties to maximise yields Investment in energy crops, short-rotation coppice and miscanthus	M T T M	F F F F
2. Crop productivity increase			
Main climatic causes of opportunity Increased availability of CO_2 Increased temperatures			
Crop yield and biomass increase leading to increased potential efficiency of physiological water use due to CO_2 increase	Introduce more productive varieties Grow quicker maturing varieties to maximise yields Investment in energy crops, short-rotation coppice and miscanthus	M T M	F F F
Crop productivity increase due to increase of the frost-free period	Investment in energy crops, short-rotation copping practices	M	F
Reduced costs of frost damage	Frost resistant varieties obtained by improved breeding or by importing them form colder locations	T	S
Reduced drought impacts and damage	Drought resistant varieties obtained by improved breeding or by importing them form drier locations	T	S
3. Forest productivity increase			
Main climatic causes of opportunity Increased availability of CO_2 Increased temperatures			
Biomass production increase	Move away from monoculture Continuous cover forests with mixed stands of native species	M M	F F
4. Improvement of production in greenhouses			
Main climatic causes of opportunity Increased temperatures Improved growth conditions			
Decreased heating costs in greenhouses	Use ground heat sources when required	M	F
5. Increased water availability			
Main climatic causes of opportunity Increased water availability due to more favourable precipitation patterns and or amounts			
Potential increase in water availability for crops in wetter seasons	Extend arable farming to new areas Extend livestock farming to new areas	M	S
	Substitute higher-yielding cereal crops, e.g. wheat for barley	M	S

6. Improvement in livestock productivity			
Main climatic causes of opportunity Increased temperatures Improved crop growth conditions			
Reduced animal housing costs	Increase stocking rate Extend livestock farming to new areas Increase ventilation in housing/dairy parlours/transportation	M M I	F F F

6.6 Adaptation options to address climate change risks

The potential adaptation measures presented in Table 27 are analysed in detail in this section in relation to the EU as a whole. It is important, prior to developing an adaptation strategy for a particular region or community or farm, to consider this analysis taking into account the region or farm's specific circumstances. This is because socio-economic situations and environmental aspects vary substantially across the EU. In particular, income, level of education, and cultural norms may have an impact. Analysis at the necessary micro-level is not possible within the scope of this project, and would become obsolete relatively quickly due to changes in trends at this level.

6.6.1 Increased risk of drought and water scarcity

Responding to drought stress and the threat of declines in crop and pasture yields requires farm level actions such as changing land use in areas that are more susceptible to drought, changing cropping by switching to less water intensive crops, and investing in rain water harvesting equipment (Tompkins *et al.,* 2005). As noted above, there are opportunities for on-farm water collection and application of more efficient application techniques that will minimise the requirement for abstraction and use from public water supplies.

Crop husbandry adaptation measures include intercropping (where available space between rows is used by different crops to allow maximum use of the soil moisture); altering row and plant spacing (to increase root access to available soil moisture); and introducing or changing fallow and mulching practices to retain soil moisture and organic matter (Iglesias *et al.,* 2006). In response to forest fires during summer drought, the introduction and maintenance of firebreaks (where areas are cleared or burnt under controlled conditions) with access to water for fire fighting, will limit fire spread and damage (Viner *et al.,* 2006).

Investing in equipment at farm level to harvest rainwater and grey water all year round and provide additional irrigation will help maintain a more constant water supply. Improving water retention in soils, absorption and run-off via restoring natural features such as hedgerows, wash/wetlands and woodlands will buffer agricultural land from heavy precipitation (NFU, 2005).

Declining summer pasture is expected to increase the need and cost for supplementary feeding of livestock. Changing the timing of grazing and cutting operations should limit the need for additional feed.

It is predicted that there will be decreases in water availability during summer months due to a change in the balance of annual rainfall, with a greater proportion falling in winter. Adaptive measures to deal with this expected problem need to be taken at the farm level. There are potentially many options to choose from including improved rainfall harvesting e.g. separation of clean water falling on the roofs of livestock buildings from 'dirty' water falling on yards contaminated by livestock excreta, to more efficient methods of irrigation, such as trickle irrigation. Farmers will need to be made aware of these options and national governments may consider providing financial support. Synergy may exist between the techniques proposed to reduce the risk of run-off, and reducing the demand for supplementary irrigation. At the national level consideration may need to be given to water charging or tradable permit schemes to promote efficient use of prescribed (reduced) sources.

Current yields of potatoes, wheat, sugar beet, maize and field beans, which are dependant on summer rainfall, will decline in areas where there is reduced water availability. Farm level adaptation options are based around i) better water management to increase irrigation and improve water efficiency; ii) increasing the use of fertilizers to maintain yields so as to reduce the effects of pests and diseases; iii) accepting that it is no longer economical to grow such water demanding crops and diversifying to alternative crops or new varieties.

There will be a need for farmers in this region to adapt to an environment in which the risk of drought is increased and the supply of water is reduced (see Box 5). With demands for water from other consumers also likely to increase, the farming sector will need to take measures to both reduce their demand for water and become more efficient with their own resources.

The adaptation strategies to cope with the risk of a decline in productivity have actions in common with those to adapt to increased drought stress. For example the adoption of new crops, such as grain maize, which are more tolerant of heat, together with more heat resistant cultivars of current crops (see Box 5). Earlier planting, so that maturation occurs before the summer when temperatures are greatest, is also an option. Diversified crop rotations and activities will help further. Farmers will need to be made aware of these options, while new cultivars will require plant breeders to prioritise the development of heat-resistant cultivars.

Box 5 Proposed adaptation measures for Canadian Agriculture

To adapt to drought the agricultural sector in Canada has identified these potential adaptation options:

Diversify Crops

More perennial crops (e.g., forages) are grown, thus improving drought tolerance by enhancing soil quality and moisture retention.

Where possible, some producers are re-introducing native grasses for pasturing. These grasses are drought resistant when rotational grazing is practiced on them.

Many prairie producers are moving away from wheat monoculture and growing a wide variety of new crops (e.g., pulses) that are more drought resistant.

A diversity of crop types and varieties are grown in rotation and in different areas of farm properties. This spreads the risk of losing an entire year's production since conditions can vary across fairly small areas and different crops vary in how they respond to those conditions.

When possible, some producers also stagger their seeding and therefore, harvesting dates by choosing a variety of crops that require a range of growing conditions so that crops are at different stages (and therefore more or less vulnerable) if and when climate/weather conditions start having a negative impact.

Land Resource Management

Conservation tillage practices were cited by all producers as having several positive outcomes for reducing risks from drought. These include: reducing soil erosion; enhancing moisture retention; and minimizing soil impaction.

Conservation tillage is also credited with limiting damage from run off and erosion during flooding.

Some producers are enhancing established shelterbelts and/or adding new ones. This can reduce negative impacts from drought by maintaining water tables, increasing biomass in soil, and ensuring surface moisture is kept on the land. Shelterbelts also provide protection from heat and wind for livestock, and can increase the heat units in adjacent fields.

Some producers cut stubble at different heights to trap snow on field surfaces thereby enhancing spring moisture levels in the soil.

Consideration should also be given to the extent to which farmers can adapt to the changed climate by growing the same crops but for different markets. For example, in areas where maincrop potatoes are currently grown reduced water availability may mean that the crop is no longer profitable. However, water resources may be adequate to produce profitable yields of early potatoes. Moreover, which careful use of the water resources available, double-cropping of early potatoes may be possible by planting in the early autumn.

For livestock farmers the reduced yields of traditional forages such as grass may lead to cultivation of alternatives such as soya or birseem. Information must be made available to the industry to facilitate such a change and research institutes may need to initiate programmes of testing or developing cultivars that can give the best results under local conditions.

The IPCC's Fourth Assessment report (2007) stated that 'on average in cereal cropping systems, changing varieties and sowing dates can compensate for a 10-15% reduction in yield, corresponding to a 1-2°C rise in temperature, and adaptive capacity at low altitudes is exceeded at 3°C local temperature rise'. On this evidence it would seem that, for regions where temperatures are forecast to increase by 4-5°C by the end of the century, it will not be possible in the lowland parts of the zone to completely adapt to the impacts on currently cultivated cereals.

Measures to adapt to the expected decrease in water availability and drought risk may be grouped under three headings. Measures to increase the water-holding capacity of soils to reduce the need for irrigation; measures that increase the collection of rainwater over winter to increase the supply for subsequent irrigation; measures to improve the efficiency with which irrigation water is applied.

Increasing the organic matter content of soils thereby improving soil structure may enhance the water-holding capacity of soils. Minimal cultivation may have a role to play but care needs to be taken to ensure that reduced cultivations do not increase run-off. Contoured cultivations supplemented by contoured hedge planting or the adoption of buffer strips at the lower edges of fields will help reduce this.

Irrigation may be used more efficiently by a range of approaches from irrigating at night when evapotranspiration is reduced to use of trickle irrigation.

These measures will tend to be applied at farm level using existing technology. However, regulatory authorities may stimulate innovation in this area by economic instruments that promote the efficient use of water.

In addition to the risk to crops from reduced water availability, there is also the likelihood that yields will be reduced, even when water supply is not limiting, from warmer temperatures leading to increased evapo-transpiration. On-farm measures to adapt to this problem would include earlier sowing, of both Autumn and Spring-sown crops so that the maturation phase occurs earlier and before the occurrence of peak temperatures in the summer.

Approaches have been proposed to adapt to this risk. One option is to shift the cultivation of current crops from areas that are vulnerable to drought. However, this may have only very limited applicability due to the large area of the affected zone.

Rainfall is predicted to decrease while evapotranspiration is expected to increase and so water supply is likely to diminish. Increasing temperatures are likely to increase demand by other sectors potentially leading to conflicting demands for a diminishing resource. Thus, if the agriculture industry aims to adapt by increasing irrigation, the water resources necessary may need to be supplied form within the farm. This may be achieved by on-farm rainwater harvesting and establishing small-scale water reservoirs on farmland while improving the efficiency with which irrigation water is used. Government agencies and regulators may provide an incentive for farmers to take action by re-negotiating water abstraction licenses and/or introducing charging/tradable permit schemes to promote efficient use of reduced water resources.

6.6.2 Decreased crop productivity

Despite the greater potential for overall crop productivity from a longer growing season in some parts of the EU, a northward shift in the cultivable zone, and increased CO_2 concentrations in the atmosphere, it is likely that yields per hectare could be reduced as a result of increased temperatures during summer leading to increased photorespiration and/or reduced photosynthesis. The main adaptive strategies to deal with this risk, which can be adopted at the farm scale, would be to grow the most heat resistant cultivars and to sow crops earlier in autumn or spring so that maturation occurs before peak summer temperatures. Crop breeding institutes will need to focus on this aspect of crop production in their breeding programmes.

Crop productivity decrease, changing to new cultivars adapted to low chill environments (e.g. blackcurrant) from existing cultivars which require winter chilling will avoid yield loss at farm level (NFU, 2005).

No specific measure was identified to combat the potential risk of land abandonment. To reduce the risk of this taking place a broad range of infrastructural measures would be needed to increase the uptake of the specific measures needed to maintain production, whether of traditional crops and livestock or as the result of introducing new enterprises.

6.6.3 Crop quality decrease

High quality wines require lower temperatures. Increasing temperatures will lead to deterioration of the grape quality needed. Changing acidity and sweetness in grapes through increased CO_2 had been identified as reducing the quality of high quality wines (EC, 1997). The use of protective and monitoring equipment such as thermal screening and thermometers will allow better temperature control, (NFU, 2005). Investment in thermal screens would provide shade from direct sunlight and prevent mineral deterioration in fruit (NFU, 2005). However, such an approach is likely to be expensive.

6.6.4 Increased risk of agricultural pests, diseases, weeds

Potential adaptation strategies have been identified to reduce the risks of proliferation of new pests and diseases and to lessen the impacts of those that do arrive. The introduction of resistant or less-susceptible varieties is one approach. Most of these measures are considered to be farm management decisions, although the dividing line between management and technical measures may be blurred. To deal with new crop pests (e.g. Colorado Beetle, or European Corn Borer) a sustainable integrated pesticides strategy should be developed (see Box 6), which is a technical measure. Some infrastructural support is needed to identify and promote the use of resistant cultivars, sustainable pesticides strategies, etc. In addition, when adapting to the pressures of new pests and diseases, the use of new pesticides needs to be carefully evaluated with respect to the potential impacts on water quality. Within greenhouses the use of thermostats and rapid cooling may be used to reduce pest and disease infestation. Livestock disease adaptation measures include vaccination of both the domestic and wild populations (Viner *et al.,* 2006).

Box 6 Crop monitoring

The UK Crop Monitor website, run by the Central Science Laboratory for the UK, provides information sourced from monitoring sites located across the country and reports up to date measurements of crop pest and disease activity in arable crops throughout England. All data gathered are being analysed to identify disease and pest risk, seasonal variation in disease development and the effectiveness of control strategies. Users will be alerted to emerging threats during the growing season and advised on appropriate courses of action.

A changing climate and associated warming is likely to lead to the introduction of new pests and diseases and changes to the intensity/occurrence of current infestations. While adaptive measures need to be taken at the farm level, research institutes and extension services will need to identify potential risks and devise appropriate strategies to deal with them. Such information will then need to be promulgated to farmers (see Box 7).

Box 7 Breeding of heat- and drought-resistant crop varieties

A major adaptive response will be the breeding of heat- and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Collections of such genetic resources are maintained in germ-plasm banks; these may be screened to find sources of resistance to changing diseases and insects, as well as tolerances to heat and water stress and better compatibility to new agricultural technologies. Crop varieties with a higher harvest index (the fraction of total plant matter that is marketable) will help to keep irrigated production efficient under conditions of reduced water supplies or enhanced demands. Genetic manipulation may also help to exploit the beneficial effects of CO_2 enhancement on crop growth and water use (Rosenzweig and Hillel 1998).

To enable farmers to combat the arrival of new or increased threats form pest and disease infestation, information needs to be provided of the potential risks and the treatments needed. Studies have been carried out to assess the likely risks, and the results need to be reviewed and updated. In many countries sophisticated pest and disease warning services already exist and these require continued support to enable farmers to adapt to the new problems. There will also be a need for researchers or extension services to develop a sustainable integrated pesticides strategy to deal with the changed pest and disease spectrum. The approach should include identification of resistant/tolerant cultivars and make maximum use of natural predators.

In order for farmers to adapt to new pest and disease pressures research and extension organisations will need to identify potential problems and develop strategies to minimise the impact of theses new problems. This may include the promotion of more resistant varieties and/or a pest control programme.

6.6.5 Increased risk of floods

Farm-level actions are needed to improve soil drainage to reduce waterlogging and the consequent impacts on stock health. However, improving drainage from fields, by increasing the rate at which water is discharged to streams and rivers may increase the risk of flooding downstream. In consequence adaptation to this risk should focus on disseminating information on minimising the adverse impacts of waterlogging and on recommending farmers move stock from those fields vulnerable to waterlogging (see Box 8).

Box 8 Proposed measures to reduce waterlogging risk (Kerr and McLeod, 2001)

At present in Scotland, waterlogged fields appear to provide one of the biggest business risks from climate change. If we consider that adaptation to current climate extremes is generally consistent with adapting to future conditions, investing in machinery that enable field operations to be carried out under conditions which would not be possible with current machinery, or developing and disseminating practices that minimise the adverse effects of waterlogging, are likely to be beneficial. The inherent variability of Scotland's climate means that events such as the timing of planting and harvesting are likely to change incrementally year by year. Forms of support that encourage flexibility of farming systems or diversification of income provision, such as the Land Management Contracts mooted in the Forward Strategy for Agriculture, become powerful agents for increasing flexibility in response to climate change as well as socio-economic drivers.

The majority of proposed adaptation measures would be implemented at the farm level. Protection of buildings and equipment should be covered by adequate farm level insurance (Viner *et al.,* 2006). With regard to the land, adaptation would aim to increase the infiltration capacity of the soil by measures ranging from improving soil structure to contour ploughing. Planting or providing 'breaks' such as hedges would interrupt downslope flow, while increasing the area of undrained farm woodlands would help to buffer peak rainfall events, slowing the movement of water from soil to watercourses (see Box 9). This will help balance the increase in water transfer from soils to watercourses bought about by improved drainage. To encourage such actions, policy makers would need to encourage farmers to act as 'custodians' of floodplain lands with appropriate compensation (Defra, 2006). Improved on-farm management alone may not fully adapt to the risk. There is likely to be a need for infrastructural adaptation including 'hard' defences and drainage systems.

Box 9 Reducing flood flows through floodplain woodland

While this report is focussed on adaptation measures for agriculture, one of the conclusions of Kerr and McLeod (2001) was that 'one consequence of the drive for more flexibility in the agricultural sector, coupled to tighter environmental obligations, will be the blurring and perhaps in the longer term the removal of the historic distinction between forestry, agricultural and nature conservation policy.' Hence we consider this example is a relevant one for consideration.

In theory, trees and wood cover should slow down flood flows creating a physical barrier and so reduce the down stream impact of a flood event. This has been harder to demonstrate in practice. Taking the river Parrett (in South-west England) as a case study, a hydraulic model was used to simulate three scenarios for a 1 in a 100 year flood event.

The first scenario represents the existing situation with the floodplain covered by pasture. In the second scenario the vegetation on the northern bank was simulated as being thick broadleaved woodland. The third scenario simulated a central block of woodland in the centre of the floodplain.

Results suggested that the establishment of floodplain woodland along the north bank of the river could have a significant effect on extreme flood events. The ‘roughness’ of the woodland reduced the velocity of water flow by around 50%, which in turn increased the depth of floodwater in the woodland by 50-270 mm (this represented an increase in flood storage volume of 71% delaying the downstream progression of the floodwater by under 2 hours). The central block of woodland had a smaller, but still significant effect.

The results suggest there may be considerable scope in using floodplain woodland in helping manage flooding problems, particularly where the cost of hard defences may be prohibitive.

There will also be a risk of flooding events due to a forecast increase in extreme rainfall events. The requirements for adaptation to the impacts of increased over-winter rainfall are likely to lead to some conflicting priorities. Improved field drainage systems would reduce the risk of waterlogging and hence reduce the risk of decreased crop yields or adverse effects on stock health. However, waterlogged soils can act as a buffer holding water to be released slowly to watercourses. Measures to improve the drainage of agricultural land may increase flooding risk elsewhere. There needs to be liaison therefore between the authorities responsible for protecting against flooding and those acting on behalf of farmers. Some synergy may be obtained by increasing the areas on farms given over to floodplains etc that allow high river flows to be dispersed away from population centres.

As reported for other zones, the majority of adaptation measures proposed would be implemented at the farm level and range from improving soil structure to contour ploughing. Providing 'breaks' such as hedges and increasing the area of undrained farm woodlands would help to buffer peak rainfall events, slowing the movement of water from soil to watercourse. This will help balance the increase in water transfer from soils to watercourses bought about by improved drainage. Policy makers would need to encourage farmers to act as ‘custodians’ of floodplain lands with appropriate compensation. Improved on-farm management alone may not fully adapt to the risk. There is likely to be a need for infrastructural adaptation including 'hard' defences and drainage systems.

6.6.6 Water quality deterioration

The main threat to water quality is through increased point-source pollution. Farm-level measures need to be encouraged that reduce run-off from agricultural land, especially when livestock manures have been applied. Diffuse pollution may also be a problem if heavy rainfall occurs in spring after fertilizer application. Fertilizer efficiency and application methods need to be improved.

The risk to water quality is likely to come mainly from point source pollution arising from run-off fertilizers applied over winter of from soils erosion leading to sediment being deposited in water courses. Hence farmers need to be made aware of best practice both with respect to the application of manures and fertilizers and controlling soil erosion. The use of buffer strips (hedgerows, vegetative rows) beside water courses can be effective in reducing nutrient leaching.

6.6.7 Loss of glaciers and alteration of permafrost

Increasing temperatures are affecting physical systems in Alpine regions and the Arctic. Glacial retreat and snow depth decrease have been noted in the Alps and Pyrenees, and these will be exacerbated as temperatures continue to rise (http://www.pik-potsdam.de/ateam/). Mountain communities’ dependant upon melt waters for their domestic and agricultural supply will need to invest in water capture and storage systems to compensated for the projected changes in seasonal water availability that will affect these regions.

In the Arctic, thawing permafrost is affecting the stability of buildings, roads and other infrastructural components. These affects will become more wide spread with rising temperatures (http://www.acia.uaf.edu/). Structural repairs and maintenance are already been carried out in the worst affected areas and programmes of preventative action are needed elsewhere.

6.6.8 Deterioration of conditions for livestock production

Wetter winters and an increased likelihood of fields remaining waterlogged into spring mean that the housing period of ruminant livestock may need to be increased, with the animals remaining inside for longer in the spring. The hotter summers forecast for this zone may also mean that ruminants may need to be housed in summer to reduce problems from heat stress or because pastures may not remain productive during the summer months. One adaptation strategy would be to change the cutting and grazing regime for grassland. While wetter winters may lead to fields remaining wet for longer in spring, the warmer and drier summers may enable farmers to harvest larger yields of silage in late spring. Thermal stress reduces productivity (as animals tend to eat less), conception rates and can ultimately threat livestock life. Moreover, soils will take longer to reach field capacity in autumn and grass growth is likely to be substantial until the end of the year. Hence the grazing season may be lengthened in autumn and into the early winter period, and hence may at least partially compensate for the reduced grazing opportunities in early spring and late summer.

Extended warm periods will see increased cases of heat stress amongst livestock. Catering for animal welfare under these conditions by increasing the amount of shade and shelter, potentially even keeping livestock indoors, together with the selection of alternative breeds more suited to warmer temperatures will reduce the occurrence of heat stress (NFU, 2005). Planting tall, fast-growing, trees such as poplar of willow on the southern edge of pastures is one method of increasing shade (see Box 10). Increased mechanical ventilation of both housing (NFU, 2005) and transportation for livestock will reduce the risk of heat stress (questionnaire respondent suggestion). Where pigs and poultry are still kept in naturally-ventilated buildings it may be necessary to adapt the building to mechanical ventilation or to construct new buildings.

Supplementary feeding, increased irrigation and drainage and altering current grazing practice through: balanced cutting and grazing, extended and buffer grazing, increased use of legumes, more frequent re-seeding (Defra, 2002) should reduce the risk of lost earnings from sheep, pigs and milk production.
Increased temperatures and decreased rainfall in summer are also likely to reduce forage yields, especially on pastures grazed during summer. Adaptation measures include growing a new range of forage crops, such as soya, or making increasing use of forage grown during early spring and late autumn.

Reduced earnings may arise from the costs of increasing the ventilation rate in buildings housing granivores; the need to provide shelter for ruminants; the costs of providing substitute feed if forage production decreases. For ruminants adaptation may be achieved by changing the pattern of housing with livestock grazing both earlier and later in the season than at present.

Box 10 Agro-forestry

Agro-forestry, by providing shade, has the potential to counteract the effects of increased summer temperatures on current crops and livestock by moderating microclimates. Shelter given by trees and shade in summer has been shown to improve yields of nearby crops and, reducing heat stress, can be beneficial for livestock. These benefits occur because of modifications to the micro-environment which reduce crop evapotranspiration and conserve soil moisture. For example, in the east of Scotland, pasture production below well-grown agro-forestry trees has been found to be up to 16% greater than conventional pastoral agriculture
(http://www.macaulay.ac.uk/fmd/agroforest.html).
Agro-forestry can augment soil water availability to land-use systems. However, in dry regions, though, competition between trees and crops may be a problem.

Granivores and intensively-raised ruminants are likely to be housed in mechanically-ventilated buildings and hence heat stress can be reduced by increasing the ventilation rate. For less intensively-raised granivores and ruminants the most cost-effective adaptation is likely to be to provide shelter in the pastures, e.g. by planting shelter belts of fast-growing trees such as poplars and willow. Another strategy would be to introduce more heat tolerant breeds of livestock.

This will require information to be made available to farmers on the husbandry requirements of new breeds. However, at present, more heat tolerant livestock breeds are often less productive. A challenge for livestock breeders will be to combine heat tolerance with productivity of temperate breeds.

Reduced yields of current forages could be compensated for by the introduction of more drought and heat resistant forage varieties. Again, this would require action by extension services to identify potential new crops and make available to farmers information on husbandry.

6.6.9 Sea level rise

The threat from rising sea levels is the one that most requires an infrastructural approach. National governments will need to decide the balance between constructing 'hard' flood defences and allowing land to be abandoned to inundation. Research into alternative options to protect soil from salt-water intrusion is needed (questionnaire respondent suggestion). The use of agri-environment schemes to support farmers who lose land to sea flooding may need to be considered. This is regarded as a high priority action because it is potentially expensive and because the implications of sea level rise are serious and an integrated strategy may need to be developed.

Decisions will need to be made at national level on priorities for 'hard' defences to protect land against rising sea levels. In practice it is likely that priority will be given to protecting population centres. National governments will also need to decide is any compensation is to be offered to farmers whose land will be inundated. For example, the Veta la Palma estate in Andalusia, Spain is located on the largest island in the Guadalquivir delta. The estate is 2m above sea level so hard defences are being considered as sea level rise threatens both the estate’s rice production and its biodiversity (the estate is part of the Natura 2000 network) (Viner *et al.,* 2006).

This is a risk that needs adaptive actions at the national or supra-national level. Strategic decisions need to be made of the extent to which vulnerable areas need to be protected by 'hard' flood defence systems, or can be surrendered. It is likely that priorities for coastal defence will be given to those areas that are most densely populated, and that agricultural land will be sacrificed. However, an assessment needs to be made of the productive quality of agricultural land and consideration given to protective measures for the most productive land.

Rising sea levels threaten some of the most productive agricultural areas in some zones, for example the Po valley. In other agroclimatic zones priority for 'hard' flood defences is likely to be given to protecting population centres. However, given the relatively small ratio of low-lying coast to river basin area, consideration might be given to constructing a defence to protect this large and very productive agricultural area.

6.7 Adaptation options to exploit climate change opportunities

The potential adaptation measures presented in Table 28 relating to potential opportunities are analysed in detail in this section. As in the previous section the focus is on general adaptation measures relevant to the whole of the EU. It would be important, prior to developing an adaptation strategy for a particular region or community or farm, to reconsider this analysis taking into account the area’s specific circumstances. This is because the socio-economic situation, as well as environmental aspects, can vary substantially across different areas of the EU. In particular, income, educational level, and cultural norms may have an impact. Analysis at the necessary micro-level is not possible within the scope of this project, and could in any case become obsolete relatively quickly with changes and trends at this level.

6.7.1 Crop distribution changes leading to increase in optimal farming conditions and crop productivity increase

These opportunities are regarded as both managerial and technical in nature. The use of new cultivars is managerial, as the main barrier to the realisation of greater crop yields is likely to be a lack of knowledge of crop production and the appropriate equipment. A switch to wheat in place of barley for example has the potential to increase overall yields, but this may be limited by soil type; the yield potential of wheat is best realised on moisture-retentive soils while barley will grow well on light, sandy soils. The introduction of new crops would also require technical support. Reduced frost (Tompkins *et al.,* 2005) will also alter the range of crops suitable, so access to information on alternative crop husbandry will be needed.

The longer growing season has been identified as offering opportunities to grow biomass crops. Not only will information need to be made available to farmers on the husbandry needed to grow these crops successfully, but a market for the product will need to be created by either building generating capacity specifically for biomass crops or by making co-firing possible in existing power stations, or both. Switching to quicker maturing varieties will maximise yields under a longer growing season (Iglesias *et al.,* 2006).

Switching from traditional to new fruit is likely to benefit from technical support by national extension services, where they exist. Relevant advice would include suitable varieties for the new climate (NFU, 2005), pest and disease problems and an assessment of the suitability of local soil types. For example, in the boreal region the prevalence of acid free-draining soils, often with high organic matter content, make the cultivation of blueberries possible. However, blackcurrants, which require a high pH soil, could only be grown after either careful selection of alkaline soils or following application of lime.

These opportunities are regarded as technical in nature as the main barrier to the realisation of greater crop yields is likely to be knowledge of crop production and the appropriate equipment. This is because increased production would come from new crops that would be productive under the changed climate, rather than the introduction of new cultivars of traditional crops. For example, while farmers in this zone might have experience of growing wheat and barley, they will not be familiar with the requirements of crops such as sorghum.

The potential benefit from the explanation of goring areas is likely to take place slowly. The expectation of higher crop yields should facilitate the necessary changes to farm practice. Increased average temperatures and a longer growing season may offer the opportunity to grow crops such as vegetables. To make this a viable option, information on the husbandry requirements for such crops will need to be made available to farmers.

While a warmer climate poses a risk to some traditional fruit growing, opportunities will be presented to grow new types of fruit. As reported above the barriers to the successful uptake of this opportunity are not only the need for growers to become skilled in new techniques but also the financial costs of grubbing existing orchards and fields and buying new fruiting stock. National governments need to decide whether this activity should be supported financially or whether uptake should be left market considerations. As an example of potential actions an initiative from Canada is reported in Box 5.

Opportunities to grow new crops such as soya are expected. Work will need to be done by government agencies and advisory services to assess the climatic and soil requirements of such crops, to identify appropriate varieties and make information on husbandry techniques available to the farming community.

Some of these measures will require little or no external input to make them possible. However, as is forecast for arable production, increased cultivation of forage legumes may only occur if farmers are made aware of the potential for these new crops and given some training or advice in their cultivation. However, increased winter rainfall may mean that pastures will be too wet to allow animals outside for grazing, although the slope of Alpine pastures will reduce waterlogging risk.

The results of studies to identify new crops that might be profitably grown need to be promulgated to the farming industry. Factors that farmers will need to be made aware of include: soil requirements, texture, pH etc., fertilizer requirements; pest and disease pressures, harvesting and storage requirements.

6.7.2 Improvements in livestock productivity

The longer growing season, greater grass production and warmer temperatures all mean that livestock housing costs should be reduced. For ruminants this will be because the longer growing season will enable livestock to graze longer. For granivores, the reduction in housing costs will be due to a reduced need for heating over winter. A further cost reduction may accrue from the increased potential to grow forage legumes. Some of these measures will require little or no external input to make them possible.

The longer growing season and subsequent earlier grass growth in spring and later growth in autumn mean that housing costs may be reduced by extending the grazing season for cattle. Such an approach is reasonably easy to adopt. The potential limitation to the widespread adoption of this practice is the forecast of increased over-winter rainfall and hence the potential prevalence of fields being water-logged over winter. However, the likelihood of waterlogging will depend greatly on location and soil type and hence in those areas least at risk from waterlogging extending the grazing season may be a very useful adaptation strategy. Decreased summer rainfall may also limit grass growth.

For those areas where extending the grazing season is not an option it may still be possible to save costs by conserving the increased grass production as silage thereby saving costs or increasing income either by reducing dependence on bought-in feeds or by increasing the stocking rate.

6.7.3 Improvements of production in greenhouses

Increasing temperatures are improving the natural crop growth conditions in greenhouses and decreasing the need for additional heating and the use of fossil fuels as a heat source. To further exploit temperature rise and minimise further dependence on fossil fuels it is recommended that greater use is made of ground heat and heat pump technologies to supplement ambient heat.

6.8 Summary of territorial risks, opportunities and adaptation

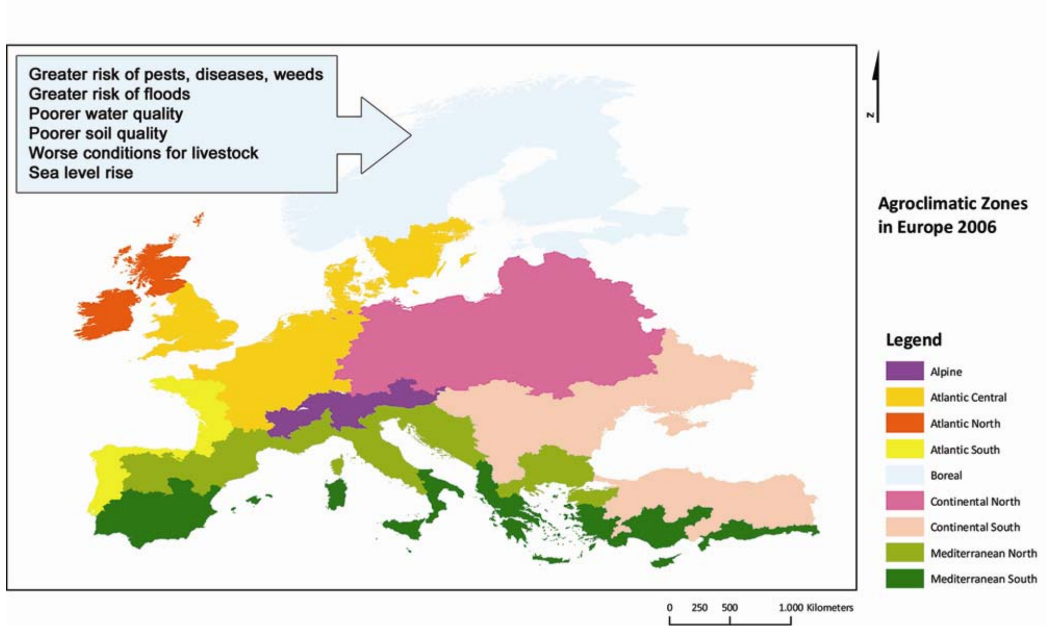
This section provides a summary of the high priority risks and opportunities that call for potential adaptation measures and the on-going adaptation actions in the European agro-climatic regions. In all regions there are already on-going adaptation actions (summarised in Table 25 and Annex E and discussed in Chapter 6). Although some of the risks may be common – such as drought – the significance of such risks and the necessary measures to adapt to them vary across the regions. This territorial perspective aims to provide means of comparing across areas highlighting the similarities and differences. Potential adaptation measures are not included in this summary to avoid repetitions, but are fully discussed in Chapter 6.

6.8.1 Boreal

High priority risks and opportunities

For the boreal zone, the assessment of impacts of climate change identified seven risks, six being high priority, for which adaptation measures should be derived. Of the 6 opportunities identified, three were assessed as being of high priority and of those three relate to increased crop production. High priority risks are highlighted in Figure 10.

Figure 10 High priority risks from climate change for the Boreal zone



Boreal Zone:
Sweden
Finland
Latvia
Estonia

Adapting to risks and opportunities

In this zone, farming will mainly need to adapt to increased rainfall. There is potential for conflict between proposed adaptation measures at the farm and at the wider scale. An obvious farm-level measure is to improve drainage to reducing waterlogging and hence improve crop growth, reduce risks to stock health and reduce the risk of point source pollution from run-off. However, the rapid removal of water from agricultural land, by increasing stream flow, may increase the risk of flooding downstream. Hence there will need to be an assessment of the impacts of any programme to improve farm drainage on the requirement for hard flood defences in vulnerable zones.

In response to the opportunities in the Boreal zone, the greater area of land available for a range of crops, longer growing season and increased temperature offer the potential to improve the productivity and/or profitability of all agricultural sectors. To maximise these opportunities in many cases farmers will need access to information on new cultivars and their husbandry. Careful consideration also needs to be given to the potential impacts of increasing agricultural production in this zone on biodiversity and the overall landscape quality.

On-going adaptation actions

Of the countries within the Boreal zone, only Finland was reported under the Nairobi work programme (SBSTA. 2007) to have a National Strategy for Adaptation to Climate Change (see Annex E). Immediate measures involve planning of water services, surveying of risk sites, preparation of general plans for risk sites, construction of irrigation systems for agriculture, improved preparation for exceptional situations and regional co-operation, increase discharge capacity of dams, improve dam safety and re-evaluate design discharges at major dams, restrictions on water use long-term: adapt national plans to climate change effects and improve climate forecasting.

Several measures were reported to be under implementation in Latvia, mainly concerned with coastal defence and reducing flood risk. Risk management for agriculture was also reported as under consideration. The Latvian State Institute of Agrarian Economics is carrying out research on the justification for an agricultural insurance system. Annual state subsidies, inter alia, for compensation damage made in agriculture, and for forest and agricultural land (soil) amelioration are also ongoing. In Sweden a survey on the vulnerability of society to climate change is in progress.

Thus national-scale measures are under consideration to cope with the consequences of increased rainfall. However, there is no mention of any national initiative to promote the uptake of practices to respond to the potential opportunities.

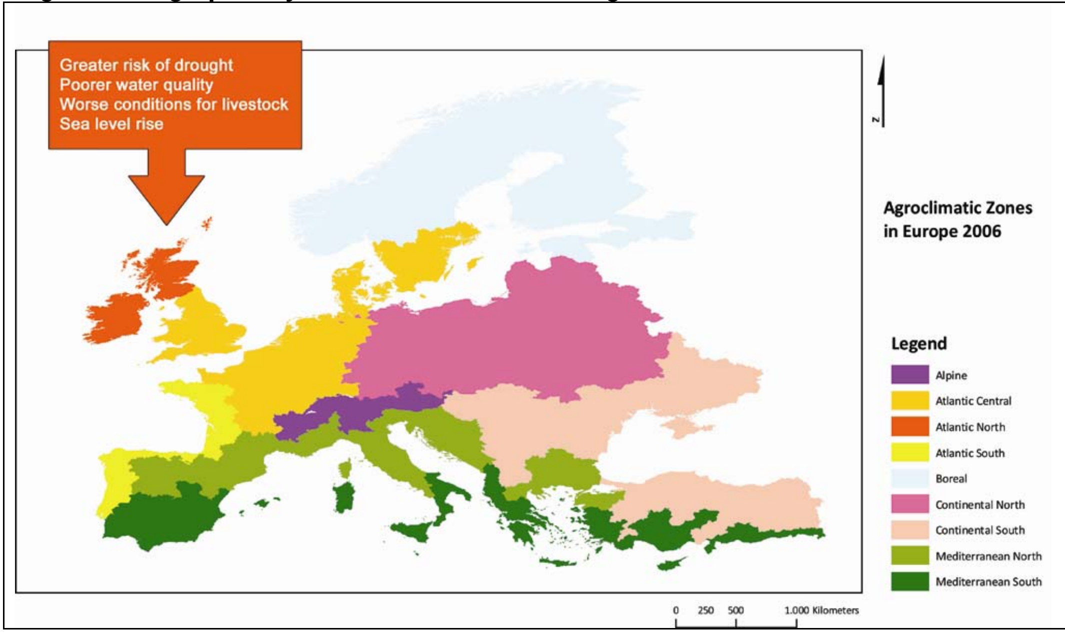
We regard adaptation to sea level rise as a high priority action because although potentially expensive the implications of sea level rise are serious and an integrated strategy needs to be developed. We also recommend that developing policies to encourage farmers to be custodians of the flood plains be regarded as a priority.

6.8.2 Atlantic North

High priority risks and opportunities

Seven risks were identified for the Atlantic North zone, four of which are high priority, for which adaptation measures should be introduced. Of the five opportunities identified, three were assessed as being of high priority and of those three relate to increased crop production, and the remainder to increased grazing for livestock. High priority risks are highlighted in Figure 11.

Figure 11 High priority risks from climate change for the Atlantic North zone



Atlantic North: Ireland Scotland

Adapting to risks and opportunities

In this zone, farming will need to adapt to the risks of intensification of winter rainfall as well as reduced summer rainfall and the likely introduction of new pests and disease, in warming conditions. Farm-level measures are needed to allow rainwater harvesting and improve drainage to reducing waterlogging and hence improve crop growth, reduce risks to stock health and reduce the risk of point source pollution from run-off and leaching of fertilizers.

The greater area of land available for a range of crops, longer growing season and increased temperature offer the potential to improve the productivity and/or profitability of all agricultural sectors. To maximise these opportunities in many cases farmers will need access to information on new crops and their husbandry.

On-going adaptation actions

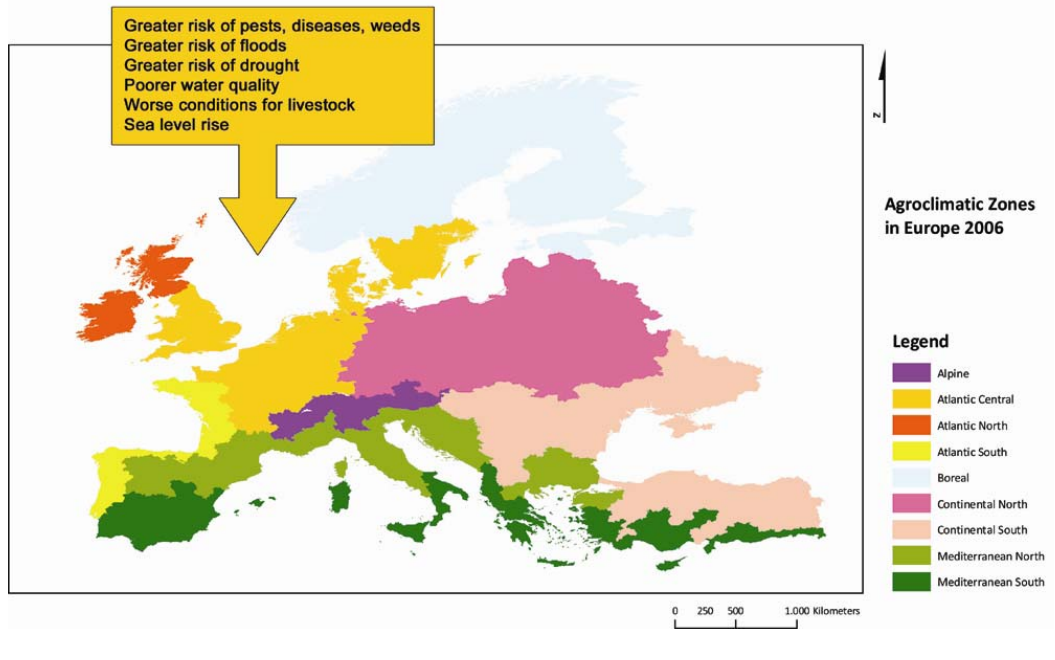
No adaptation measures for agriculture were reported for Ireland. A considerable number of initiatives are reported for the UK, and many of these will include Scotland. In addition, the Scottish Executive commissioned the report of Kerr and McLeod (2001), which has been quoted above. While the section on agriculture is brief and couched in general terms, the recommendations are similar to those made above.

6.8.3 Atlantic Central

High priority risks and opportunities

Our assessment of the impacts of climate change identified nine risks in the Atlantic Central zone, six of which are high priority. Of the five opportunities identified, three were assessed as being of high priority relating to increased crop production, water availability and livestock production. Some of the high priority risks are highlighted in Figure 12.

Figure 12 High priority risks from climate change for the Atlantic Central zone



Atlantic Central:
UK
France
Germany
Denmark
Sweden

Adapting to risks and opportunities

In this zone, farming will need to adapt to increased winter rainfall and rising sea-levels. Farm-level measures to give up or protect land from salt water intrusion and measures to improve drainage to reducing waterlogging and hence improve crop growth, reduce risks to stock health and reduce the risk of water pollution from run-off. However, the rapid removal of water from agricultural land, by increasing streamflow, may increase the risk of flooding downstream. Hence there will need to be an assessment of the impacts of any programme to improve farm drainage on the requirement for hard flood defences from sea and rainwater flooding in vulnerable zones.

The greater area of land available for a range of crops, longer growing season and increased temperature offer the potential to improve the productivity and/or profitability of all agricultural sectors. To maximise these opportunities in many cases farmers will need access to information on new cultivars and their husbandry.

On-going adaptation actions

Several of the countries in this zone are considering adaptation measures (Annex E). Those reported for Belgium focus on water management, with an emphasis on flood control. Reported initiatives in France make no mention of agriculture.

Germany

Consistent with our identification of the risks of coastal inundation of the German coast a National Strategy on Integrated Coastal Zone Management is being developed with the Integrated Coastal Defence Management for Schleswig-Holstein being updated.

The Netherlands
As would be expected the development of adaptation programmes in the Netherlands emphasises that spatial plans consider water management from the start. Sea level rise and flooding are recognised as the main threats to coastal areas, especially low-lying areas. The Space for the Rivers Policy Programme, which is under implementation, requires the creation of extra space for rivers to adapt to higher levels of river discharge, thus reducing flooding risk, and zoning of land around major rivers to reduce groundwater and surface water pollution (Annex E).

The Dutch proposals also explicitly mention the need for the agricultural sector to take stock of climate change, implying that farmers should optimise their production processes. The government has a supportive role in providing alternatives through science and making instruments climate proof. It is recognised that adapting to changing conditions is to a large extent normal agricultural practice. Dutch farmers have been highly successful in doing so when they have adequate technical training and financial resources. The Dutch government and the agricultural sector have reached agreement on a state guarantee for insurance policies for damage as a result of heavy rainfall. In return the sector will not longer apply for government compensation in the case of an extreme event. As a result crop damage caused by heavy rainfall has been an insurable risk in the Netherlands since 2004 (Annex E).

UK
The risk of sea level rise is also recognised in the UK, as is the increased risk of flooding, although the emphasis is on the risk to dwellings rather than to agriculture. Nevertheless, the UK is one of the few countries to explicitly address agriculture via DEFRA's Review of Climate Change Impacts and Adaptation (Agriculture) Research Programme (Defra, 2005b). This programme aims to initiate the preparation of alternative agricultural options and other response measures, including alternative crops, cultivation methods and pest, weed and disease controls.

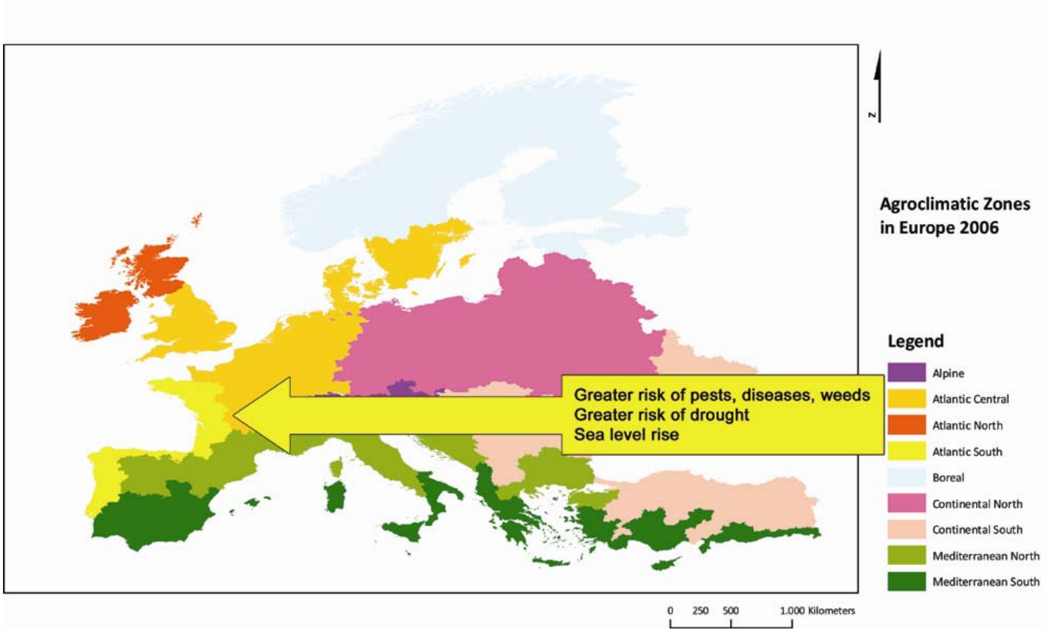
The risks identified of coastal inundation, flood risk from increased winter rainfall and the impacts of extreme events are being addressed, which is appropriate as we regard this as a high priority action in this zone. Although potentially expensive, the implications of sea level rise are serious and an integrated strategy needs to be developed. However, adapting to the increased risk of summer drought and taking advantage of the potential for increased production feature less prominently except for the UK.

6.8.4 Atlantic South

High priority risks and opportunities

Nine risks were identified for this zone, three of which are high priority. Of the four opportunities identified, one was assessed as being high priority and relates to water availability. High priority risks are highlighted in Figure 13. Potential adaptation measures are presented in Table 28 above.

Figure 13 High priority risks from climate change for the Atlantic South zone



Atlantic South: France Galicia (North western Spain) Portugal

Adapting to risks and opportunities

Farm-level measures that improve water supplies, changing to less water-demanding crops and screening fruit and orchard crops from direct sunlight will limit impacts on the arable sector. Potential risks (heat waves) and opportunities (rise of forage productivity) can be anticipated for livestock due to warming and more shade and shelter for livestock will be needed to avoid heat stress. Using woodland for this will provide co-benefits of increasing rainfall retention in soils to reduce the risk of winter flooding and run-off.

The greater area of land available, the longer growing season and increased temperatures offer the potential to improve the productivity and/or profitability of all agricultural sectors. To maximise these opportunities farmers will need access to information on new crops and their husbandry.

Ongoing adaptation options

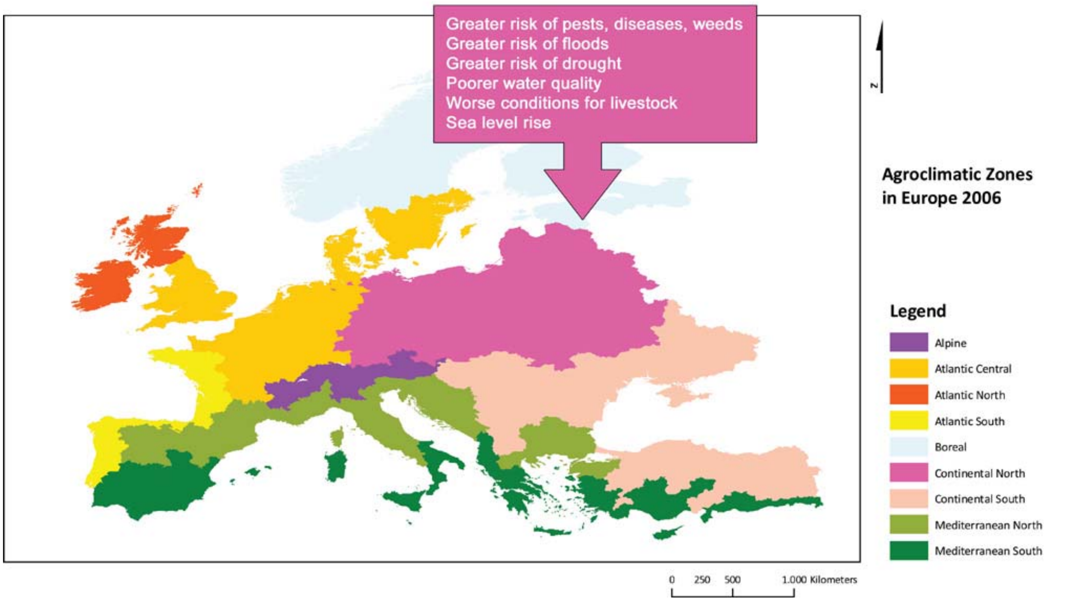
In Portugal increased monitoring of the quality of water sources and of the water distributed for consumption is under development, together with water storage measures. Several ad-hoc specific measures in the licensing, land use management and infrastructure domains that enhance the country's capacity to adapt are also ongoing.

6.8.5 Continental North

High priority risks and opportunities

Nine risks needing adaptation measures were identified in this region, of which six are regarded as high priority (Figure 14). Six opportunities have been identified for this zone, of which three are regarded as being high priority.

Figure 14 High priority risks from climate change for the Continental North zone



Continental North:
Germany
Poland
Lithuania
Czech Republic
Slovakia

Adapting to risks and opportunities

Adaptation to winter flooding and summer drought by the agricultural sector is a top priority in the Continental North zone. Farm level adaptive measures to capture additional winter rainfall will reduce flood and water quality risk and allow farmers to respond to summer drought.

To effectively maximise opportunities in the Continental North zone, changing to new cultivars and different crop varieties at farm level will allow farmers to make the most of increasing temperatures and CO_2.

On-going adaptation options

None of the countries in this zone were reported as considering adaptation measures (Annex E).

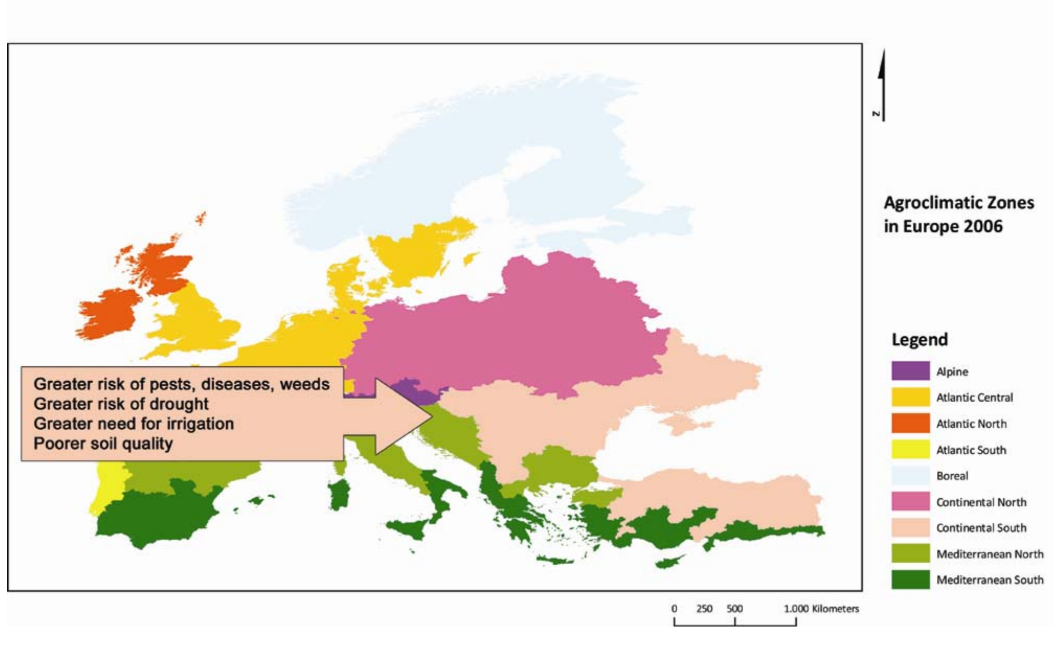
Since none of the countries included in this region has presented – to the moment – adaptation polices, here we present the key issues that may be relevant to future adaptation policies. These include policies addressing flooding risks, both from sea level rise and from increased winter rainfall. As with other zones, policies to encourage farmers to be custodians of floodplains have the potential to reduce flood risk. In addition consideration needs to be given to encouraging the uptake of new crops and cultivars in order to harness the potential for increased agricultural production.

6.8.6 Continental South

High priority risks and opportunities

In this zone eight risks have been identified of which four are regarded as being of high priority (Figure 15). Two opportunities have been identified of which one is regarded as high priority.

Figure 15 High priority risks from climate change for the Continental South zone

	Continental South: Hungary Romania Turkey

Adapting to risks and opportunities

The greatest risks in this zone are forecast to be a decrease in water supply due to a decline in annual rainfall, reduced crop yields and increased heat stress to livestock. The priorities for adaptation measures will be to identify suitable new crops and new cultivars that can be grown in place, or in combination with, those currently cultivated. Information will need to be given to farmers to enable them to cultivate new crops and crop breeding programmes will need to focus on producing drought- and heat-resistant cultivars. Priority should also be given, by farmers, to conserving water on their farms to provide a source for irrigation and to apply irrigation in the most efficient manner.

On-going adaptation actions

Approaches under development in Hungary focus on flood control, conservation and environmental protection, eco-tourism, agro-ecological farming, and rural development. A National Action Plan on Climate Change (2005) exists for Romania, which highlights the need for an Action Plan on Adaptation by 2007 (Annex E).

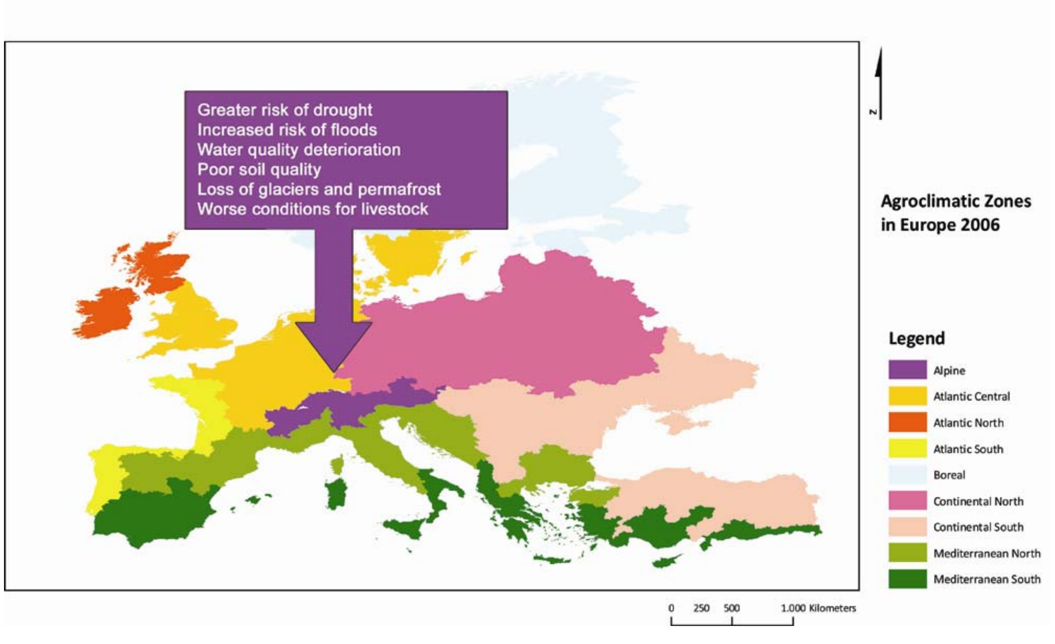
The measures proposed for this zone in the national action plans appear well linked to the risks and opportunities identified, albeit no explicit mention of maintaining water resources.

6.8.7 Alpine

High priority risks and opportunities

The assessment of the climate change impacts identified nine risks, six of which are high priority, for which adaptation measures should be introduced (Figure 16). Of the five opportunities identified, three were assessed as being of high priority and of those three relate to increased crop production.

Figure 16 High priority risks from climate change for the Alpine zone



Alpine: western Austria, Slovenia

Adapting to risks and opportunities

In this zone farming will need to adapt to intensification of winter rainfall and altered rivers hydrological cycles, flash floods and summer drought. Farm-level measures are needed to improve natural buffering to reduce erosion and landslides and drainage to reducing waterlogging and hence improve crop growth, reduce risks to stock health and reduce the risk of point source pollution from run-off. However, the rapid removal of water from agricultural land, by increasing stream flow, may increase the risk of flooding downstream. Hence there will need to be an assessment of the impacts of any programme to improve farm drainage on the requirement for hard flood defences in vulnerable zones. Win-win measures include the collection of winter rainfall for summer irrigation.

Longer growing season and increased temperature offer the potential to improve the productivity and/or profitability of all agricultural activities. To maximise these opportunities in many cases farmers will need access to information and advice on new cultivars, their husbandry, and market outlets

On-going adaptation actions

In Austria the development of integrated flood risk management within model river catchments (e.g., Danube and its alpine tributaries) is ongoing. Options to change cropping patterns and agricultural management strategies increase the focus on water-saving or more efficient irrigation techniques and the development of new cultivars with extended growth periods; multi-stress resistance and improved water use-efficiency are all under development.

In Slovenia strategies for flood and drought mitigation under National Environmental Programme (determination of risk areas, regulation of land use) are under development.

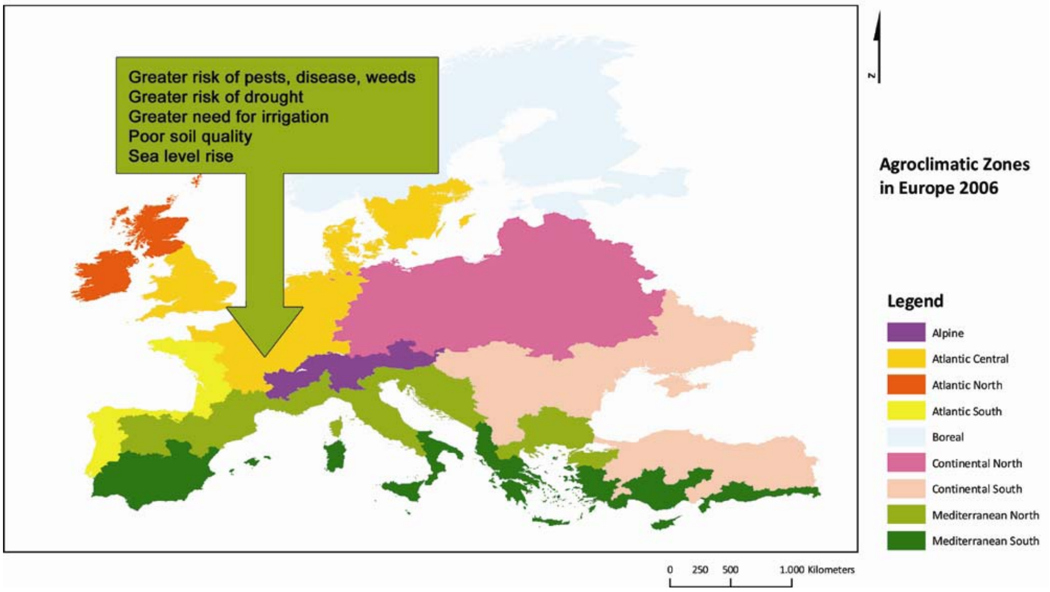
Measures proposed correspond reasonably well with those proposed in this study, with the risk of flooding and the need to evaluate new crops and cultivars being assessed.

6.8.8 Mediterranean North

High priority risks and opportunities

Nine risks were identified in this zone of which five were considered to be high (Figure 17).

Figure 17 High priority risks from climate change for the Mediterranean North zone



Med North: Northern Spain, Southern France and, Corsica, Northern Italy, Bulgaria, the Macedonian region of Greece

Adapting to risks and opportunities

Farming in this zone will need to adapt to both crop drought stress and livestock heat stress and the subsequent losses in yield and earnings. Farm level agro-forestry so as to provide shade for animals and nocturnal irrigation for crops will both need to be implemented at farm level.

In this region, farming will need to adapt to a hotter, drier climate that will increase demand for reduced water resources. While adaptive measures can be taken by farmers themselves, particularly with regard to harvesting and storing water for irrigation, and using irrigation more efficiently, national bodies need to provide information and advice on a range of potential measures. These include new crops and cultivars, soil and husbandry requirements for those cultivars and integrated strategies to deal with the new pest and disease problems likely to be encountered.

On-going adaptation actions

In Italy plans are ongoing to address potential water crises, providing both technical and financial emergency measures, in particular for water resource protection.

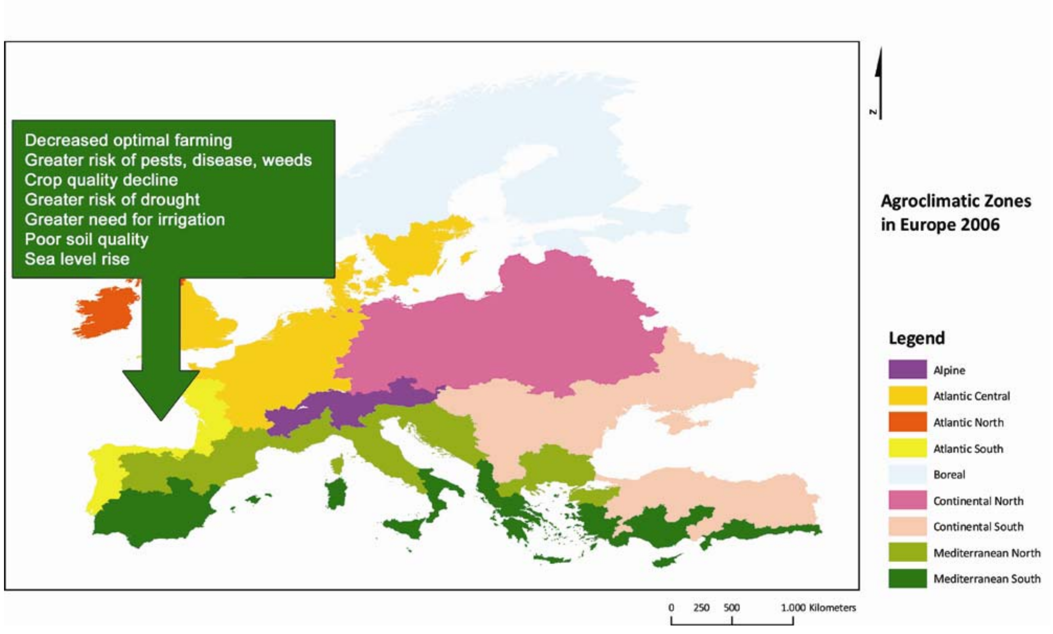
In Spain there is a coordinated Programme between National and Regional Spanish Governments on Climate Change Impacts and Adaptation R&D, albeit no specific programme for agriculture was reported by the National Focus Points in Nairobi (see Annex E). Actions focus on better spatial assessment of impacts of changed weather variables change on crops (modelling), water savings (modernisation of irrigation equipment).

6.8.9 Mediterranean South

High priority risks and opportunities

Analysis identified nine risks of which seven were classified as high (Figure 18). No opportunities for this zone were identified.

Figure 18 High priority risks from climate change for the Mediterranean South zone



Med South: Southern Spain, southern Italy, Greece, southern Turkey

Adapting to risks and opportunities

Increased summer drought and its subsequent impacts – crop drought stress, livestock heat stress and reduced forage yield in combination with loss of agricultural land to sea level rise are all high priority in the Mediterranean South zone. As no opportunities have been identified in this zone, and therefore cannot be used to compensate against the risks, it is paramount that adaptive measures against the risks identified – such as mechanically ventilation for livestock and growing drought resistant crop varieties – are adopted at farm level with adequate support at the sectoral level.

On-going adaptation actions

In Italy monitoring and assessment of measures for reforestation and olive tree cultivation are being carried out to combat desertification. A methodology for the assessment of the economic and environmental damages caused by desertification-related drought events is being prepared together with a national thematic GIS of vulnerability to desertification.

Cyprus is introducing adaptation strategies to combat water shortages. In Malta the government is planning a major flood relief project which will involve the catchment of storm water, its storage in galleries and its use for irrigation. This would mean that less water would be extracted from the aquifer, giving it time to recharge itself in volume and quality.

Thus the measures being addressed are focussing on potential water shortages and reducing the risk of conflict with other users which have been identified as a high risk in this zone as well as the assessment of measures to combat desertification.

6.9 Stakeholder consultation on adaptive measures

The questionnaire ran for six weeks from 27 June until 8 August 2007. Of the 151 people who were invited to take part, 14 responded to say that it was not their area of expertise, 17 were on annual leave or out of the office. In total 46 people responded (see Annex F and G for details) with usable and complete answers. This gave the questionnaire a very good success rate of 38%, when on average 10% success is expected from such questionnaires.

In order to maintain continuity with the assessment of impacts of climate change, we have summarised and reported the responses from each agro-climatic zone. The sample size was too small to enable a statistical analysis of the responses. The percentages referred to in the figures correspond to the measures that have been either considered or adopted in the following adaptation strategy categories:

- CP/LS Mgmt: Crop/Livestock management – encourage new crop varieties and animal breeds
- Water Mgmt: Water management – more efficient water practice
- Cont/Mon: Controlling/Monitoring – of biodiversity/pests and disease
- Struct/Fin: Structural/Financial – capital investment in farm structures/equipment

The reported analysis and outcomes can only be considered as indicative. This does not intend to be exhaustive regarding national action on adaptation.

6.9.1 Boreal

Country responded (number of respondents): Sweden (3)

Although this agro-climatic zone covers four EU member states, all the respondents were from Sweden, so the results may be biased toward that country.

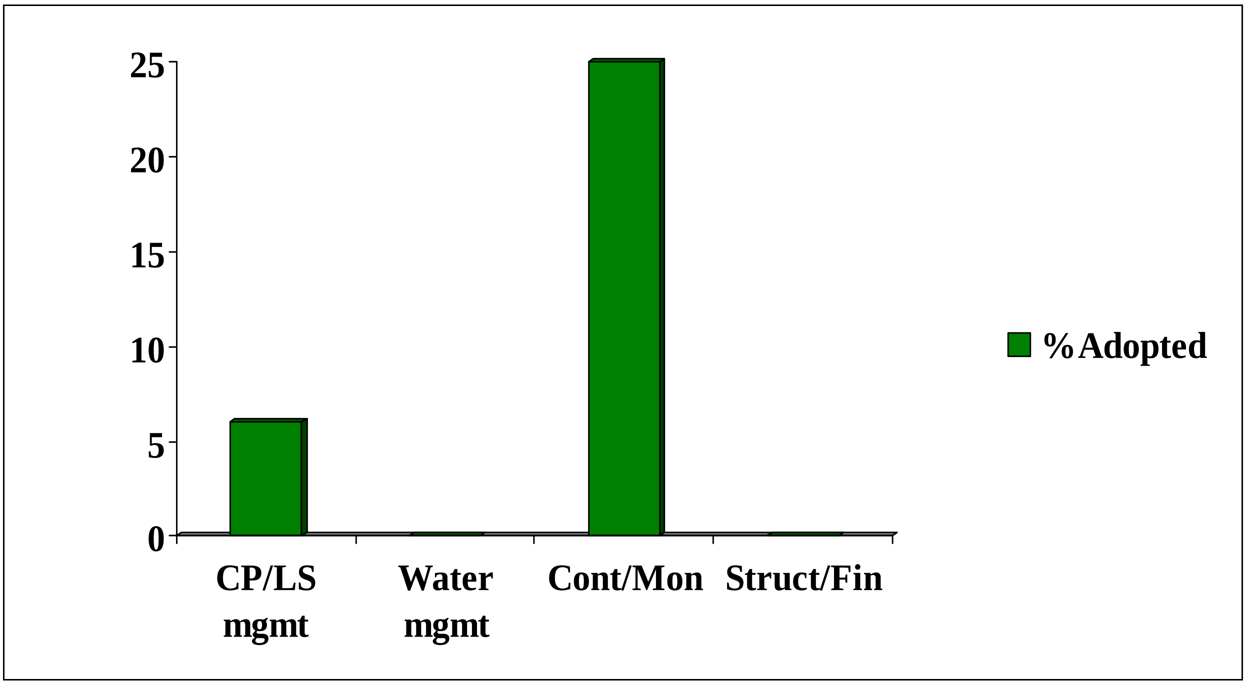
Observed climate change was reported by 2 of the 3 respondents from the Boreal zone (Annex H table H.1). However, the potential for intensification of the hydrological cycle due to climate change, leading to increased incidence of floods, water deficits or droughts, was deemed unknown by 2 of the 3 respondents. Flooding was deemed high priority in our risk assessment for this zone but was not flagged as significant, as yet, by any respondent. In answer to the question, 'Did you feel the need to make changes in your traditional practices in order to adjust to environmental conditions?' none of the respondents in this zone replied yes. Two of the respondents were aware of assessments made in their zone following the 2003 heat wave but only one out of three had attended climate change events.

Results of the options for adaptation measures in the Boreal zone (Figure 19 and Annex D) reveal that the majority of these options proposed were unknown to the respondents. Of the controlling/monitoring options less than one quarter were reported to have been traditionally adopted, whereas less than one fifth of crop/animal and nearly a quarter of water management options have not been considered because no measures may have been suggested or identified yet (but research has started across all areas). Crop management options were generally not considered by the respondents. This may reflect the lack of concern over adverse impacts of climate change but suggests either a lack of awareness of potential benefits or an assumption that autonomous developments are all that are required to respond to potential opportunities. This conclusion needs further investigation and is a potential topic for discussion at the workshop.

The fact that no uptake of measures to improve water management options was reported, either as adopted or under consideration, suggests awareness may need to be raised of the possible consequences for the hydrological cycle.

With respect to monitoring options, 2/3 respondents reported soil monitoring was already carried out. This may be valuable as potential for increased agricultural production, identified in the risk assessment for this zone, may be limited by soil quality.

Figure 19 Considered/adopted options for adaptation measures – Boreal



6.9.2 Atlantic North

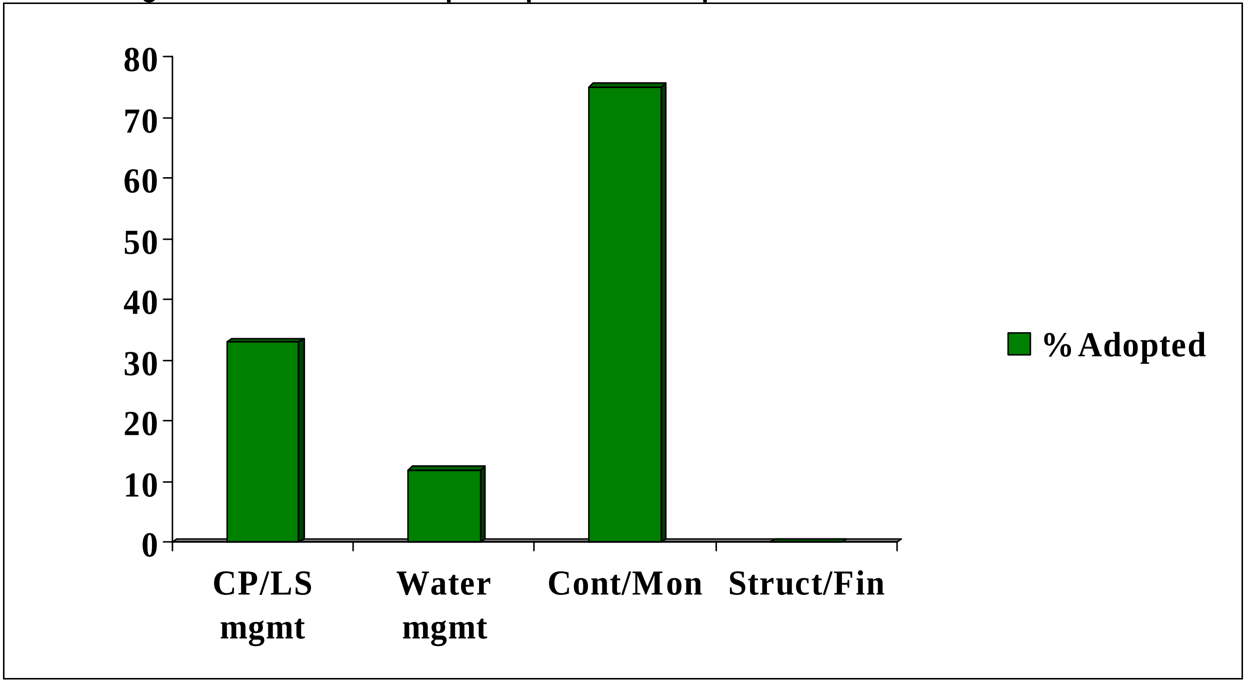
Country responded (number of respondents): Ireland (2)

This small zone only covers two countries and replies were received from Ireland giving the possibility that the results of the questionnaire may be biased.

Both respondents observed climate change in the Atlantic North zone (Figure 20 and Annex H Table H.1). One reported intensification of droughts and floods. This may refer only to flooding as both respondents reported that no water deficits have been experienced as yet, nor have any changes been made to traditional practices as a response to this. Summer drought was deemed a high priority in the risk assessment for the Atlantic North agro-climatic zone, but may not be deemed significant as yet, although the option of 'altering conservation practices for dry summers' was reported to be under consideration. Flooding, which was flagged by the questionnaire, was not listed as a risk in this zone (therefore low priority) in our risk assessment. Neither party were aware of any assessment made in their country following the heat wave of 2003 nor have attended climate change events organised by their agricultural services.

Adaptation options for the Atlantic North zone show that a large proportion of crop/animal water and structural/financial management options may have not been considered. This was reported as being due to hedgerows and eco tillage being biodiversity issues (crop/animal), irrigation not being practiced in Ireland (water) and unknown for structural/financial options. Significantly, out of the 4 adaptation areas the only notable area – controlling/monitoring – showed that 50% of these measures have been considered in the Atlantic North zone.

Figure 20 Considered/adopted options for adaptation measures – Atlantic North



6.9.3 Atlantic Central

Countries responded (number of respondents): UK (8), Germany (2), France (1) and Netherlands (2)

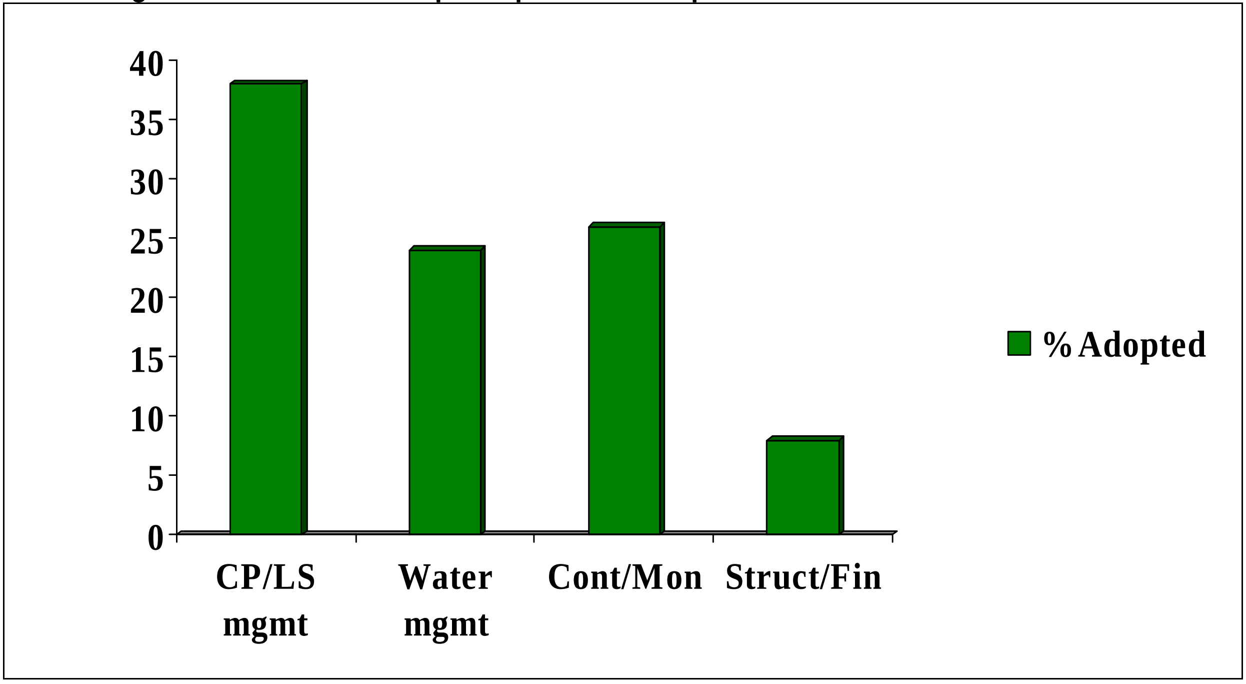
This zone covers eight EU member states and responses were received from four of those countries. The results may therefore be considered reasonably representative.

9 out of 13 respondents observed climate change and the need to make changes in traditional practice (Annex H Table H.1). Reasonably high agreement for the intensification of droughts and floods between the respondents (12/13) and the risk assessment was recorded. From the questionnaire, droughts and water deficit were reported as less significant (8 out of 13) than flooding. Three quarters of the Atlantic Central respondents were aware that assessments had been made following the 2003 heat wave, but only half of the respondents have attended climate change and agriculture events organised by their country's agricultural services.

All the adaptation measures in Figure 21 for the Atlantic Central zone show a very large proportion of 'unknown'. Two thirds of the controlling/monitoring management options and structural/financial adaptation management options were reported as unknown. Here it is not clear across the zone whether the individual measures had been adopted or not (most likely due to the respondents role/expertise not being directly relevant to the particular question or measure).

Although in this region a greater proportion of adaptive measures were reported as being adopted or considered than in the Atlantic north, less than one fifth of all the adaptation options listed may have been traditionally adopted according to the questionnaire. On average, over a quarter of crop/animal management options may not been considered. Reported reasons for this include: it is simpler to take out light land for setaside or Higher Level Stewardship and that new pests and diseases are not well identified at present.

Figure 21 Considered/adopted options for adaptation measures – Atlantic Central



6.9.4 Atlantic South

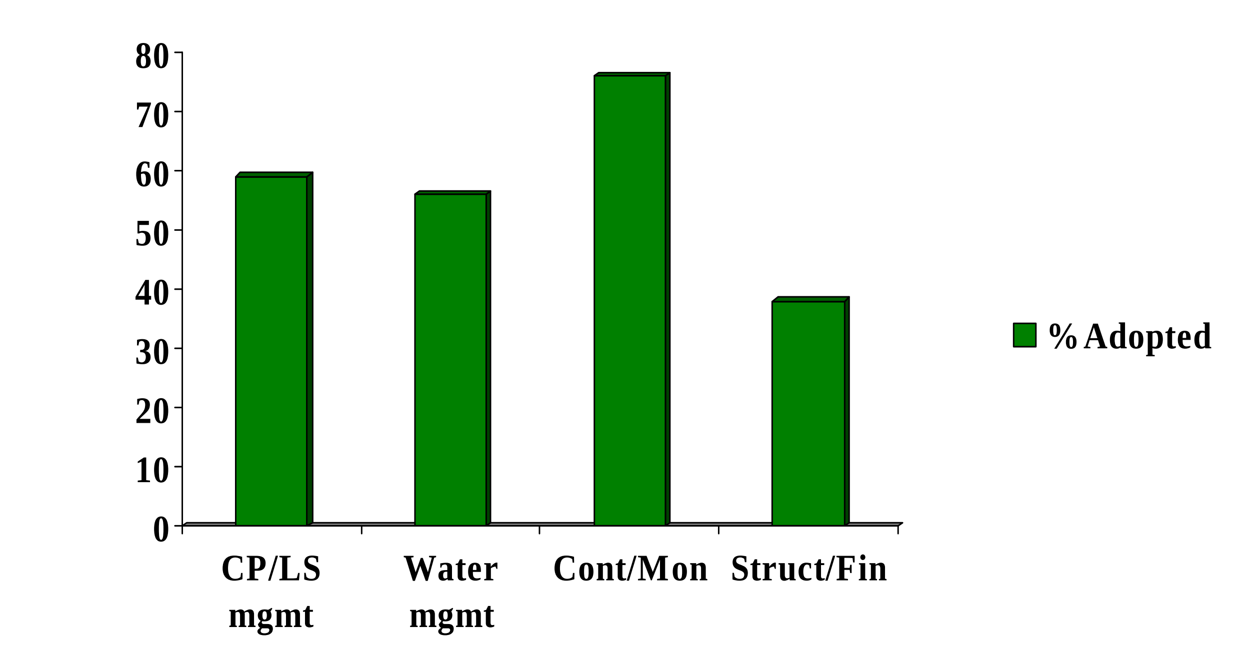
Country responded (number of respondents): Portugal (2)

This agroclimatic zone covers three EU member states. While responses were received from all of them, only one country's responses are reported here. Only small proportions of Spain and France are included in this zone.

Observed climate change was identified by both respondents (Annex H Table H.1) as was the intensification of floods and droughts. Only drought was assessed as high priority in our assessment of risk for this zone. One of the respondents was aware of assessments made on the impacts of the 2003 heat wave in their region and has attended climate change events organised by their country's agricultural service.

Figure 22 of the adaptation measures for the Atlantic South zone shows, compared with the more northern Atlantic zones, greater proportions of adaptive measures are implemented or are under consideration.

Figure 22 Considered/adopted options for adaptation measures – Atlantic South



6.9.5 Continental North

Countries responded (number of respondents): Slovakia (2), Czech Republic (2), Poland (1), Lithuania (3), Estonia (2), Latvia (1)

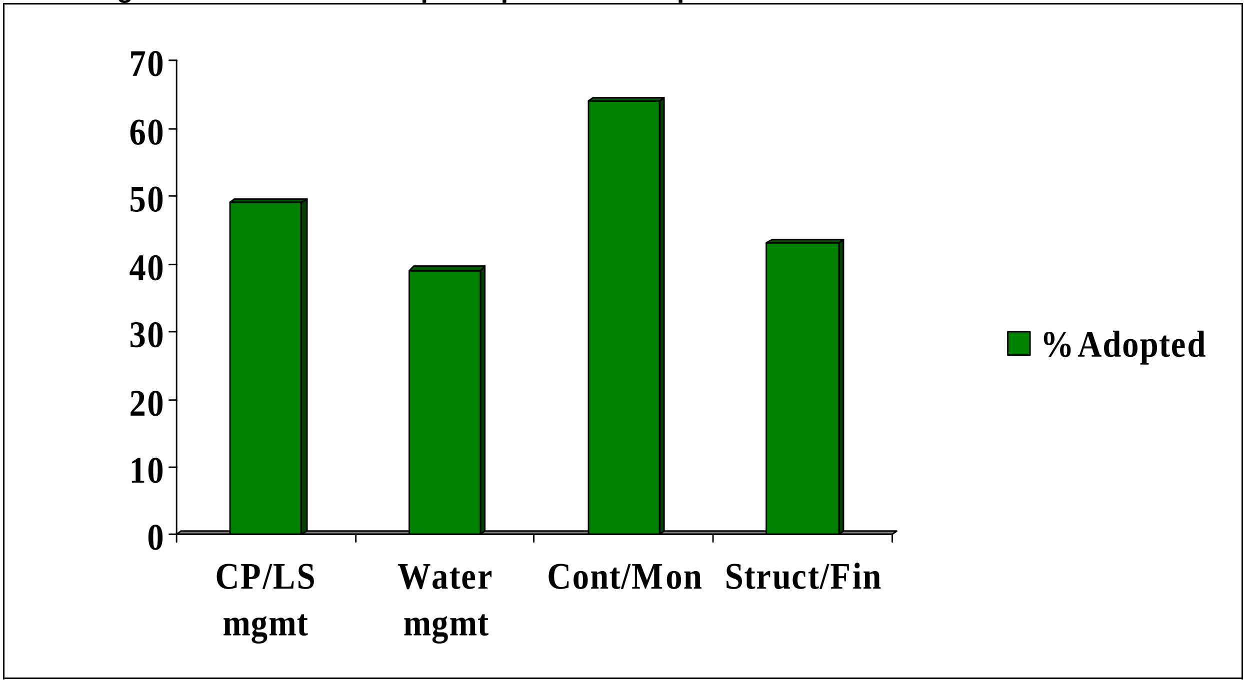
This agro-climatic zone covers eight EU member states and responses were received from all of them. The responses for this zone can therefore be regarded as being fully representative. In two cases responses were reported for zones that occupy a greater proportions of those two countries.

9 out of 11 respondents have recorded observed climate change and the intensification of droughts and flooding in the Continental North zone. However, only 6 of the 11 reported water deficits and the need to change traditional practices. The same proportion of respondents reported attending climate change and agricultural events (Annex H Table H.1).

The water related issues correspond well to the risk assessment for this zone undertaken in the impact assessment where flooding, water quality, waterlogging and water supply were all given a high priority ranking. Nearly three quarters of the respondents are aware of assessments made in the Continental North zone following the heat wave in 2003.

Figure 23 reveals that of the adaptation measures for this zone, both crop/animal and controlling/monitoring management options have been traditionally adopted or recently adopted respectively. Of the crop management options, enhancing the efficiency of fertilizer use, and maximising effectiveness of labour and machinery, were reported to be already adopted or under consideration by the majority of respondents. Nearly one third of water management options have not been considered, although water issues were flagged as significant by respondents and ranked as high priority risks. Reasons for this include: that management options requiring less water were already covered under marketing through the price of water and subsidies for modernising irrigation systems. The percentage of unknown options remains fairly constant at less than one third of all adaptation measures.

Figure 23 Considered/adopted options for adaptation measures – Continental North



6.9.6 Continental South

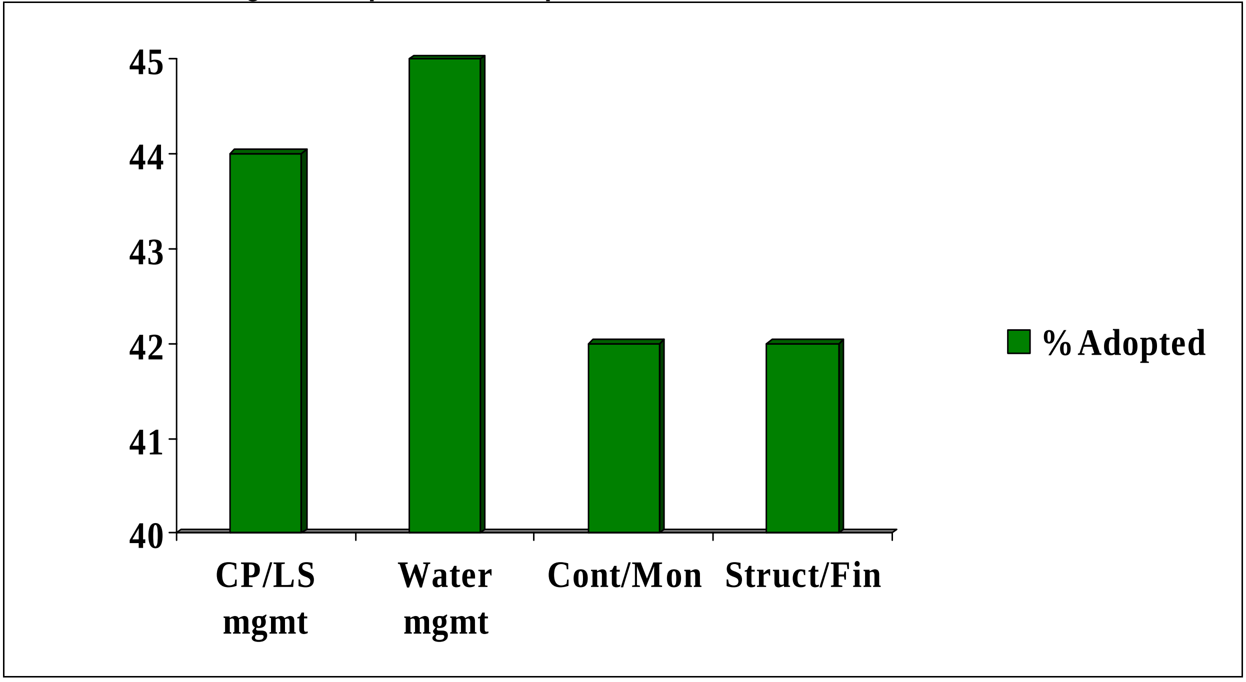
Countries responded (number of respondents): Romania (2), Hungary (1)

This agro-climatic zone only covers parts of two EU member states and responses were received from both.

The intensification of droughts and floods and observed climate change have been identified in the Continental South zone by all the questionnaire respondents, with 2/3 reporting water deficits and attendance at climate change events (Annex H Table H.1). All three respondents reported the need to make changes in traditional practice in their country and were aware of assessments made following the heat wave in 2003. This correlates well to the risk assessment carried out for the Continental South, where drought and water quality were given high priority. Flooding however, was not deemed significant.

Adaptation options for this zone (Figure 24) show that nearly one third of all proposed measures are under current consideration. The average results are generally spread across the possible responses, with most areas receiving less than one quarter of respondents, making it unclear about the level of adoption of each measure in this zone. Developing breeds or changing to breeds adapted to changed conditions, especially drought and heat resistant crop varieties and encouraging a change in sowing dates were reported by 2/3 of respondents.

Figure 24 Options for adaptation measures – Continental South



6.9.7 Alpine

Country responded (number of respondents): Austria (4)

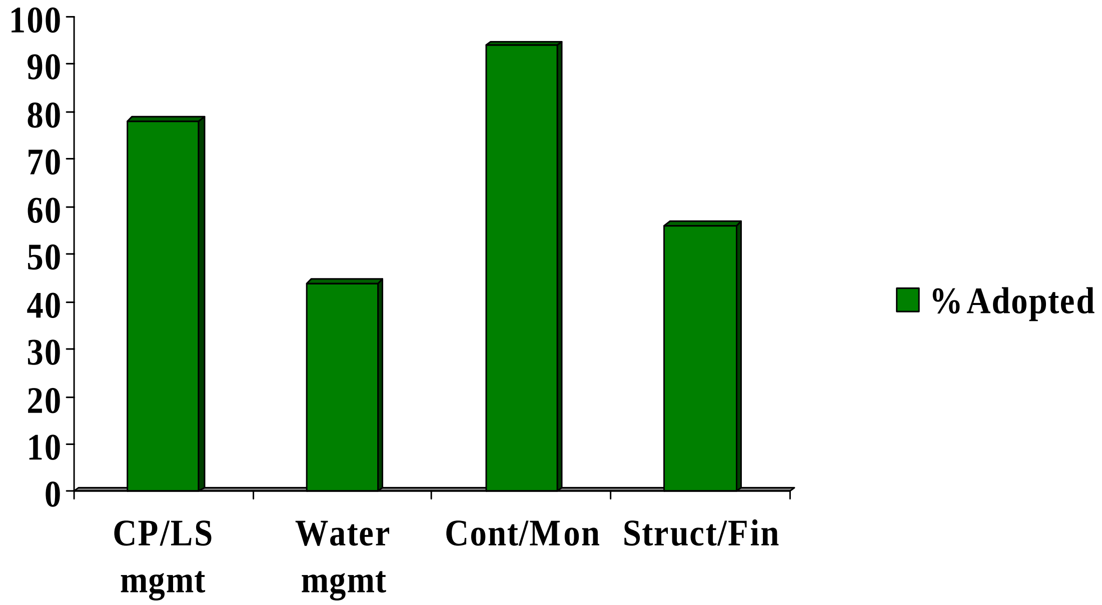
This agroclimatic zone covers two countries and all four responses came from one of them. However, given the unique character of this zone we conclude that the responses will be reasonably representative.

Observed climate change, including intensification of droughts and floods, was recorded by all the respondents (Annex H Table H.1). All respondents reported observed changes in their traditional practices to account for this. High agreement is seen between the respondents and the assessment of the impacts of climate change, which gave both drought and flooding high priority.

Only two of respondents were aware of assessments that had been made following the heat wave in 2003 in their region. Three of the respondents in the Alpine region have attended events organised by their agricultural services to increase awareness and knowledge transfer of climate change.

Figure 25 shows that crop/animal and controlling/monitoring management options have been traditionally adopted or recently adopted respectively. Although acknowledged by all respondents as a high risk, around half of respondents reported that these options had not been considered. Water and structural/financial management adaptation options have not been considered in the Alpine zone. Namely, these measures include: upland management to slow run-off, securing livestock during extreme flooding, altered water conservation for dry summers and the adoption of water re-use technology. The reported reasons for not considering these measures were: not enough information and communication, lack of projection of extreme events with high confidence and lag time and finally generous water rights and abstraction permits in Austria.

Figure 25 Considered/adopted options for adaptation measures – Alpine



6.9.8 Mediterranean North

Countries responded (number of respondents): Bulgaria (2), Slovenia (1), and Italy (1)

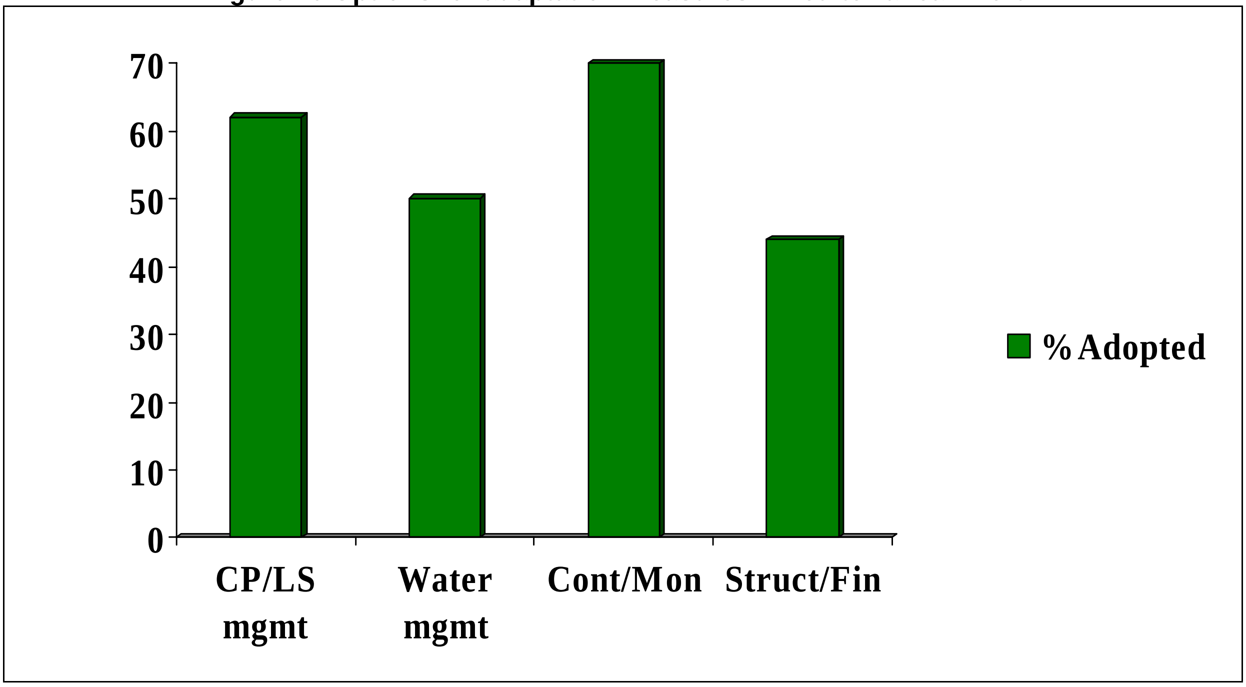
This zone covers six EU member states. Responses were received from all of them but in some cases were reported elsewhere in zones which covered a greater proportion of the member state.

All respondents have observed climate change in this zone. Three quarters identified the intensification of droughts and floods and the need to make changes to traditional practices. This is in agreement with the risk assessment carried out for this zone where drought, water supply shortages were deemed high priority.

Three quarters of questionnaire participants from the North Mediterranean zone have attended climate change events organised by their agricultural service and were aware of assessments made of the impacts of climate change on the 2003 heat wave.

The majority of proposed crop management adaptations were reported to be already adopted by between one and three of respondents, Three quarters of respondents reported that ' Adopt measures to reduce the impacts of extreme precipitation events ', while half report measures to conserve water are traditionally implemented. Figure 26 reveals that of the adaptation options in this zone, like the Continental North zone, around one third of all options in each adaptation area were unknown. Less than half of both crop/animal and controlling/monitoring management options have been traditionally adopted in this zone. Water management options are slightly lower at only one third, this difference is important as this area is deemed significant by both the risk assessment and questionnaire respondents. One third of structural/financial management options in the Mediterranean North have not been considered, but the reasons for which were not clear.

Figure 26 Options for adaptation measures – Mediterranean North



6.9.9 Mediterranean South

Countries responded (number of respondents): Spain (2), Greece (1)

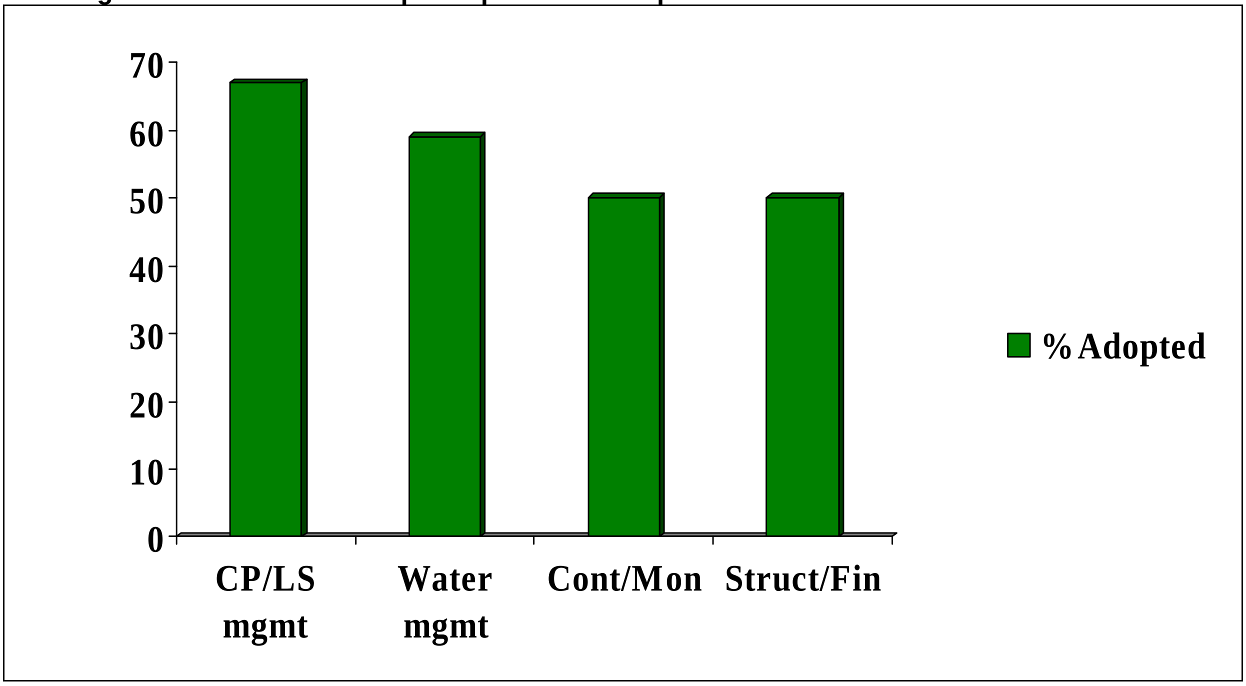
This zone covers four EU member states. Responses were received from all of them but in some cases were reported elsewhere in zones which covered a greater proportion of the member state.

Observed climate change, intensification of droughts and floods, water deficits and the need to change traditional practice were all recorded by all respondents in the Mediterranean South zone.

Awareness and knowledge transfer of climate change was lower, with 2/3 of respondents having attended events and were aware of assessments made following the 2003 heat wave in their country.

Two thirds of respondents reported that 'adoption of suitable upland farm or land management practices so that upland areas are used to slow run off and reduce peak water flows ' had already taken place. Monitoring new pests and diseases were reported as under consideration. 67% of the possible changes in farm structure, such as buildings, irrigation systems, heating or cooling structure were reported as having taken place by respondents. Figure 27 and Annex H reveal that like both the Mediterranean North and Continental North zones, one third of the adaptation options seem unknown. Roughly, one third of known adaptation measures for crop/animal and water management options are traditionally adopted in the Mediterranean South zone. This reconfirms the risk assessment for this zone where drought water supply was deemed a high priority.

Figure 27 Considered/adopted options for adaptation measures – Mediterranean South



6.10 Adaptation challenges faced by European agriculture

This section discusses some of the challenges to adapting for the European agricultural sector. A primary challenge is planning, which requires a definition of the objectives and plans for implementation, and coordination between policies. The specific territorial challenges are also outlined. Finally, the section raises the issue of a main externality of agricultural production that is the possible disturbance of agro-ecosystems that may lead to biodiversity loss.

6.10.1 Planning for adaptation

Adaptation planning is inherently challenging. Uncertainties in climate change science, long planning horizons, adequate consideration of both positive and negative effects, potential for both risks and opportunities in the same area, and a need to find cost-effective measures are all factors in adaptation decision-making. More regional and local assessments of impacts and adaptation options are needed, and there is an important interplay with the findings of ongoing agronomic research.

Knowledge transfer to the farm community and to those working closely with farmers (advisors, rural practitioners) is essential to enable adaptive action. Knowledge transfer between scientists, political decision-makers and the people directly affected by climate change is currently weak, and existing information is poorly used. One of the difficulties is the number and range of stakeholders involved in adaptation. Another challenge is the inherent uncertainty in climate science and impacts projections: uncertainty can lead to confused messages and inertia, if it is not communicated in the right way.

While there is a continuing need to strengthen the climate change knowledge base (through research), improved understanding of climate change science will be insufficient on its own for adaptation policy development and to drive adaptation action. There is a complementary need to engage stakeholders, by developing suitable methodologies for assessment of impacts, vulnerabilities and planning as a pre-requisite for cost-effective adaptation. From an agricultural perspective, stakeholders in adaptation include rural programmers, farm advisors, as well as farmers, and it will be important to provide the kind of information that will help them directly in devising and applying adaptation options. For instance, a typical assessment of the scientific literature is the impact of climate change on crop yields under current management practices. This indicates a potential risk, but it provides little or no guidance about how the producers should react to such knowledge and what type of adaptation measures they could take to alleviate the potential negative impacts.

Wider influences on farmers' behaviour, such as changes in demand and market prices, must be considered alongside climate change. It is important to consider whether adaptations are sustainable, or rendered irrelevant by other sectoral drivers. This holistic approach should also ensure that adaptation decisions and investments are both cost-effective and proportionate to the risks or benefits that may be incurred.

Farming involves not only the production of crops and livestock, but also the management of people, supply chains, markets, building and transport infrastructure, insurance, etc. The indirect impacts of climate change in these other areas will have cumulative affects alongside the changes in crop productivity at farm level.

The development of adaptation measures must take into account future socio-economic scenarios as well as future climate change scenarios. Practitioners need to understand the relevance of a future climate to a future society, rather than to society today. Credible socio-economic scenarios are required to provide a framework for adaptation decision-making for practitioners.

With so many competing pressures and drivers, and so many contributing factors to consider, not only in understanding the impacts of climate change, but also in developing adaptation options, it is likely that the role of training and advice facilities for the agriculture sector could become more important. While there may be many simple adaptation measures that could theoretically be introduced to address a particular risk or opportunity, these may only be practically possible under certain circumstances. For example, changing cropping patterns, or introducing new crops may only be an option for the farmer who already has an understanding of alternative crop practices, and who knows of new market outlets for the new products.

A final challenge for consideration is that of finance. As indicated in Chapter 6 of this report, many potential adaptation options are low-cost and technically manageable by individual farmers. However there are also adaptations that require large scale and long-term effort, either in farm management or in infrastructure development. In order for farmers to be able to consider and take up such options, it may be necessary for financial support mechanisms to be made available.

The sectoral approach to impacts and adaptation developed in this study has provided options for wide-ranging problem. However adaptations often involve combined effort across many sectors. Agriculture is sensitive to the responses in other sectors; particularly water, tourism and biodiversity conservation, and so adaptation measures for agriculture will be strongly influenced by policies in other sectors.

Adaptation is unlikely to be facilitated through the introduction of new and separate policies, but rather by the revision of existing policies that currently undermine adaptation and the strengthening of policies that currently promote it. If adaptation is to become “mainstreamed”, it will be necessary for relevant polices, such as the CAP and the Water Framework Directive to address the issue more directly. Existing agreements also have a part to play. For example, the Convention on the Protection of the Alps (1991) may need to be reconsidered in the light of climate change.

6.10.2 Specific territorial challenges

The development of adaptation measures must include the participation of a range of stakeholders, as they are both the demand-drivers and end-users of climate impact assessments and vulnerability analyses. Agricultural stakeholders include national and local policy-makers, academic and commercial researchers, trade associations and representative bodies, and individual farmers and land managers. The questionnaire employed in this study aimed to engage with these stakeholders, and it revealed a range of current understanding and practice of adaptation across the EU. Table 28 summarises the specific territorial challenges.

Table 28 Summary of the territorial challenges to adaptation of agriculture to climate change

Agro-climatic zone	Specific territorial challenges to adaptation
Boreal	Awareness of increasing flood risk and the potential benefits of climate change for crop production is low and needs to be raised.
Atlantic North	Awareness of climate change impacts on the hydrological cycle and of potential increases in crop production needs to be raised.
Atlantic Central	While there is a high level of awareness that intensification of the hydrological cycle (one of the prime climate change risks) will lead to increased winter flooding and reduced water availability in summer, there is limited awareness of the need to change agricultural practices to realise the potential for increasing agricultural production.
Atlantic South	While the need to make changes in traditional practices in order to adjust to new environmental conditions is recognised, awareness of impacts on the hydrological cycle needs to be improved.
Continental North	While adoption of measures (either traditional or recent) to address the altered hydrological cycle is evident, this needs to be seen as a higher priority.
Continental South	There is a high level of awareness of the need to adapt water management to hotter, drier summers; there is also good awareness of the need to adapt crop and livestock production to climate change.
Alpine	There is reasonable of awareness of the potential impacts of climate change, but greater emphasis on adaptive measures for crop and livestock production than for management of water resources - which should be a higher priority.
Mediterranean North	There is a high level of awareness of the need to adapt water management to hotter, drier summers; there is also good awareness of the need to adapt crop and livestock production to climate change.
Mediterranean South	More adaptation measures have been adopted or are under consideration here than in the other agro-climatic zones; this is consistent with the expectation that the region will be worst affected by climate change.

6.10.3 Implications of agricultural changes for agro-ecosystem balance and biodiversity

We have shown that the agriculture sector will adapt to climate change impacts through implementation of a range of management, technical/equipment and infrastructural measures. These measures have the potential to impact both negatively and positively on biodiversity; this will depend upon specific local circumstances and the availability of incentives to minimise threats and maximise opportunities.

Changes in food production due to climate change are likely to have significant impacts on biodiversity, as the agri-environment is central to a great many aspects of biodiversity conservation. The introduction of new crop types and agricultural practices will have mixed benefits. For example, an increase in flowering crops will benefit species requiring nectar sources; whilst intensification of fruit production is likely to be detrimental to wildlife (such systems are characteristically poor in biodiversity). The effects of regional shifts in agricultural production (such as the changing balance between livestock and crop production) are difficult to predict; these will depend upon existing land uses and the ability of new land uses to continue to support biodiversity. Changing farming practices are likely to be detrimental to biodiversity if phenological change is unable to keep pace with them.

The impacts of biofuel and biomass crops on biodiversity will depend on the type of crop grown and the intensity of its production. For example, short rotation coppice planted on degraded land may provide some benefits, particularly if native species are used, whereas intensive monocultures could reduce habitat connectivity and present barriers to species' dispersal.

Increasing habitat connectivity to facilitate species dispersal in response to climate change is a key adaptation objective for conserving biodiversity. However, there is some uncertainty about the most effective means of achieving this, particularly as different species will disperse over different scales and, therefore, will favour different approaches. Testing a range of measures at a range of spatial scales would provide the evidence needed to guide future planning and implementation. Examples of measures to improve agro-ecosystem balance include:

- hedgerow and woodland restoration/planting
- ditch restoration/management
- pond and scrape restoration/creation
- water level management
- grass strip margins in arable fields
- crop-free margins in arable fields
- reduced pesticide/herbicide usage
- crop patterns to encourage wild birds
- flower-rich (pollen/nectar) grassland seed mixes
- winter stubbles
- summer fallows.

The activities of the agriculture sector affect the functioning of a range of ecosystems. Maintaining ecosystem services for the benefits of agriculture is, therefore, closely linked to biodiversity conservation. For example, species-rich communities will ensure the availability of pollinators and natural predators. Farmers can benefit natural ecosystems through the sensitive choice of crop types and careful management of semi-natural habitats, including woodland, wetland and riverine environments. This will, in turn, reduce the vulnerability of natural and agricultural systems to climate change and increase their ability to adapt to inevitable impacts.

7 Potential role of the CAP towards adaptation

This section builds on the identified priority risks and opportunities from climate change (Chapter 5), and potential adaptation measures (Chapter 6). This section evaluates the contribution of the present CAP measures towards adaptation, evaluating whether and how they can facilitate adaptation potential, and identifies specific existing policy measures that could be continued or strengthened, as well as those which may present an obstacle to adaptation.

The relevant measures have been assessed through a SWOT framework (Strengths, Weaknesses, Opportunities and Threats). Where appropriate, further detail is provided on results from the questionnaire and the workshop. Finally, the study suggests the development of new instruments appropriate to increasing the resilience of farming to climate change impacts.

7.1 Analysis of market and direct income support measures

This section examines market and income support measures covering direct payments to farmers that fall under Pillar 1 of the CAP with respect to adaptation to climate impacts.

7.1.1 Single Payment Scheme (SPS)

Since the recent CAP Reform of 2003, the CAP's Pillar 1 or direct payments have become much simplified through the introduction of "decoupling". Decoupling seeks to break the link between production and direct payments with farmers receiving a fixed payment per area of land instead, irrespective of its production or potential to produce. The granting of the single payment is however dependant on the farmer complying with requirements of cross-compliance.

Table 29 The Single Payment Scheme – potentially support management, technical and infrastructural options

S	• SPS secures a minimum level of income that is decoupled from production, and so gives farmers the freedom to respond to market signals. • Receipt of decoupled payment allows farmers to respond to their physical environment, by for instance cultivating the most appropriate crops. • SPS provides a platform against which to attach other policy measures, such as cross compliance that can facilitate adaptation.
W	• SPS is a horizontal, non-sector specific income support measure, often related primarily to past levels of production and support. This potentially represents an inefficient use of the direct support payment from an adaptation perspective. • In isolation, the SPS is unlikely to bring about adaptation. It merely creates the mindset whereby adaptation 'may' occur (the speed, severity and costs associated with impacts will dictate if responses are sufficient). Other more targeted measures are therefore required.
O	• Further decoupling where crop specific support has been continued such as for tobacco will encourage a more responsive production farming system.
T	• High commodity prices or adding to environmental obligations linked to the Single Farm Payment may result in farmers choosing not to submit SPS claims. • Although SPS secures a minimum income level, farmers will continue to face weather-related risk, which is a main source of variation affecting income. Other measures will be required to support farmers in the medium to long term as weather-related risk is anticipated to increase in severity.

7.1.2 Cross Compliance

The system of cross-compliance reduces payments to farmers who do not respect EU-standards associated with agricultural activity, including environmental and other legislation set at EU level.

Beneficiaries of direct payments must also maintain agricultural land in good agricultural and environmental condition. Member States lay down the conditions for this - these include on-farm obligations, such as soil practices and other.

Statutory Management Regulations (SMRs)

Table 30 SMRs - potentially support management options

S	• SMRs provide a basic standard that have horizontal impact. • SMRs can be considered a tool to speed up Member State implementation of the various Regulations and Directives listed in Annex III of Regulation 1782/2003
W	• None of the existing SMRs relate specifically to climate change relate to agriculture • The current cross compliance framework applies to a large number of farms and over a wide area of land, it imposes standards on farms and in areas irrespective of whether certain environmental problems occur there or not.
O	• There is potential to include additional legislation that facilitates adaptation to climate change (for example the Water Framework Directive (WFD)). This would have the effect of “climate change proofing” direct support payments.
T	• None

Good Agricultural and Environmental Conditions (GAEC’s)

Table 31 GAEC's - potentially support management options

S	• Member State flexibility to address specific local agricultural and environmental priorities. • As GAEC’s are decided on a national or regional level, they can be updated to reflect present and changing knowledge and continue to reflect local issues. • GAEC’s are relevant for adaptation as set out rules for better soil management, which is essential for adaptation.
W	• There is no explicit reference to climate change adaptation or even climate change itself within the conditions. It is therefore reliant on the Member State or region’s understanding and appreciation of climate change issues relating to agriculture. • There is no formal requirement for Member States to identify major environmental pressures (which may include climate impacts) or justify the inclusion or exclusion of corresponding GAEC standards. • Member States may not prioritise adaptation.
O	• Include standards relating to adaptation such as water management into the GAEC framework will guide the development of relevant GAEC’s by Member States
T	• None.

Requirement to maintain permanent pastures area

Table 32 Permanent Pasture

S	• Maintenance of a minimum of 90% of permanent pasture (at reference levels) allows habitats and dependant species to survive.
W	• Only the maintenance of the amount of permanent pasture per Member State is stipulated rather than the actual sites. As a result the habitat value of permanent pasture is not taken into consideration.
O	• Identify any correlation with the Natura 2000 sites to see if permanent pasture areas could add to the habitat sizes. This would only work if the permanent pasture sites stay permanent.
T	• As the site of permanent pasture is not taken into consideration, long-standing habitats of high nature value are not prevented from being cultivated if other equal land areas become available as substitutes.

7.1.3 Market intervention and supply control instruments

Table 33 Intervention - potentially supports management options

S	• Ensures base commodity prices, so reduces risk to farm businesses. Lowering financial risks of growing a particular crop will reduce a farmers' vulnerability to extreme events.
W	• Retaining intervention may cause farmers to concentrate on the short-term financial gains of growing a certain crop rather than looking towards future trends and necessary adaptive actions.
O	• Intervention could be targeted towards new crops or cultivars, more resilient to anticipated climate impacts to encourage and support their uptake.
T	• Intervention reduces the farmers' market-orientation, which can skew production decisions irrespective of necessary adaptations that need to be considered as a result of existing or future climate change.

7.1.4 Farm Advisory Service (FAS)

The Farm Advisory System (FAS) is a system for advising farmers on land and farm management. Participation is voluntary but under the Council regulation 1782/2003 "MS advisory activity shall cover at least the Statutory Management Requirements and the Good Agricultural and Environmental Condition". Farmers are encouraged to take part with a facility to claim for assistance (up to a of 80%) to use the provided service (subject to a ceiling of €1500).

Table 34 FAS - supports technical options

S	• FAS is an accessible way for farmers to learn about climate change and how to adapt to it. Changes in precipitation patterns, drought, flood management and temperature will all impact on land management and husbandry practices. • The FAS has a key role in realising adaptive capacity via: Education of risks and impacts (now or near future) Planning of farm businesses (now or near future) Knowledge Transfer of Research and Development findings on changing crops, cultivars, husbandry (near future) • Member States have the flexibility to deliver technical advice on locally relevant themes and topics.
W	• Participation is voluntary • Added subject areas may increase the funding requirement for FAS. Due to the capped and falling direct payments budget additional funds may not be available.
O	• Increasing the scope of the FAS beyond cross-compliance (SMR and GAEC) related advice could support strategic business decisions likely to be necessitated as a consequence of climate change. Such advice could guide longer-term capital investment decisions relating to infrastructure or the adoption of farm practices that reduce vulnerability and link with measures of the Rural Development Plan. • If the GAEC's are updated to include adaptation advice, the FAS will be able to advise farmers and land managers.
T	• None.

7.1.5 Set-aside

Set-aside is the term that refers to the removal of farmland from production, usually with the overall aim of reducing the production of arable crops, in particular cereals. Farmers producing a significant amount of arable crops are required to 'set aside' a proportion of their land as a condition for receiving support payments. The current percentage is 10 % of the land eligible for the single payment scheme. Small farms are exempted. This obligation has been abolished for 2007/2008 campaign and its future maintenance is currently under assessment by the Commission.

Table 35 Setaside - potentially supports management and infrastructural options

S	• Originally a production management measure, set aside has been noted to increase the opportunities for environmental benefits in terms of providing wildlife habitats and lending itself as a physical buffer for run-off, reducing the levels of diffuse pollutants entering surface and ground waters, improving soil structure etc. These are all useful outcomes in terms of adaptation. • It is a mandatory, horizontal instrument inclusive of all farmers receiving the SPS. • Set aside land has been use, on a local scale, to accommodate floodwaters from winter flooding – an infrastructure option
W	• There are questions as to whether it is an appropriate tool to use to achieve environmental outcomes as they are already offered under agri-environment (i.e. protection and enhancement the agricultural environment), which can be targeted more appropriately. • It is a horizontal, non-targeted measure and is non-site specific. Its siting and management therefore may not necessarily facilitate adaptation.
O	• DG Agriculture commissioned an evaluation of set-aside in 2002, including its role from an environmental perspective. The evaluation concludes that, although set-aside was introduced as a market management tool, where managed appropriately, it does provides some environmental benefits, in particular because of the lack of inputs used. The maintenance of an appropriate green cover throughout the year does however limit erosion and the leaching of nitrates. Under cross-compliance, Members States must ensure that set-aside is managed in order to protect the environment. If the set-aside area is along a watercourse it can, under certain conditions, reduce nitrate and pesticide run-off. The sowing of certain plants can considerably enrich the soil with organic matter. The effect of set-aside on the landscape (e.g., diversity, aesthetics) is considered as rather neutral. In addition, long-term and, to a lesser extent, non-rotational set-aside areas can contribute to the protection of animal and plant biodiversity. Permanent set-aside is evaluated as important for the maintenance of certain bird populations, as the non cultivated plots provide "stepping stones" for birds in the most intensively managed arable areas. • Set aside land located in flood plains can be used to accommodate floodwaters in times of high discharge and/or storage for times of water shortage.
T	• If set aside rules are maintained, set aside may hinder the realisation of the potential of the advantages that Climate Change will bring to some areas, such as Northern Europe, where productivity could increase. As more Southern areas become less productive, maintaining set aside levels at present rates will reduce the production capacity of Europe.

7.1.6 Article 69, specific support measures

According to article 69 in the Council Regulation 1782/2003 Member States can retain up to 10 % of the component of national ceilings and target it at a specific eligible sector for the ‘protection or enhancement of the environment’, or for ‘improving the quality and marketing of agricultural products’. This offers a way to protect any particularly vulnerable production sectors, many of which play an important role in maintaining high nature value farmed landscapes. An example where it has been implemented is in Scotland, where Article 69 provides around £20m of funding per year for the Scottish Beef Calf Scheme.

Table 36 Article 69 - potentially support technical options

S	• Member States can retain 10% of the national ceiling and use it to support economically marginal sectors that are associated with environmental benefits.
W	• There is no explicit reference to climate change so redistribution of retained funds is dependant on the Member State prioritising climate change adaptation • Targeting specific sectors may be a crude use of funds as the impacts of climate change on sectors may vary with geography
O	• The flexibility of how the 10% of the national ceiling component is distributed could be increased to enable greater targeting of funds, for example to geographic areas vulnerable to climate change rather than to a sector as a whole.
T	• None

7.1.7 Specific Crop Support

Table 37 Specific crop support - potentially supports management options

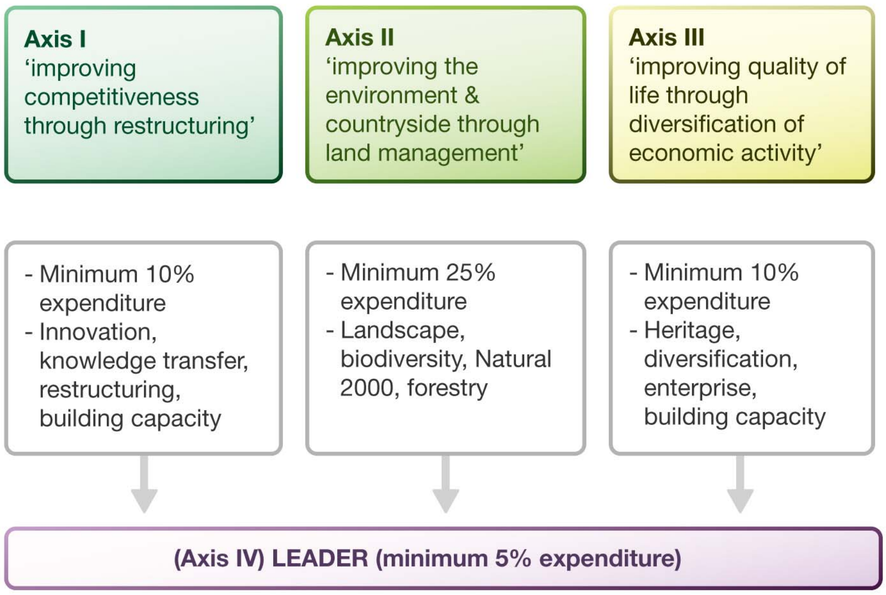
S	• Individual crop support can help maintain existing wildlife habitats in the short-term such as in the Ebro Delta in Spain. This helps build ecosystem resilience to support ensuring successful adaptation to climate change impacts and shift to new climate space in the medium to long term.
W	• Maintaining a dependence on production linked income support may reduce the willingness of farmers to adapt as well as their adaptive capacity. • There will be a shift in the climate space of species in response to climate change. It is possible in the short term to maintain existing habitats and populations but in the medium to long term these will need to shift to track climate change. It would be more prudent to ensure complementarity with biodiversity adaptation plans, planning for the medium to long term on assisting the movement of species to more appropriate locations.
O	• None
T	• None

7.2 Analysis of rural development measures

The European Agricultural Fund for Rural Development (EAFRD) has four axes for action. Axis 1 focuses on improving competitiveness of farming (and forestry) sector through support to improve human and physical capital in the land based industries. Axis 2 relates to land management and natural resources. Axis 3 aims to support diversification of rural economies and improve the living conditions on the wider rural society. Axis 4 underpins all of these with a provision of funding for bottom up or Leader projects as shown in Figure 28. Furthermore each axis has a minimum spend associated with it in an attempt to create a more balanced use of the funds across the Member States also indicated.

Climate change is one of the key priority areas defined in the EU's strategic guidelines for rural development policy, Point 3.2, iii) states that "*Appropriate agricultural and forestry practices can contribute to the reduction in greenhouse gas emissions and preservation of the carbon sink effect and organic matter in soil composition, and* ***can also help in adapting to the impacts of climate change***". The Commission encourages Member States to include measures to tackle and adapt to climate change when designing and implementing their rural development programmes. However, national programming seems to focus on gas emissions and mitigation measures than on the adaptation, which may perceived as a more long term concern.

Figure 28 The EARDF axes and minimum spends on each axis



The following sections examine the most relevant measures of the Rural Development Programme's four Axes. Measures are grouped according to the 'type' of adaptation option that could be enhanced – infrastructure, technical/equipment, or management to maintain consistency with the adaptation options outlined in Chapter 6.

7.2.1 Axis 1 – Competitiveness, improving physical and human potential

Support to infrastructure

Table 38 Support to infrastructural options

Modernisation of agricultural holdings	
S	• This is an area where capital investments are likely to be large and would otherwise be a barrier to change. • Through modernisation farmers can be supported to adapt to projected climate changes. Infrastructure improvements can help overcome a variety of issues including water scarcity, extreme events such as flooding and warming, heat stress through improved ventilation of animal housing systems. • The plantation of perennial energy crops such as short rotation coppice has the potential to provide buffer strips to cope with extreme events such as flooding. This new crops and market outlet may also represent an opportunity to diversification of farm activities.
W	• Planning is not a European competence. This makes it difficult to obligatory that climate change adaptation concerns are taken into consideration of proposed investments. • The looseness of the strategic guidelines within Rural Development plan in relation to climate change may lead to investment in building infrastructure that is designed to cope with current, not future, climate extremes.
O	• Member States and farmers should be more aware of the opportunities for adaptation this measure provides.
T	• Climate change concerns do not presently have to be included when considering farm modernisation (no mention in the European regulation), investments may be supported that are not adaptive in nature due to lack of understanding or awareness by the farmer, architects, builders or the department providing the support. • Data at the resolution of the regional scale may not be sufficient to direct appropriate decisions as the appropriateness of investments to localised climate impacts. • Funding increases the capital value of a business, thus increasing the farmer's vulnerability. Therefore the need for insurance is further heightened.

Restoring agricultural production potential and prevention actions	
S	• Presently this measure has financed restoration rather than prevention actions but it is directly applicable in offsetting the negative impacts of climate change and adapting further. For instance it can support changes in land use to maximise yields under new conditions
W	• As it has not been used for climate change adaptation, farmers and funding bodies may not be aware of its potential.
O	• Ensure deliverers of Rural Development measures are aware of the potential of this measure in relation to its use to facilitate adaptation
T	• None

Improving and developing infrastructure related to the development and adaptation of agriculture	
S	• Support to measures for improving water management such as increasing efficiency in water use for irrigation or the creation of hard defences or improved drainage against increased risk of flooding. • It can further provide support to improve field drainage and soil absorption capacity or allow better use of precision farming techniques.
W	• None
O	• None
T	• None

Technical/ Equipment/ Farm Management

Measures aimed at promoting knowledge and improving human potential and farm management.

Table 39 Technical/ Equipment/ Farm Management options facilitating adaptation

Vocational Training and information actions including diffusion of scientific knowledge and innovative practices, for persons engaged in the agricultural, food and forestry sectors	
S	• This is an ideal platform to raise awareness among farmers about the implications of climate change and their options and costs for adaptation, such as switching to alternative crops or how to deal appropriately with increased water logging. • It can provide signposting to funding available to assist farmers. • As training is delivered at Member State and/or regional level adaptation options can be place specific reflecting local potential impacts.
W	• Under Pillar 2 training is not statutory as with the advisory service under Pillar 1. Some Member States may have different priorities other than training. • Climate change adaptation is not explicit as a topic to be covered within the training.
O	• Climate change adaptation options could be included within the training topics as a priority. It is important that climate change is not taught only as a stand alone issue but integrated within all subject areas such as animal welfare, crop varieties, pests weeds and diseases and so on.
T	• As mentioned under the FAS heading under Pillar 1, the information provided must be up to date, relevant and constructive. Any misinformation will increase the individual farmers' vulnerability, as it will impact their future decisions on investments, modernisation, farming practices and planning.

Use of advisory services by farmers and forest holders	
S	• This can broaden the audience reached.
W	• Inclusion of climate change issues is not required.
O	• Farmers could be made aware of the range of advice on offer, including that on climate change adaptation options, as well as the fact that there are both negative and positive impacts.
T	• None

Setting up of farm management, farm relief and farm advisory services, as well as of forestry advisory services;	
S	• Provides Member States with the support to set up high quality services
W	• None
O	• Relevant advice should be included on local and appropriate adaptation options
T	• None

Cooperation for development of new products, processes and technologies in the agriculture and food sector and in the forestry sector	
S	• This provides support to create the ideal platform for knowledge transfer and support new adaptation measures, such as changing cultivation practices or converting ambient storage to refrigerated stores
W	• The opportunities offered under adaptation are ignored
O	• Adaptation will necessitate the uptake of new products, processes and technologies. Pooling experience, advice and finances to achieve this will enable successful adaptation. This cooperation should be encouraged across local, national and European groups.
T	•

Participation of farmers in food quality schemes	
S	• As climates change so will the crops that can be grown and their associated quality. Being part of a food quality scheme will provide a forum where new management measures can be discussed and experimented with.
W	• None
O	• Extend the participation maximum to longer than 5 years as climate change will have a much longer effect
T	• None

7.2.2 Axis 2 – Land management and the environment

Table 40 Axis 2 measures that could facilitate infrastructural options

Animal Welfare Payments	
S	• This measure allows farmers to take a long-term approach to their housing and other animal welfare needs with regards to predicted changes in temperature in particular
W	• None
O	• Funding relating to this measure could be used by farmers to upgrade their existing livestock housing to take into account predicted changes such as temperature rises or heavier precipitation that would negatively affect their livestock in the future. This long term view should be encouraged.
T	• None

Table 41 Axis 2 measures that could facilitate technical options

Afforestation measures	
S	• Afforestation can be used as an adaptation measure where water scarcity will reduce arable production potential.
W	• Farmers may not take future trends into account when deciding to use this measure thereby investing in practices and species that may place them at higher risk in the future.
O	• Encourage the planting of trees in those areas where increased wind temperatures, soil erosion or high temperatures have been identified so as to minimise soil erosion and provide shelter for agricultural crops, rural communities and habitats.
T	• It is important that the tree species used for the afforestation are appropriate to their environment. For example species with high water demands will not thrive and can make water scarcity issues more pronounced. • By its very nature, forestry is a long-term industry, and the consequences of management decisions made now may only become apparent in fifty years time. It is therefore essential that any management decisions taken now, such as choice of species, location and growth potential are made with future climate change scenarios in mind.

Non-productive investments	
S	• Landscape elements can help reduce Climate Change impacts • This can assist in the maintenance of Natura 2000 sites or other high nature value areas, thereby increasing their adaptive capacity.
W	• None
O	• This can be highlighted as a measure to be used as an adaptation tool as investments into adaptive technologies are likely to not be productive
T	• None

Table 42 Axis 2 measures that could facilitate management options

Agri-environmental Measures	
S	• These measures include improved resource management (e.g. soil and water), which will help meet changing and more difficult environmental conditions. • Conservation of genetic resources is crucial to select the genetic material resistant to changing diseases and insects and tolerant to heat and water stress. • The additional funding associated with this measure incentivises farmers to take action • Options include restoration of woodland and preventative measures for forest fires. Both of these can help farmers adapt by providing buffers to extreme events and promotes habitat variety. • Member States can tailor measures to fit their individual circumstances. This flexibility can be targeted to appropriate farm systems, landscapes or areas • The measures will assist in increasing the environment's own capacity to adapt/withstand change
W	• While Member States are obliged to include agri-environment measures in their Rural Development Plans, the measures are voluntary for farmers • Agri-environment schemes do not include all farmers due to national limitations on co-financing and political limits on the European budget as a whole. • Member States may not prioritise adaptation in its national strategy.
O	• Agri-environment schemes can be used in several ways to help address water scarcity, soil, and biodiversity and landscape management.
T	• None.

Natura 2000	
S	• Allocating sites of particular natural interest will allow those habitats and species to increase their resilience and therefore increase their capacity to adapt to climate change.
W	• Many Natura 2000 sites look at individual occurrences of particular species without protecting viable populations and their interconnecting habitat – which all need to adapt together to climate change. According to Opdam and Wascher (2004) it is highly probable that the size and spatial cohesion of current ecological networks will not be enough to maintain biodiversity levels.
O	• Natura 2000 sites may need to be re-evaluated or boundaries changed to reflect changes in biodiversity due to tracking of climate change. • The choice of sites could evolve to become based on the ecosystem approach rather than individual species, thereby improving the quality of the habitat and the connections between them. • The network approach needs to be improved with the creation of robust corridors between protected areas. Many species have a small dispersal capacity and require habitat to reproduce within close proximity. These robust corridors are based on integrated area requirements and dispersal capacity of a wide range of species (Vos *et al.,* in press). • The importance of biodiversity within the context of climate change should be more widely communicated.
T	• None

Payments linked to the Water Framework Directive	
S	• As the WFD integrates water quality, water resources, physical habitat and, to some extent, flooding for all surface and ground waters as part of river basin management it could link new policy and participative mechanisms that are being established for River Basin Management Plans to emerging national adaptation strategies. It is a dynamic piece of legislation allowing local issues to be addressed. • Many river basins cross political boundaries thereby increasing communication of stakeholders. • It has the potential to put the means (via compulsory or voluntary measures) to achieve an optimised water use by farmers
W	• There is no explicit mention of the risks climate change poses in achieving environmental objectives of the WFD
O	• Encourage Member States to design policies within this measure that can help farmers and rural areas cope with forecasted water issues, such as flooding and drought. • The enhanced communication across political borders could be taken advantage of in terms of adaptation knowledge transfer. • The co-ordinated objectives of the WFD present opportunities to facilitate and join up (rather than constrain) climate adaptation across sectors.
T	• None.

Natural handicap payments in mountain areas and payments in other areas with handicaps	
S	• By compensating for natural handicap, farming systems that maintain sustainable land management are more resilient to climate impacts. This will help maintain areas of high environmental and/or amenity value.
W	• Present support levels may not be sufficient to maintain agricultural practices in light of climate change impacts.
O	• The definitions of the characteristics of what is a natural handicap could be could be expanded to include those areas that will be particularly negatively affected by climate change. With limited production capacity due to changes in temperature and precipitation or increased frequency of significant events, these areas will become particularly vulnerable. By reducing land abandonment in these areas and supporting adaptation measures these areas could help buffer other areas from the severe impacts of climate change.
T	• Maintaining production in areas that are not viable may make the rural European Union less likely to get involved in training and diversification thereby reducing their adaptive capacity.

7.2.3 Axis 3 – Enhancing quality of life of wider rural community and promoting economic diversification

Table 43 Axis 3 measures that could facilitate management options

Diversification into non-agricultural activities	
S	• Diversification of income sources will reduce a farmer's, and communities', vulnerability to climate change impacts. Named examples of diversification activities include supporting the transformation of redundant agricultural building into other uses such as offices, tourist accommodation and retail spaces.
W	• None
O	• Predicted climate change must be taken into account to assess the future impacts on the new source of income.
T	• Particularly with relation to changes in building use, climate change risks may not be taken into account in their design and future use potentially raising the user's vulnerability

Support for business creation and development (micro-enterprises)	
S	• Funding entrepreneurship supports those that take advantage of opportunities. Climate change will offer some opportunities and taking advantage of these will be a positive form of adaptation. • Encourages the development of basic services for the rural economy and population • As rural areas make up 90% of the EU, it is important that they are all involved in adapting to climate change. Axis 3 provides local communities the opportunity to identify actions that can be undertaken in their area to adapt to climate change
W	• These funds will also be awarded to sectors outside agriculture, which decreases the budget available for farmers to adapt. • There may be too much emphasis on short term rather than medium to long term goals
O	• Ensure that climate change is taken into account, maximising new opportunities such as greater tourism potential, and safe guarding the business against the adverse effects through sufficient insurance and appropriate building design.
T	• None

7.2.4 Axis 4 – Leader

Management, technical/equipment and infrastructure adaptation options can all be accessed through this Axis.

Table 44 Analysis of Leader

S	• The strengths of the Leader axis are many due to its bottom up ability to cater for local problems identified by local people.
W	• This bottom up nature can be a weakness in itself, as local people may not have the skills to understand and accommodate climate change adaptation, nor have it as a priority. This may be a result of looking to shorter tem goals rather than understanding the longer-term picture.
O	• Trans regional and trans national cooperation can be promoted to enable knowledge transfer when ecosystems track climate change. Knowledge of the management of these ecosystems will need to move accordingly. This can also be facilitated through the Rural Networks.
T	• Local communities may not be well placed or sufficiently aware of their options to make decision on climate change adaptations. This may result in maladaptive schemes being presented.

7.3 How the CAP can support adaptation

The process of embedding a new climate dimension into the CAP has already begun with guidelines given to Member States in the Strategic Guidelines for rural development programmes for the period 2007-13 should address climate change. Furthermore the European Commission is looking at options to manage climate change risks and tools to aid adaptation, recognising the fact that agriculture will play a significant role.

To support this process, the appropriateness of existing policy measures in a future CAP in facilitating adaptation is discussed including consideration as to which measures should be continued or modified The development of new instruments that can increase the resilience of farming to climate change impacts is proposed.

7.3.1 The potential role of existing direct income support measures towards adaptation

SPS and Cross Compliance

Decoupling the link between land management practice and production, and attaching conditionality to the Single Payment Scheme has created a more market responsive and flexible agricultural sector that is associated with higher environmental standards.

The Single Payment Scheme provides a platform against which to attach other policy measures, notably cross compliance, which in turn links direct aid to standards relating to agricultural land, agricultural production and activity. The standards have raised awareness of statutory environmental, animal welfare and food safety standards (SMRs) and, as a sanctioning tool, have made farmers accountable for good practice. Importantly the obligation to adhere to Good Agricultural & Environmental Condition (GAEC) also provides important flexibility to introduce specific measures that address priority issues within each Member State. A third objective of cross compliance is to maintain the existing area of permanent pasture as it is regarded to have a positive environmental effect.

Cross compliance is an important tool in ensuring that the Single Payment is environmentally neutral. Yet though adaptation potential may be result from some existing SMRs, such as those relating to habitats and nutrient management, the current standards were not devised to reduce climate risk vulnerability *per se*. There is a case therefore for reviewing the current cross compliance framework to work towards the development of a CAP that facilitates future adaptation. Questions relating to the scope of cross compliance are to be addressed during the forthcoming revision of the CAP according to Communication from the European Commission on the mid-term Health Check reform

(COM (2007) 147, November 2007). The Commission will explore the possibility of tackling climate change issues through, amongst others, new the introduction of new cross compliance requirements.

A potential option here can be to incorporate field level soil management plans into cross compliance. Currently, under existing soil SMRs measures are taken equally across the whole agricultural area. By requiring Single Payment claimants to assess risks and tailor soil management measures at the resolution of the farm will help avoid soil problems such as erosion.

New legislative requirements that facilitate adaptation potential could be added to Annex III of Regulation 1782/2003. For example, inclusion of the Water Framework Directive or water quality/quantity standards into cross compliance would encourage improved resource management and best practice, which would be especially important where water scarcity or intensity of water use are anticipated.

There are difficulties however in supplementing existing cross compliance requirements. Strong resistance to proposals to expand the number of SMRs or a broadening of the scope of GAEC is likely as indicated by the results from this study's questionnaire (question 52 see Annex H). Over half of respondents (56%) answered in the negative to supplementing cross compliance with additional adaptation-related measures. In contrast, over three quarters respondents (79%) were more supportive of specific adaptation measures being included within voluntary opt-in through agri-environment schemes. Respondents cited that if any new standards were added they should be simple to understand and implement, be cost neutral and add specific benefits to the farmer.

Agri-environment measures can be used to help adapt to natural disasters. For example, compensating farmers for income foregone where land is dedicated as flood plain would strengthen resilience to extreme rainfall events.

If the costs of implementing new measures is not, or even perceived to be, proportionate, farmers are likely to opt out of SPS by not submitting claims and could lead to land not being kept in accordance with good agricultural and environmental condition or even persuade farmers to exit farming leading to land abandonment. It is also worth acknowledging that this policy measure may weaken over time if relative Pillar One payments continue to shrink, especially if commodity prices rise sufficiently high enough for claimants to forego their Single Payment, and result in increasing numbers of claimants opting-out of the SPS.

Member States have considerable flexibility in determining GAEC standards within the framework given by current legislation (that mainly cover soil management). This has certain strengths and weaknesses in relation to adaptation.

In developing their own GAEC's, Member States or regions can take into account the specific characteristics, including soil and climatic condition, existing farming systems, land use, crop rotation, farming practices and farm structures. The potential for future development of GAEC's that oblige farmers to undertake highly appropriate management practices that assist with adaptation can be formulated.

However, no formal requirement for Member States to identify major environmental pressures or justify the inclusion or exclusion of corresponding standards exists. To ensure adaptation is appropriately considered by Member States, the European Union could require them to justify their choice of GAEC standards by relating these to identified and evidenced environmental pressures. In this way, where climate risks and impacts are priority issues, standards relating to adaptation measures can be incorporated into GAEC standards. Where this is not deemed appropriate, or less of a priority, evidence provided by the Member State can justify omitting adaptation standards. This approach would ensure future GAEC's take account of adaptation needs yet would not compromising member state flexibility. The Commission would also have the opportunity to request a strengthening of adaptation options under GAEC standards where serious gaps in addressing climate change arise.

Permanent Pasture

According to the preamble of Regulation 1782/2003, the rule concerning permanent pasture is included due to its 'positive environmental effect.' Concerning adaptation the maintenance of a minimum of 90% of permanent pasture relative to reference levels should ensure the continuation of habitats and species that support agricultural production, allowing them to increase their resilience in the face of climate change.

However, the rules only stipulate the area of permanent pasture to be maintained by the Member State but does not take require the actual siting of the pasture. There is no requirement to retain environmentally important permanent pasture (semi-natural pastures and high nature value grassland such as wetlands in flood plains) and so pasture of a higher habitat and biodiversity value is not safeguarded.

The rules concerning permanent pasture could be modified to reflect the grassland type so that the proportions within reference amounts are retained. In this way, habitat and biodiversity degradation will be avoided, to retain suitable habitats.

Farm Advisory Service (FAS)

The Green paper 'Adapting to climate change in Europe – options for EU action' highlights the importance of integrating research results into policy and practice. The FAS has the potential in realising adaptive capacity, especially if SMR and GAEC standards that the Service is required to cover, evolve to include adaptation measures.

Currently, as stated in Regulation 1782/2003, the Service should assist farmers in identifying changes to farm management practices required by the SMRs and GAEC standards. Considering the fact that the FAS is often integrated into broader advice packages that include farm business and agronomic advice covering technical and management aspects relating to adaptation is feasible.

Broadening the scope of FAS beyond current SMRs and GAEC standards to include adaptation will inevitably require additional funding. This may be difficult as it is funded through the capped and falling nature of Pillar One. Targeting adaptation advice to the most vulnerable sectors or areas or holdings is one option that may make this option viable as delivery costs would be less.

Certain Member States have already adopted targeted approaches to delivering existing the FAS. Non-conformity with the cross compliance requirements, prioritizing farms in Nitrate Vulnerable Zones and Natura 2000 areas, targeting young farmers or farms that have made structural investments in the last 3 years have all been suggested or utilized at Member State level to target FAS advice (Povellato and Scorzelli, 2006).

To fund an expanded FAS able to provide advice concerning new technologies and management practices that facilitate adaptation, Member States could be allowed to retain the penalties placed on non-compliant claimants (currently 25%).

Article 69, specific support

The ability for a Member State to retain 10 % of the component of national ceilings and target it at a specific eligible sector for the 'protection or enhancement of the environment' through Article 69 of Regulation 1782/2003 could be of use in relation to adaptation. This article offers a way to protect production sectors, many of which play an important role in maintaining high nature value farmed landscapes.

This article could be improved by conferring greater flexibility in how the 10% of the national ceiling is targeted. In relation to adaptation, the provision to target money at certain areas in a Member State rather than at the sector as a whole could support those most vulnerable to climate impacts which may be equal across a whole sector.

7.3.2 The potential role of rural development measures towards adaptation

Unlike adding further standards under cross compliance where there are limited funds and potential for political disharmony, the Rural Development programme provides a framework to help encourage adaptation in the agricultural sector.

Rural Development measures can help support adaptation at a number of different scales and in a number of different ways. There is present linkage between implementation of the **Water Framework Directive** (WFD) and the CAP as mentioned in paragraph 34 of the preamble to Regulation 1698/2005. This link could be exploited more heavily as up to now the WFD has assumed major importance in the engineering and water sectors but little importance in the land use planning sector

(White and Howe, 2003). The WFD can provide a structure within which to deal with flood risk, water resources and other issues such as diffuse pollution, in an integrated way by focusing on the River Basin Planning process. Community co-funded research projects such as AquaTerra are seeking to develop an integrated modelling approach for the river-sediment-soil-groundwater system as an aid to assessments of climate change, changes in land-use and diffuse pollution – all with a view to defining long-term management scenarios. This process can also allow diverse policies with different time frames to be tackled coherently and across political borders. To do this, those implementing the WFD on the ground need to be made aware of the climate change issues and their potential role in adaptation and its relationship with land management and therefore the CAP. Wilby *et al.,* believe this requires rapid development or adaptation of policy on biodiversity conservation and the management of agri-environment schemes in the face of climate change.

Agri-environment schemes have the potential to offer much support for many adaptation options, including those outside the focus of the WFD.

It is essential that agri-environment schemes should be implemented and targeted as a key part of a considered spatial plan and considered in conjunction with forestry and other schemes. Furthermore they need to be dynamic and evolve as the climate changes. The fact that the impacts need not necessarily all be negative, for example managed realignment of the coast, has the potential to both promote biodiversity and reduce flood defense costs must also be emphasized.

One of the weaknesses is that despite the presence of national and regional priorities, activity at the local level can have a significant influence on agri-environment schemes, as experienced by the Entry Level Scheme in England. Management “on the ground” is often complicated with a large number of stakeholders operating on very different timescales for planning and budgets and tends to favour the preservation of habitats and species and thus may hinder more coordinated plans for adaptation. In addition, climate change is a long-term challenge that requires agreements and commitments on appropriate timescales.

The Rural Development Plan may potentially benefit further by guiding or placing an obligation on Member States to meet or consider the impacts of future climate change, in particular across Axes 1 and 3.

Amending the strategic guidelines for Axis 1 so investment on technologies that improve coping capacity relative to anticipate local climate are referred to would deliver specific benefits in terms of adaptation. Current Axis 1 guidelines, although making reference to the development of renewable energy material and biofuels, thereby reflecting the European Union’s energy and mitigation objectives, do not refer to adaptive capacity building options. Expanding this Axis so that it encourages technologies that reduce vulnerability to severe weather, such as water efficient technologies, increased animal shelter or conversion of ambient storage to refrigerated stores for example, would facilitate improvements of farm holdings so that they are more resilient.

It should also be considered that proposed farm modernisation may be inappropriate in relation to climate adaptation. Safeguards, in the form of additional guidance under this Axis would ensure that any investment made does not damage or degrade the environment.

Similarly to Axis 1, guidance relating to Axis 3 expenditure should be actively encouraged in the strategic guidance to promote adaptive capacity and dissuade investment on improvements that can be environmentally negative. Opportunities such as diversification into coppicing for the production of renewables, forest management or the development of tourism as a non-agricultural income are examples of positive support under this axis.

To ensure investments made under Axis 1 and 3 bring benefits in terms of adaptation it would be worth exploring the possibility of linking funding to cross compliance. Cross compliance standards are already applied to certain Axis 2 measures and extending it would act as a sanctioning tool if those benefiting from Axis 1 and 3 support were found to not be observing them.

A key priority of rural development support is to safeguard rural communities. In the discussion in section 5 of this report it states, “With a move away from agricultural support, the cost of most adaptive measures may have to be borne by farmers themselves. Those farming on marginal land, where incomes are low, are at greatest risk….There is a danger that these areas, which may account for only a small proportion of national gross domestic product, could be neglected. Adaptation is, therefore, a major issue for maintaining incomes across rural communities.”

Measures under article 37 of Regulation 1698/2005 (areas with natural or other handicaps) support the most vulnerable areas across the EU. The communities that rely on these payments will need them more than ever as their Single Farm Payment reduces and the negative impacts of climate change make their mark. It is possible that the criteria for naturally handicapped areas could recognise the potential and existing threats of climate change, so as to support communities as they adapt to future scenarios.

8 Conclusions

8.1 Climate change impacts, risks and opportunities for EU agriculture

This report explores the impacts of climate change that might affect European agriculture, building on extensive analyses of several hundred published studies. In examining the challenges to be faced by European agriculture, the report defines European agro-climatic zones and farming systems as an aggregated framework for assessing impacts; documents the methods used for the assessments of impacts and the evaluation of risks and opportunities; and provides an analysis of those in each agro-climatic zone.

The following conclusions were drawn from analyses of potential impacts drawn from existing scientific literature:

Climatic changes, in general, are likely to shift the zonation of optimal production areas for specific crops in the EU. Temperature increases tend to speed the maturation of annual crops, therefore reducing their total yield potential. In turn, such changes in productivity and zonation may affect the total agricultural output of the EU and its share of international commodity trade.

The combination of long-term change (e.g. warmer average temperatures) and greater occurrence of extreme weather events (e.g. droughts and floods) can have adverse impacts on agricultural production. Two variables are highlighted as particularly critical for agriculture: future precipitations patterns and their distribution throughout the year, and the incidence of extreme weather events.

Higher temperatures and overall greater precipitation in some regions are likely to result in an increased spread of weeds, pests and diseases.

Although there is a large variation in projected impacts in each EU region, overall the studies are consistent in the direction of change and spatial distribution of effects.

The report also evaluated specific risks and opportunities in each agro-climatic zone and the following conclusions can be drawn:

In the **Alpine, Boreal, Atlantic north and central,** and **Continental north zones**, risks relate mainly to potential changes in precipitation patterns, with projected increases in winter rainfall and decreases in water availability in summer. Hence strategies are needed to reduce the effects of winter flooding, water logging and reduced water quality, while implementing measures for capturing and storing water to ensure adequate supply during the summer.

Rising sea levels are a particular risk in the **Atlantic central zone**, requiring either improved defences or the abandonment of land due to inundation and saline intrusion.

Whilst influxes of new pests and diseases present a high risk in the **Boreal, Atlantic central,** and **Continental north zones**, there is likely to be considerable opportunity in these zones for increased agricultural production. The yields of current crops are set to increase, together with the area of land over which crops might be grown. There is also potential for the introduction of new crop types, and may be an opportunity for increased livestock production in some zones. However, there is also a possibility that optimal growing conditions may shift from areas that have a large proportion of fertile soils towards those where soils are less fertile and, therefore, less able to support higher yields.

In the **Atlantic south, Continental south** and **Mediterranean zones**, the greatest risks are reduced crop yields and conflicts over reduced water supply. Strategies need to be developed to adopt cultivars or crops better suited to water and heat stress. Problems from new pests and diseases are also considered a high risk in these zones. There are few opportunities, although in parts of the **Continental south zone** (Hungary, Romania), there may be some scope for the introduction of new crops.

8.2 EU agriculture: finding ways to adapt to climate change

Assessment of the national adaptation strategies for EU Member States cited in the Nairobi report, together with the appraisal of potential adaptation options to address the risks and opportunities identified in this report and the information gathered from the questionnaire leads to the following conclusions:

The review of national adaptation strategies highlights an emphasis on reducing the risk of flooding, either from sea level rise or from increased rainfall. There are also proposals, mainly from southern Member States, to increase capture and storage of water to ensure adequate supplies. While some mention is made of such measures in northern states, it is important that these are promoted more widely. As precipitation patterns change, their limited capacity for water storage may need to be increased to capture a greater proportion of winter rainfall than is currently the case.

Measures to adapt crop and livestock production, in particular the potential gains in productivity forecast for northern regions, need to be given greater priority. At the same time, there is a need for EU measures to help support communities in southern regions who will suffer from reduced agricultural production. While in a global economy it might be argued that the market should be left to resolve such issues, many other regions of the world are also forecast to face difficulties in maintaining current levels of production.

Many of the possible adaptation measures can be applied at farm level, with the majority of measures being management-related. This implies that these should be more easily orchestrated, with many categorised as applicable over a mid-term timescale (5-10 years). However, before many of these can be implemented, short-term measures involving policy development and partnerships must first be put in place.

The questionnaire results reveal reasonable, and in some cases good, agreement across all nine agro-climatic zones with the priorities identified for each zone in the risk assessment. The responses did, however, differ according to the projected impacts (e.g. the need for irrigation being significant in the Mediterranean south zone, but not in the Atlantic north). In general, there was a greater awareness and greater adoption and/or consideration of adaptive measures in the southern agro-climatic zones than in the north. This reflects a greater likelihood of adverse impacts on crop production in these zones and hence a greater urgency to take action to maintain current production, insofar as is possible, or seek alternative modes of production.

The questionnaire also revealed that less action appears to be in prospect in northern zones. This is likely to be a consequence of the less damaging projected impacts on production. However, the forecast changes/intensification of the hydrological cycle may lead to an increased risk of winter flooding and reduced availability of water in summer; measures need to be implemented to lessen the impacts of these changes. Furthermore, there are likely to be opportunities for increased agricultural production. If these potential increases are to be realised, which would be desirable to compensate for inevitable declines in the south, a more active approach to identifying and promoting adaptation measures may be needed.

8.3 Implications for European agricultural policy

Following an examination of existing market, direct income support and Rural Development policy measures, potential measures that can support adaptation were identified. This led to the following observations and conclusions:

- Supplementing current Statutory Management Requirements with new legislation that addresses climate-related impacts would provide a further incentive for Single Payment Scheme (SPS) claimants to adapt. Any additional requirements would need to be simple to understand and implement, be cost-neutral and add specific benefits to the farmer.

- The flexibility that Member States can exercise in determining Good Agricultural and Environmental Condition standards allows for highly appropriate and localised management practices that assist with adaptation. The potential of GAEC's would be maximised by requiring Member States to identify major environmental pressures, which may include climate impacts, and justify the inclusion or exclusion of corresponding standards.
- Member States should be required to make provision for training farmers on climate change issues, particularly new entrants such as young farmers. Developing the role and scope of the Farm Advisory System would be a feasible option for effective knowledge transfer. Targeting this service may be required due the capped nature of the Pillar 1 budget. However, training allowances can be further expanded and explored under the Rural Development measures in Axis 1 through measures aimed at promoting knowledge and improving human potential.

The **Rural Development Programme** has the potential to benefit further by underlining the need for Member States to meet or consider the impacts of future climate change across Axes 1, 2 and 3. To ensure investments made through the Axes brings benefits in terms of adaptation, linking funding to cross compliance should be explored.

Mitigation to climate change is explicitly mentioned throughout the Rural Development regulations. This could be expanded further to emphasise adaptation and ensure that the many measures that could be exploited to support adaptation have the framework in which to do so.

Agri-environment schemes have the potential to offer much support to many adaptation activities.

Adaptation to climate change needs to occur at **all spatial levels**. The Rural Development measures can do this through careful co-ordination from the grassroots Leader programme all the way up to integration with river basins through the Water Framework Directive.

The **Leader** arm of the Rural Development Programme has the potential to be increasingly constructive in supporting adaptation to climate change. The officials facilitating these programmes must be trained so as to guide the participants to take into account and exploit long-term changes.

Insurance, particularly against major events, needs to be considered and encouraged to allow farmers to increase their farming business resilience to the impacts of climate change. This will provide a safety net for farming businesses if and when severe weather events occur, and will also make an immediate financial and personal connection between the future realities of climate change and the farmers' business activities through the premiums that would be paid. This may provide further impetus for farmers to adapt their business and buildings so as to reduce their premiums.

Those farming on marginal land, where incomes are low, are at greatest risk from climate change. Creating sustainable rural communities in the context of climate change will involve supporting these communities. Adjusting the criteria for those eligible for support under **Article 36** of Regulation 1698/2005 of the Rural Development programme to include areas that will be particularly affected by climate change may be an option to facilitate their adaptation.

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10 Glossary

CAP	Common Agricultural Policy
CO_2	Carbon dioxide
DG-AGRI	Directorate-General for Agriculture and Rural Development
DMI	Danish Meteorological Institute
EU	European Union
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HadCM	GCM produced by the Hadley Centre
HIRHAM	RCM produced by the DMI
ECHAM	GCM produced by the European Centre for Medium Range Weather Forecast model, modified in the Max-Planck Institute for Meteorology in Hamburg
IPCC	Inter-governmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
RCA	RCM produced by SMHI
OCYP	Ocean and isoPYCnal model, produced by the Max-Planck Institute for Meteorology in Hamburg
O_3	Ozone
OECD	Organisation for Economic Cooperation and Development
OGCM	Ocean Global Climate Model
PESETA	Projections of Economic impacts of climate change in Sectors of Europe based on bottom-up Analyses, co-ordinated by the JRC
PRUDENCE	Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects
RCM	Regional Climate Model
SMHI	Swedish Meteorological and Hydrological Institute
SRES	Special Report on Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change

ANNEXES

Annex A

Socio-economic scenarios A1, A2, B1 and B2

The Rapid Growth Scenarios (SRES A1)
The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The implications of the A1 scenario for climate impacts and adaptation are:

- Agriculture: Rapid increase in income translates into a shift towards increased consumption of meat and dairy products. Intensification of agricultural systems. High income translates into suburbanisation.
- Natural ecosystems: Stress and damage at the local level and uncertain at the global level.
- Coping capacity: Increased local due to increase in income and technology.
- Vulnerability: Increased.

The Heterogeneous World Scenarios (SRES A2)
The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines. Implications of the A2 scenario for climate impacts and adaptation are:

- Agriculture: Lower levels of wealth and regional disparities.
- Natural ecosystems: Stress and damage at the local and global levels.
- Coping capacity: Mixed but decreased in areas with lower economic growth.
- Vulnerability: Increased.

The convergent World Scenarios (SRES B1)
The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives. The implications of the B1 Scenario for climate impacts and adaptation are:

- Agriculture: Extensification of agricultural systems, prioritisation of high quality products and environmentally friendly practices.
- Natural ecosystems: Environmental protection is a priority and it is addressed intensively at the global scale.
- Coping capacity: Technology is not available at the same level as Scenario A1, but systems are more resilient to changes.
- Vulnerability: Decreased in stable systems but increased in areas exposed to extreme events.

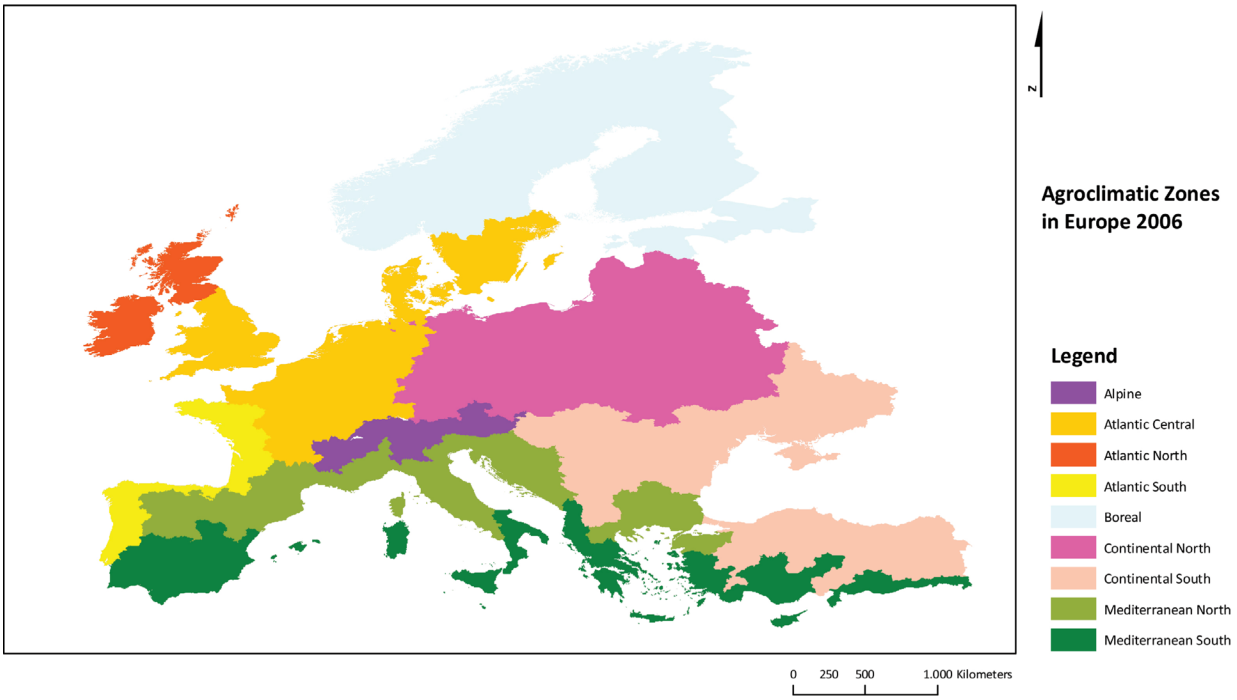
The Local Sustainability Scenarios (SRES B2)
The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels. The implications of the B2 scenario for climate impacts and adaptation are:

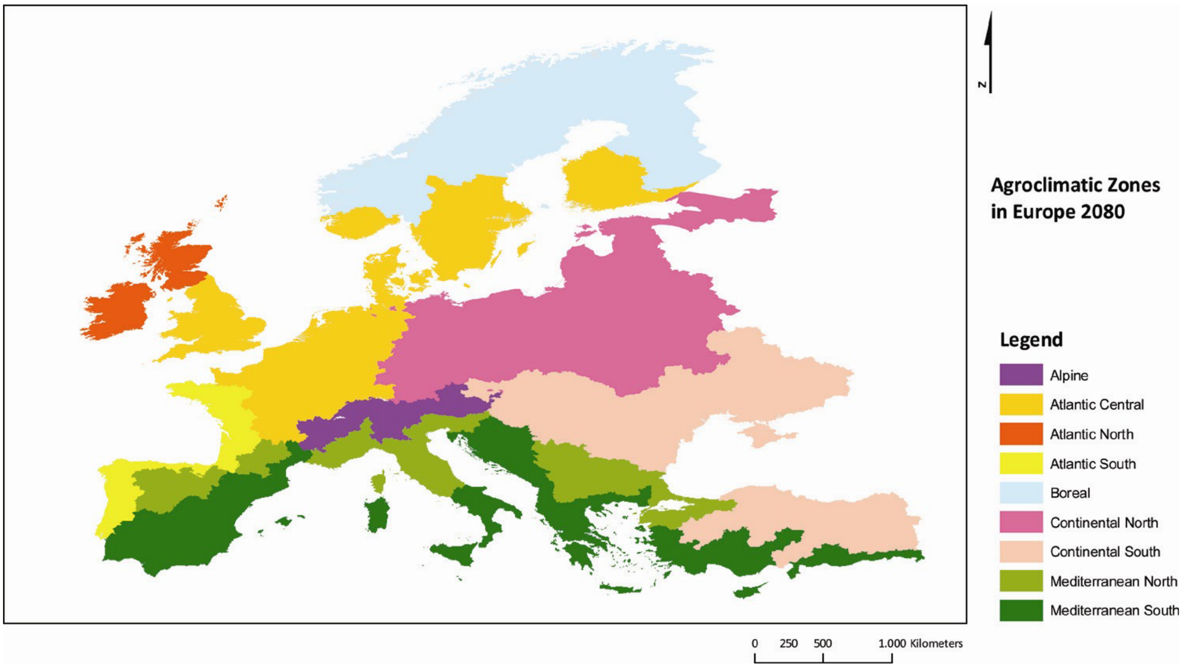
- Agriculture: Lower levels of wealth and regional disparities.
- Natural ecosystems: Environmental protection is a priority, although strategies to address global problems are less successful than in other scenarios. Ecosystems will be under less stress than in the rapid growth scenarios.

- Coping capacity: Improved local.
- Vulnerability: global environmental stress but local resiliency.

Annex B

Agro-climatic areas in 2006 and 2080




N
Agroclimatic Zones
in Europe 2080
Legend
Alpine
Atlantic Central
Atlantic North
Atlantic South
Boreal
Continental North
Continental South
Mediterranean North
Mediterranean South
0 250 500 1.000 Kilometers

Annex C

Potential impacts of climate change on farming activities in Europe

Table C.1. Climate change and related factors relevant to agricultural production at the global scale.

Climate factor	Expected direction of change	Potential impacts on agricultural production and food security	Confidence level of the potential impact	References
Atmospheric CO_2	Increase	Increased biomass production and increased potential efficiency of physiological water use in crops and weeds. Modified hydrologic balance of soils due to C/N ratio modification. Changed weed ecology with potential for increased weed competition with crops.	Medium	Acock, 1990 Agrell, 2004 Arnell *et al.*, 2002 Fuhrer *et al.*, 2003 Gill *et al.*, 2002 Jablonski *et al.*, 2002 Kimball *et al.*, 2002 Milchunas *et al.*, 2005 Norby *et al.*, 2003, 2004 Nowak *et al.*, 2004 Ollinger *et al.*, 2002 Picon-Cochard *et al.*, 2004 Schafer *et al.*, 2002 Shaw *et al.*, 2002 Stacey *et al.*, 2002 Teyssonneyre *et al.*, 2002 Tubiello *et al.*, 2006b Wullschleger *et al.*, 2002 Ewert *et al.*, 2007 Lemmen *et al.*, 2004 Zhao *et al.*, 2003
		Agro-ecosystems modification.	High	Cox *et al.*, 2001 Ehleringer *et al.*, 2002 Karnosky *et al.*, 2003 Zvereva *et al.*, 2006
		N cycle modification.	High	Allard (2003, 2004) Newman *et al.*, 2001 Ross *et al.*, 2004 Liu *et al.*, 2005 Daepp *et al.*, 2001
		Lower yield increase than expected.	Low	Long *et al.*, 2006
Atmospheric O_3	Increase	Crop yield decrease.	Low	Ashmore 2005 Fiscus *et al.*, 2005 Vandermeiren 2005
Sea level rise	Increase	Sea level intrusion in coastal agricultural areas and salinization of water supply.	High	Nicholls *et al.*, 2004

Climate factor	Expected direction of change	Potential impacts on agricultural production and food security	Confidence level of the potential impact	References
Extreme events	Poorly known, but significant increased temporal and spatial variability expected Increased frequency of floods and droughts	Crop failure Yield decrease Competition for water.	High	Adger 1999 Bradford 2000 Burke *et al.,* 2006 COPA-COGECA 2003 Hanson *et al.,* 2000 Hisdal *et al.,* 2001 Vogt *et al.,* 2000 Ferreyra *et al.,* 2001 Ciais *et al.,* 2005 Motha *et al.,* 2005 Reichstein *et al.,* 2002
Precipitation intensity	Intensified hydrological cycle, but with regional variations	Changed patterns of erosion and accretion. Changed storm impacts. Changed occurrence of storm flooding and storm damage. Increased water logging Increased pest damage.	High	Arnell 1999 Nohara *et al.,* 2006 Rosenzweig *et al.,* 2001; 2002
Temperature	Increase	Modifications in crop suitability and productivity. Changes in weeds, crop pests and diseases. Changes in water requirements. Changes in crop quality.	High	Rosenzweig *et al.,* 2001 Parry *et al.,* 1999, 2004 Caldwell *et al.,* 2005
	Differences in day-night temp	Modifications in crop productivity and quality.	Medium	Dhakhwa *et al.,* 1998 Volder *et al.,* 2004 Mearns *et al.,* 1996
Heat stress	Increases in heat waves	Damage to grain formation, increase in some pests.	High	Beniston 2004 Schar *et al.,* 2004 Wheeler *et al.,* 2000

Source: own elaboration

Table C.2. Effects of climate change on European agriculture and related issues.

Impact described	Direction of change	Confidence level	Reference
Agriculture	Benefits for northern countries and drawbacks for southern	High	PESETA Project
Agriculture, ecosystems, land use	Benefits to crop production in northern countries and drawbacks in southern countries. Negative impacts on ecosystem potential diversity and limitations to ecological corridors. Large potential shifts in land use	High	ACCELERATES Project
Agriculture, ecosystems, forestry, land use	Benefits to crop production in northern countries and drawbacks in southern countries. Negative effects in forest and ecosystems due to major changes in land use	High	ATEAM Project
Agriculture, diffuse pollution	Benefits to crop production in northern countries and drawbacks in southern countries. Mixed effects for nitrogen leaching in all regions, but predominantly negative effects	High	PRUDENCE Project
Agriculture and forestry	Benefits for northern countries and drawbacks for southern	High	Maracchi *et al.*, 2004
Water resources	Decrease in water resources availability, increase in demand	High	Henrichs *et al.*, 2001 Nijssen *et al.*, 2001
Forest productivity	Increase of stem wood production in European forests	Medium	Nabuurs *et al.*, 2002
Cities' vegetation	Changes in distribution of species	Medium	Sukopp *et al.*, 2003
Methodology for assessment	Southern countries more affected in general terms	Medium	Van minnen *et al.*, 2002

Source: own elaboration.

Table C.3. Climate change impacts on agro-climatic zones in Europe. Climate change and related factors relevant to agricultural production and the effects of climate change on main agricultural determinants are reported in this document. NOTE: Since most of the socio-economic studies include explicitly some level of adaptation, those are not included in this evaluation of impacts and will be included in the second report.

Agro-climatic area	Region	Impact described	Direction of change	Confidence level	Reference
Alpine	Alps	Snow melt increase	Intensification of hydrological cycle (increased erosion, floods, Glacier retreat	High	Barnett, 2005
Alpine	Alps	Extreme climate events	Increase in extreme climate events affecting vulnerable areas like mountains	Medium	Beniston 2000, 2003, 2004
Alpine	Alps	Differences in temperature	General increase in differences between daily and night temperature	Medium	Diaz *et al.,* 1997, 2003
Alpine	Alps	Snow melt increased speed	Secondary effects of glacier retreat on tourism economy	Medium	Elsasser, 2003, 2001
Alpine	Alps	Plant species distribution	Distribution of species in mountainous areas may shift upwards	Medium	Grabherr, 1994, 1999
Alpine	Alps	Permafrost thaw	Accelerated permafrost thaw, destabilization of soils, landslides	High	Gruber *et al.,* 2004
Alpine	Alps	Permafrost thaw	Accelerated permafrost thaw, destabilization of soils, landslides	High	Haerbeli *et al.,* 1998a, 1998b
Alpine	Alps	Permafrost thaw	Accelerated permafrost thaw, destabilization of soils, landslides		Harris *et al.,* 2003
Alpine	Alps	Snow cover depth	Observations in decreased depth with differences among regions	High	Laternser *et al.,* 2003
Alpine	Alps	Temperature increase	Higher than average temperature increase. Decrease of snow cover depth and loss of biodiversity	High	Maish, 2000
Alpine	Alps	Glacier retreat	Accelerated rate of glacier mass loss in the last decade	High	Paul *et al.,* 2004
Alpine	Alps	Effects on biodiversity	Inventory of biodiversity and species distribution and observed changes	Medium	Pauli *et al.,* 2001
Alpine	Alps	Impacts on vegetation	Vegetation is quite stable but land use change is highly possible	Medium	Theurillat *et al.,* 2001
Alpine	Alps	Pastureland changes as response to T and CO2	Distribution of land use will change due to changing conditions	Medium	Riedo *et al.,* 2001

Agro-climatic area	Region	Impact described	Direction of change	Confidence level	Reference
Atlantic	France	Glacier mass balance	Accelerated rate of glacier mass loss, secondary impacts on economy	High	Vincent, 2002
Atlantic	Ireland	Barley and potato changes in cropping areas	Definition of agro-climatic regions, observed changes in distribution	Medium	Holden *et al.*, 2003
Atlantic	Portugal	Water resources	Decreased available water resources. Increased floods	Medium	De Cunha *et al.*, 2002
Atlantic	Portugal	Forest fires	Increased frequency and intensity	High	Santos *et al.*, 2002
Atlantic	UK	Increased wheat yield	Increased wheat yield with higher temperatures	Medium	Atkinson *et al.*, 2005
Atlantic	UK	Livestock conditions	Changes in health, nutrition, productivity	High	Defra, 2000
Atlantic	UK	Changing ecosystems	Land use change, ecosystems disturbances and fragmented populations	Medium	Preston *et al.*, 2002
Atlantic	UK	Floods and land use	Increased flood frequency	High	Reynard *et al.*, 2001
Boreal	Finland	CO_2, O_3 increases	Negative effects on several forest species. Lower productivity	Medium	Kaakinen *et al.*, 2004 Carter *et al.*, 1996
Boreal	Finland	Suitability of spring wheat	Increase in crop suitability	Medium	Saarikko *et al.*, 1996
Boreal	Finland	Evaluation of regional yields	Positive relationship among yield and temperature	Medium	Saarikko, 2000
Boreal	Norway	Permafrost thaw, forests	Destabilization of soils, landslides, negative effects on forests	High	Haeberli *et al.*, 2002
Boreal	Norway	Terrestrial ecosystems	Changes in populations distributions, biodiversity loss	Low	Holten *et al.*, 1992
Boreal	Norway	Pest distribution changes	Increase in pest populations and distribution with increased temp	Medium	Rafoss *et al.*, 2003
Boreal	Norway	Weather extremes and forests	Increased susceptibility of trees to extremes and pests	Medium	Schylter *et al.*, 2006
Boreal	Sweden	Glaciers response to CO2	Glaciers retreat with increased CO2 and temperature	Medium	Scheenberger *et al.*, 2001
Boreal	Sweden	Boreal forests insects	Increase in pest populations and distribution with increased temp	Medium	Volney *et al.*, 2000
Boreal	Sweden	Short rotation forestry	Decrease in productivity of short rotation forests	Low	Weih, 2004

Agro-climatic area	Region	Impact described	Direction of change	Confidence level	Reference
Continental	Austria	Snow cover melting	Increased rate of melting	High	Hantel *et al.,* 2000
Continental	Bulgaria	Wheat and maize yield decrease	Decrease in precipitations leading to low harvesting.	Medium	Alexandrov *et al.,* 2000 Eitzinger *et al.,* 2003
Continental	Czech Republic	Flood frequency	Increase in frequency and intensity	High	De Roo *et al.,* 2003
Continental	Croatia	Snow parameters	Glacier retreat and snow depth decrease	High	Gajic_Capka, 2004
Continental	East Europe	Wetlands/agriculture	Disappearing of wetlands, encroachment of agriculture	Medium	Hartig *et al.,* 1997
Continental	Germany	Forest structure and functions	Modification of forest structure and functions, decreased productivity	Medium	Lasch, 2002
Continental	Germany	Hydrological regimes	Intensification of cycles, more extreme events, need for management	High	Middlekoop *et al.,* 2001
Continental	Moldova	Crop production	Increase in crop production with increasing temperature, pests too	High	Corobov, 2002
Continental	NE Austria	Wheat and soybean yield different effects	Increase in yields specially in solid soil	Medium	Alexandrov *et al.,* 2002
Continental	Poland	Agriculture	Changes in crop productivity and distributions	Medium	Stuczyinski *et al.,* 2000
Continental	Romania	Water resources	Increased frequency of extreme events	High	Cuculeanu *et al.,* 2002
Continental	Slovakia	Summer flash flood frequency and intensity	Increased frequency and intensity of floods	High	Lapin *et al.,* 2003
Continental	Slovakia	Forestry	Increased mortality of trees	Medium	Mindas *et al.,* 2003
Continental	Slovakia	Mean monthly runoff	Decrease of runoff up to 50% in mountain	High	Szolgay *et al.,* 2003
Continental	Slovakia	Snow trends	Snow cover early-melting	High	Vojtek *et al.,* 2003
Mediterranean	France	Hydrological impacts	Increase in frequency and intensity of floods	High	Ludwig *et al.,* 2003
Mediterranean	Greece	Maize yield changes	Decrease in yields	Medium	Kapetanaki *et al.,* 1997
Mediterranean	Italy	Grapevine yield	General increase in yields	Medium	Bindi *et al.,* 2000, 2005 Salinari *et al.,* 2006
Mediterranean	Italy	Effects on cropping systems	Decrease of yields up to 40% under current management conditions	High	Tubiello *et al.,* 2000, 2002

Agro-climatic area	Region	Impact described	Direction of change	Confidence level	Reference
Mediterranean	Spain	Yields and irrigation needs	General decrease in yields and increase in irrigation requirements	Medium	Guereña *et al.*, 2001
Mediterranean	Spain	Crop yields variations		Medium	Iglesias *et al.*, 1997, 2000
Mediterranean	Spain	Increased production risk	Increased variability of yields and associated risk	Medium	Iglesias *et al.*, 2007
Mediterranean	Spain	Water availability	Decrease in water availability and increase in water demand	High	Iglesias *et al.*, 2003
Mediterranean	Spain	Modifications in vegetation	Decreased productivity, changes in distribution	Medium	Lazaro *et al.*, 2001
Mediterranean	Spain	Reduced diversity of seedlings	Loss of diversity in Mediterranean species	Medium	Lloret *et al.*, 2004
Mediterranean	Several countries	Wheat cropping systems	Changes in drainage of soils leading to increased salinity	Low	Van Ittersum *et al.*, 2003
Mediterranean	Several countries	Desertification	Water resources deficit, affected soil structure	Medium	Karas, 1997

Source: own elaboration.

Annex D

Description of risks and opportunities

Table D.1. Description of Risks and Opportunities

Risk or opportunity	Consequences for agricultural production	References	Certainty	Likelihood
RISKS				
Crop area changes due to decrease in optimal farming conditions	Farming optimal conditions altered resulting in increased risk to rural income Changes in crop varieties result in loss of indigenous species Need for relocation of farm processing industry Soils deterioration due to land use changes Land abandonment due to very large changes in optimal conditions	NFU, 2005 Ewer *et al.,* 2005 Metzger *et al.,* 2006 Olesen *et al.,* 2002 Rousevell, 2005, 2006	H H H H H	H
Crop productivity decrease	Crop productivity decrease due to average temperature increase Crop productivity variability risk increased Crop productivity decrease that leads to land abandonment Agricultural trade intensification with potential increase of crop prices	NFU, 2005	H	H
Increased risk of agricultural pests, diseases, weeds	Pest populations increase and distribution with increased temp, boreal forest Pollution by increased use of pesticides	Chakraborty *et al.,* 2003 Chen *et al.,* 2001 Chen *et al.,* 2004, 2005a, 2005b Cocu *et al.,* 2005 Crozier *et al.,* 2006 Easterling *et al.,* 2001 Gan, 2004 Iglesias *et al.,* 2002 NFU, 2005 Patterson *et al.,* 1999 Rafoss *et al.,* 2003 Runion, 2003 Todd *et al.,* 2002 Volney *et al.,* 2000	M M M M M M M M M M M M M M	M
Crop quality decrease	Crop quality reduction in fruits, vegetables, grapevines Damage to grain formation due to heat stress	NFU, 2005	H	H
Increased risk of floods	Increased expenditure in emergency and remediation actions Flash flood frequency and intensity increase Increased waterlogging	Alexandrov *et al.,* 2000 Barnett, 2005 Eitzinger *et al.,* 2003 Kerr and McLeod, 2001 Ludwig *et al.,* 2003	M H M M H H	H

Risk or opportunity	**Consequences for agricultural production**	**References**	**Certainty**	**Likelihood**
		Middlekoop *et al*, 2001		
Increased risk of drought and water scarcity	Conflicts among water users Water supply reduced Groundwater abstraction intensification, depletion and pollution Damage to wetlands	Eckhardt, 2003 Hanley *et al.*, 2005 Lehner *et al.*, 2000 Tompkins *et al.*, 2005 Alcamo *et al.*, 2003 Alcamo *et al.*, 2001 Arnell, 1999, 1999, 2004 Boorman *et al.*, 1997 Eisenreich, 2005 Gleick, 2003 Guereña *et al.*, 2001 Henrichs *et al.*, 2001 Iglesias *et al.*, 2003 Mimikou *et al.*, 2001 Nijssen *et al.*, 2001 NFU, 2005 Ronenzweig *et al.*, 2005 Vorosmarty *et al.*, 2000 Defra, 2002 Alexandrov *et al.*, 2000 Döll, 2002 Eitzinger *et al.*, 2003 Fisher *et al.*, 2006 Izaurralde *et al.*, 2003 Iglesias *et al.*, 2003 Tompkins *et al.*, 2005 Tubiello *et al.*, 2000, 2002 Hunt *et al.*, 2006	H H H M H H H H H H M H H H H H H H M H M H H H M H H H	H
Increased irrigation requirements	Water availability decrease, water shortage in irrigated areas	Alcamo *et al.*, 2003 Alcamo *et al.*, 2001 Arnell, 1999, 1999, 2004 Boorman *et al.*, 1997 Eisenreich, 2005 Gleick, 2003 Guereña *et al.*, 2001 Henrichs *et al.*, 2001 Iglesias *et al.*, 2003 Mimikou *et al.*, 2001 Nijssen *et al.*, 2001 NFU, 2005 Ronenzweig *et al.*, 2005 Vorosmarty *et al.*, 2000	H H H H H H M H H H H H H H	H
Water quality deterioration	Water quality loss due to reduced water flow during water scarcity periods	Arnell, 1999 Kerr and McLeod, 2001 Lapin *et al.*, 2003 Nohara *et al.*, 2006	M	M

Risk or opportunity	Consequences for agricultural production	References	Certainty	Likelihood
		Reynard *et al.,* 2001 De Roo *et al.,* 2003 Rosenzweig *et al.,* 2001; 2002		
Soil erosion, salinisation, desertification	Desertification due to water resources deficit, loss of soil structure, land abandonment Soil salinisation increase Erosion and accretion increase Land abandonment Pollution by nutrient leaching Soil C/N ratio modification modified hydrologic balance of soils Soil drainage changes leading to increased salinity Water logging increased	Kerr and McLeod, 2001 Viner *et al.,* 2006	M H	H
Loss of glaziers and alteration of permafrost	Glacier retreat and snow depth decrease Permafrost thaw acceleration, destabilisation of soils, landslides	ATEAM final report. http://www.pik-potsdam.de/ateam/ Arctic Climate Impact Assessment. http://www.acia.uaf.edu/	H H	H
Deterioration of conditions for livestock production	Livestock changes in health, nutrition, productivity, heat stress Loss in grazing quantity and quality	Defra, 2000 Haeberli *et al.,* 2002 Kerr and McLeod, 2001 NFU, 2005 Döll, 2002 Frank *et al.,* 2001 Fisher *et al.,* 2006 Hunt *et al.,* 2006 Izaurralde *et al.,* 2003 Mitchell *et al.,* 2001 Tubiello *et al.,* 2000, 2002	H H M H H L H M H L H	M
Sea level rise	Sea level intrusion in coastal agricultural areas and salinisation of water supply	Nicholls *et al.,* 2004 Viner *et al.,* 2006	H H	H
OPPORTUNTIES				
Crop distribution changes leading to increase in optimal farming conditions	Crop suitability increase	Atkinson *et al.,* 2005 Defra, 2000 Hanley *et al.,* 2005 Kerr and McLeod, 2001 Riedo *et al.,* 2001 Stuczyinski *et al.,* 2000 NFU, 2005 Tompkins *et al.,* 2005	M HM H M M M H H	M
Crop productivity increase	Crop yield and biomass increase leading to increased potential efficiency of physiological water use due to CO_2 increase Crop productivity increase due to increase of the frost-free period	Kerr and McLeod, 2001 Riedo *et al.,* 2001 Acock, 1990 Agrell, 2004 Alexandrov *et al.,* 2002	HM M M M M M	M

Risk or opportunity	Consequences for agricultural production	References	Certainty	Likelihood
	Reduced costs of frost damage Reduced drought impacts and damage	Arnell *et al.*, 2002 Atkinson *et al.*, 2005 Bindi et al 2000, 2005 Corobov, 2002 Defra, 2000 Ewert *et al.*, 2007 Fuhrer *et al.*, 2003 Gill *et al.*, 2002 Jablonski *et al.*, 2002 Kimball *et al.*, 2002 Lemmen *et al.*, 2004 Milchunas *et al.*, 2005 NFU, 2005 Norby *et al.*, 2003, 2004 Nowak *et al.*, 2004 Ollinger *et al.*, 2002 Picon-Cochard *et al.*, 2004 Salinari *et al.*, 2006 Saarikko *et al.*, 1996 Schafer *et al.*, 2002 Shaw *et al.*, 2002 Stacey *et al.*, 2002 Teyssonneyre *et al.*, 2002 Tompkins *et al.*, 2005 Tubiello *et al.*, 2006b Wullschleger *et al.*, 2002 Zhao *et al.*, 2003	M M H M M M M M M M M H M M M M M M M M M M M M M M	
Forest productivity increase	Biomass production increase	Viner *et al.*, 2006 Mitchell *et al.*, 2007	M H	H
Water availability	Potential increase in water availability for crops in wetter seasons	NFU, 2005 Brown *et al.*, 1999 Döös *et al.*, 1999 Chen *et al.*, 1994 Gregory *et al.*, 2005 Darwin, 2004 Evenson, 1999 Matthews *et al.*, 1997 Parry *et al.*, 2001, 2004 Peng *et al.*, 2004 Rosenzweig *et al.*, 2001 Tompkins *et al.*, 2005 Tubiello *et al.*, 2006a	H	H
Lower energy costs for glasshouses	Lower energy costs for glasshouses	NFU, 2005	H	H
Improvement in livestock productivity	Reduced housing costs for animals due to milder winters	Defra, 2000 NFU, 2005	H H	H

Annex E

Adaptation measures reported by Member States

Table E.1. Examples of adaptation strategies and actions relevant to the agriculture sector in Europe – taken from the UNFCCC SBSTA, Nairobi, 2006

Adaptation action	Status
EU Commission	
Thematic Strategy for Soil Protection (COM(2006)231) and proposal for a Soil Framework Directive (COM(2006)232).	Under development (expected adoption date is 2009)
Effectiveness of adaptation and mitigation measures related to changes of the hydrological cycle and its extremes: quantify the efficiency (cost and benefits) of current and novel adaptation and mitigation measures related to changes of the hydrological cycle and its extremes in Europe. Analysis of the social and economic implications. Develop (adaptive) management strategies (including considerations on resilience and mitigation measures) for risks caused by long term changes of the hydrological cycle taking into account economic and social pressures (e.g. population and GDP growth, land use) under current and future climate conditions.	Under consideration - call for projects under FP7
Impacts and feed-backs of climate policies on land use and ecosystems in Europe: research to assess the impacts of climate (and other sectoral) policies on land use and ecosystems and the resulting feed-back on the climate system. Regional climate models should be coupled with land use models to improve the representation of explicit biophysical and economic mitigation and adaptation strategies in agriculture and forestry. Improved methodologies should include explicit crop/trees growth models with sufficient, sub-national spatial detail to estimate the responses and adaptation possibilities of crops and trees to scenarios of extreme climate events and changes in weather patterns. Models to include scenarios for the distribution and pressures from socio-economic drivers with sufficient geographical details. Impacts of climate mitigation measures need to be covered with sufficient details on bio-energy sources and pathways. Research should help assess and evaluate the impacts of alternative policy scenarios and estimating the associated costs and benefits of the policies.	Under consideration - call for projects under FP7
European Climate Change Programme: the European Commission is exploring options to improve Europe's resilience to climate impacts and, including means to adapt to the impacts of unavoidable climate change and how best to assist local, regional and national efforts. Main objective of the ECCP work on adaptation is to define the European Union role in climate change adaptation, through an intensive stakeholder engagement process to consider the following sectors: Impacts on water cycle and water resources management and prediction of extreme events; Marine resources and coastal zones and tourism; Human health; Agriculture and forestry; Biodiversity; Regional planning, built environment, public and energy infrastructure, Structural funds; Urban planning and construction; Development cooperation; Role of insurance industry; Building national strategies for adaptation (country reports).	Under development

Adaptation action	Status
Full costs of climate change: quantification of damage, adaptation and mitigation costs for global emission scenarios including those that stabilize atmospheric concentrations covering countries important in international climate negotiations. This includes a coherent, up-to-date representation of socio-economic drivers. Emissions of reactive gases and air pollutants as well as changes in land cover must be considered. Mitigation costs are to reflect (induced) technological change and need to include non-CO2 greenhouse gases and sinks and consider recent abatement technologies. Emphasis should be on better estimates for damage and adaptation costs. Damage estimates are to include market damage, non-market damage, catastrophic events and damage related to changes in air-quality (co-benefits). Damage needs to be expressed in physical terms and, to the extent possible, monetary terms and needs to cover all relevant sectors. Explicit treatment of uncertainty is essential. Energy aspects need to be covered. The participation of international partners is encouraged.	Under consideration - call for projects under FP7
Austria	
Change of cropping patterns and agricultural management strategies.	Under development
Water-saving or more efficient irrigation techniques.	Under development
Development of new cultivars with extended growth periods, multi-stress resistance and improved water use efficiency.	Under development
Belgium	
Coastal areas: Sigma Plan for flood protection and control (including new controlled flooding zones).	Under implementation
Cyprus	
Adaptation strategies to combat water shortage.	Ongoing
Introduction of severe water restrictions on domestic and agriculture water supplies.	Under development
Implementation of irrigation programmes according to crop needs.	Under development
New and improved irrigation systems.	Under development
Finland	
National Strategy for Adaptation to Climate Change: adaptation measures identified as immediate (2005-2010), short-term (2010-2030) and long-term (2030-2080). Immediate: planning of water services, surveying of risk sites, preparation of general plans for risk sites, construction of irrigation systems for agriculture; short-term: improve preparation for exceptional situations and regional co-operation, increase discharge capacity of dams, improve dam safety and re-evaluate design discharges at major dams, restrictions on water use; long-term: adapt national plans to climate change effects and improve climate forecasting	Ongoing
Five-year research programme to support the implementation of the National Adaptation Strategy: 15 projects in forestry, agriculture, spatial planning, built environment, floods, drought and biodiversity were started in 2006.	Ongoing
France	
National observatory on climate change impacts (ONERC): collects information from research and informs policy makers (including local communities) on impacts, vulnerability and adaptation.	Ongoing since 2002
National adaptation strategy.	Published 2007
National adaptation plan.	Under development
Assessment of costs of impacts and adaptation at national level.	Under development
Germany	
KomPass: ‘Competence Centre’ on climate change impacts and adaptation.	Ongoing
National Adaptation Strategy.	Under development

Adaptation action	Status
Klimastudie Brandenburg: guidelines on improvement of landscape water balance and impacts of moderate climate change on semi-natural ecosystems, managed forests and agricultural yields.	Ongoing
INKLIM (Hesse): assessment of climate change impacts until 2012 and possible adaptation measures in different sectors, including agriculture.	Ongoing
KLARA (Baden-Wuerttemberg): assessment of climate change impacts on vulnerable sectors, including agriculture.	Completed
Hungary	
VAHAVA project: coordination, publication/dissemination and expert debates on climate change issues.	Under development
New Vásárhelyi Plan: emergency reservoirs along upstream and middle Tisza sections to enhance flood safety. Focus on flood control, conservation and environmental protection, ecotourism, agro-ecological farming, rural development.	Under development
Italy	
Establishment of a National Action Plan (IMELS, 1999) and a National Committee to Combat Desertification.	Ongoing
National plan for irrigation: specific funds are allocated to alleviate the effects of extreme events (including droughts).	Ongoing
Rural Development Plan: the National Strategic Plan includes specific measures for water quantitative protection, especially for "improvement of agricultural sector and forestry competitiveness" and "environmental and rural areas improvement".	Ongoing
CLIMAGRI climate change and agriculture project: improved the knowledge of linkages between agriculture and climate change. Focus on climate change impacts, but with a view to support implementation of response measures and draw recommendations for adaptation. Sub-projects: 1. Climatic analysis and future scenarios; 2. Italian agriculture and climate change; 3. Drought, desertification and water resources management; and 4. Data dissemination and communication.	Completed 2001-2004
Latvia	
Project ASTRA: developing policies and adaptation strategies for climate change in the Baltic Sea region (2005-2007).	Ongoing
Risk management conception in agriculture (2007).	Under consideration
Malta	
Draft National Rural Development Strategy for the period 2007-2013: recognises the impact of inundation, increased risk of flooding, deterioration and erosion of soil, accelerating desertification processes, as well as damage to the landscapes, agriculture and animal husbandry operations and to natural terrestrial and marine ecosystems with loss of biodiversity. Also highlights the likelihood of future water shortages and outlines priority actions to be undertaken in order for agriculture to adapt to climate change.	Under development
PRODIM: a transnational Interreg III B-funded project to develop a comprehensive pro-active management plan to combat drought and water scarcity in drought-prone areas of the Mediterranean region, with particular reference to the islands and coastal areas.	Under implementation
Government is planning a major flood relief project for Birkirkara, which will involve the catchment of storm water coming from Mosta, Naxxar, Iklin, Attard and Balzan, its storage in galleries and its use for irrigation by farmers.	Under consideration

Netherlands	
National Spatial Adaptation Strategy to Climate Change: being developed by national government in cooperation with waterships, regional and local governments. Focuses on the effects of climate change in the Netherlands under the main themes: safety (against flooding), the environment, biodiversity and economic sectors. Strategy is stressing the need for spatial adaptation to climate change and is using leading principles in order to adapt. Also stresses the need for a transition within society (awareness into action). National government will agree the national strategy and a national adaptation agenda in 2007.	Under development
Agricultural sector has responsibility to cope with climate change: farmers should optimise their production process through choices about what to produce and where. Government has a supportive task to provide alternatives through science and make instruments climate proof. Adapting to changing conditions is to a large extent normal agricultural practice. Dutch farmers have been highly successful in doing so given that they have adequate technical training and financial resources.	Ongoing
Dutch government and the agricultural sector reached agreement on a state guarantee for insurance policies for damage as a result of heavy rainfall in 2004: sector no longer applies for government compensation in the case of an extreme event. Crop damage caused by heavy rainfall is now an insurable risk in the Netherlands.	Ongoing
Water managers throughout the Netherlands (Rijkswaterstaat for the large river, lake and coastal water systems and the regional Water Boards for the smaller backwater systems) are currently developing adaptation strategies: aimed at re-arranging the spatial design of the landscape to enhance its flexibility to retain and store freshwater surpluses at times of high precipitation and/or peak river discharges and, at the same time, enhancing flow capacities of the river systems to ensure their ability to cope with higher peak discharges.	Ongoing
Portugal	
National Adaptation Plan for the Water Resources Sector: integrated with the National Climate Change Adaptation Plan and the new generation of River Basin Plans.	Under consideration
Research and development efforts on climate change, climate change impacts and adaptation.	Ongoing
Several ad-hoc specific measures in the licensing, land use management and infrastructure domains that enhance the country's adaptation capacity.	Under implementation
Implementation of several new irrigation schemes, private or collective.	Under implementation
Rehabilitation of existing irrigation schemes to improve irrigation efficiency.	Under implementation
Groundwater abstraction for animal husbandry in drought conditions.	Under implementation
Portuguese National Action Programme to Combat Desertification: includes soil and water conservation; recovery of areas most threatened by desertification; research, experimentation and diffusion; ensuring that desertification is included in development policy; implantation, monitoring and assessment.	Ongoing
Romania	
National Action Plan on Climate Change (2005): highlights the need for an Action Plan on Adaptation by 2007.	Under consideration

National sectoral research programme: to assess Romanian agro-climatic potential and establish favourableness for the main crops in order to initiate a sustainable management system in the agricultural domain according current climate and climate change scenarios. Also elaboration of specialized agricultural systems with reference to climatic regions, taking into account their vulnerability to extreme events and impact on vegetal production, whilst considering changes in crop systems and structure, obtaining new genotypes with high tolerance to extreme events, annual planning and establishment of crops, including plant species and hybrids with different vegetation periods.	Under consideration
New agro-climatic mapping 'AGROCLIMA ROMANIA': identification and classification of vulnerable areas to extreme events.	Under consideration
Implementation of 'dry-farming' technologies in the most vulnerable areas to drought: to develop crop schemes with better limitative climate tolerance.	Under consideration
Use of wind energy for irrigation of drought vulnerable areas.	Under implementation
Attitude Code for Farmers: specialised assistance dedicated to local communities regarding the adaptation of technologies and agricultural practices to climate change. Chapter 3 contains brief description of practices, benefits and dangers. Topics include soil and land use, water management in agriculture, disease and pests.	Ongoing
ACCRETe 'Agriculture and Climate Changes: how to Reduce human Effects and Threats': assessment of climate change impacts on agriculture. Recommendations for good practice to mitigate effects of climate change, to combat drought and desertification, and on efficient water use in agriculture.	Under implementation
Climate neutral land use patterns: improve land management approaches and planning at local, regional and national scale.	Under consideration
Agro-meteorological programme: monitoring of meteorological parameters and agro-meteorological parameters for the most important crops. In-situ measurements of soil moisture and observation of phenological change. Use of simulation models for crop-weather relationships to assess the impact of climate change on yield and plant water use. Use of GIS and remote sensing to determine spatial variability of agro-meteorological parameters. Research and elaboration of case studies related to climate change impacts on agriculture and the environment. Training of agro-meteorology specialists and dissemination of information to end-users and decision makers.	Under implementation /ongoing
Code of good practice: crop rotation, dropping irrigation, feri-irrigation.	Under development
Slovenia	
Strategies for flood and drought mitigation under National Environmental Programme: determination of risk areas and regulation of land use.	Ongoing
Spain	
National Adaptation Programme to Climate Change (PNACC).	Ongoing
Coordinated research programme between national and regional governments on climate change impacts and adaptation.	Under development
Sweden	
Commission on Climate and Vulnerability: internet-based adaptation guidelines.	Published Oct 2007

United Kingdom	
Adaptation Policy Framework: co-ordination of adaptation activities across UK Government, involving comprehensive coverage of sectors; coherent approach across departments, levels of government, and wider public sector; provision of strategic direction, without duplication of existing efforts; definition of roles and responsibilities; provision of sound evidence base for decision-making; identification of threats and opportunities.	Ongoing
UK Climate Impacts Programme (UKCIP): set up in 1997 and funded by the UK Department for Environment, Food and Rural Affairs (Defra), UKCIP helps organisations assess how they might be affected by climate change, so they can prepare for its impact. Based at the University of Oxford, UKCIP works with stakeholders/partners and co-ordinates research - based on stakeholders' needs - on how climate change will have an impact on their activities, and ways in which they can adapt to minimise these impacts. UKCIP provides a bridge between researchers and decision-makers in government organisations and business.	Under implementation
'Preparing for a Changing Climate in Northern Ireland': the report examines the impacts of climate change and identifies the threats and opportunities together with the adaptive strategies required over 13 different sectors.	Under implementation
UK DEFRA Sustainable Agriculture Climate Change Adaptation Research Programme: to initiate preparation of alternative agriculture options and other response measures, including alternative crops, cultivation methods and pest, weed and disease controls.	Under implementation
Rural Climate Change Forum: a stakeholder forum, co-chaired by a DEFRA minister that provides advice on climate change and rural land management, including adaptation and managing the impacts of climate change.	Under implementation
Strategic review of the impacts of climate change on land management in England and Wales: conducted by the Environment Agency.	Initial review completed
Agricultural Change and Environment Observatory (ACEO): funded by DEFRA and others, it provides evidence for policy making on the range of environmental issues for agriculture. One of the aims is to look at the links between the changes observed in farming practices and observed environmental changes, including adaptation to climate change. 'Farmers' Voice' survey 2006 (part of ACEO research programme) includes a chapter on adaptations as a result of climate change.	Under implementation
Vale of Evesham Project: specifically examining the impact of an extreme weather event (heat wave of 2003) on farms in the Vale of Evesham and the measures that farmers took in response.	Under consideration.

Annex F

Questionnaire

Information from EU Member States on National strategies to adapt to climate change in the agriculture sector

Context: The ADAPTATION Project

The ADAPTATION projects aims to identify good practices in adaptation of agriculture to climate change. There is a large amount of information and knowledge already available on coping with climatic variability and climate change. Nevertheless to the moment, there is no comprehensive overview available for all Member States. This questionnaire intends to complement the extensive consultation activities that have occurred during 2006 under European Panel of Climate Change (EPCC).

The aims of this questionnaire

1. To collect information on existing and planned adaptive measures in the EU-27 countries in relation to the impacts of climate change on agriculture.

2. To fill key gaps in knowledge, especially related to specific measures for adaptation in the Common Agriculture Policy (CAP).

In order to develop a communication strategy and consider revisions in the CAP, the European Commission will benefit from additional information on:

- The possible situation with regard to implementation of climate change adaptation measures in 2030.
- The role of the extension and advisory services.
- Capital investment requirements.
- Insurance and weather derivative schemes.

The Questionnaire has four sections:
Section I: Identifies the respondent to be able to classify the responses by stakeholder group and interest, especially in relation to their relationship with the CAP (Questions 1 to 20)
Section II: Identifies the adaptation measures that could be of interest (Questions 20 to 47)
Section III: Identification of further policy adaptation and the role of CAP revision to benefit farmers under climate change (Questions 48 to 57).
Section IV: Provides you the opportunity to identify any additional adaptation options that were not included in this questionnaire.

The questionnaire is very extensive to incorporate the possible answers of many stakeholder groups. Please, spend more time on the questions that directly interest you or related to your area of expertise.

We will process the results and send a comprehensive summary to all respondents.

Your response is very important for the future adaptation of agriculture to climate change: Thank you for completing the following questionnaire!

Section I: Information on the respondent

I.A. Personal information

1. Name:
2. Organisation:
3. Email:
4. Tel:
5. Address:
6. Country:
7. Role/involvement in agriculture sector:

I.B. Concerns about the effects of climate change on agriculture

8. Have you identified current changes in climate?
9. Have you identified an intensification of droughts or floods?
10. Have you experienced water deficits during irrigation periods?
11. Did you feel the need to make changes in your traditional practices in order to adjust to environmental conditions?
12. During the summer of 2003, climate extremes resulted in stress to agricultural production on many parts of Europe. Have any assessments in your region been made of the response of farmers to extreme weather events during 2003 or other climate extreme year?

I.C. The role of agricultural extension services

13. What current extension and/or advisory services are provided in your country?
14. What type of information is provided?
15. Do you attend seminars, courses, etc organized by agricultural services?
16. What kind of information is most needed in relation to climate change?

I.D. The influence of CAP in agricultural practices

17. For which activities and crops are CAP payments made in your country?
18. Do farmers have to comply with agro-environmental measures to get these payments?
19. If so, what kind of agro-environmental measures need to be complied with?
20. What aspects of CAP affect farming most directly?

Section II: Definition of the adaptive measures of agriculture to climate change

The following sets of questions aim to identify and characterize the current and potential adaptive measures adopted to minimize the impacts of climate change on agriculture. For each of the individual adaptation measures (Questions 21 to 47), please try to fill information about:

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

II.A. Adaptation of crops and crop management

21. Encourage introduction of new crops that require lees water

(a) Adoption of the measure: please select:
_______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

22. Encourage introduction of new crops that adapted to higher temperatures

(a) Adoption of the measure: please select:
_______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

23. Encourage changes in sowing dates

(a) Adoption of the measure: please select:
_______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

24. Provide shade and drinking water for animals at pasture

(a) Adoption of the measure: please select:
_______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

25. Develop breeds or change to breeds adapted to changed conditions, especially drought and heat resistant varieties

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

26. Restoring natural features such as hedgerows to help reduce erosion

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

27. Develop farming practices that minimize susceptibility to new pests and diseases

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

28. Increase ground cover, by changing field design e.g. to expanded field margins

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

29. Enhancing the efficiency of fertilizer use

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

30. Developing land management practices to adapt to changes in soil properties

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

31. Maximising effectiveness of labour and machinery

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

32. Facilitate the transfer of technologies from relevant climatic zones

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

II.B. Adaptation of agricultural water management

33. Adopt suitable upland farm or land management practices so that upland areas are used to slow run off and reduce peak water flows

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

34. Adopt measures to reduce the impacts of extreme precipitation events

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

35. Encourage introduction of new management techniques e.g. requiring less water

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

36. Introduce measures to secure safety of livestock during extreme flooding events

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

37. Introduce measures to decrease sea level intrusion and salinisation o f the agricultural land

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

38. Alter conservation practices for dry summers

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

39. Adopt more effective use of irrigation

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

40. Increase in irrigation area and or water volume

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

41. Adopt water re-use technology, please explain

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

II. C. Controlling, monitoring, and information systems

42. Monitoring the changes on biodiversity that may occur due to changes in agricultural crops (for example, changes in rice fields modify the habitats of many bird species)

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

43. Monitoring new pests and diseases

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

44. Monitoring changes in soil properties

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

45. Information systems to raise awareness of the changes and possible risks and opportunities

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

II.D. Structural and financial adaptation

46. Permanent changes in farm structure, such as buildings, irrigation systems, heating or cooling structure

(a) Adoption of the measure: please select:
_______ Traditionally adopted
_______Recently adopted
_______Under current consideration
_______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

47. Establishing business plans with regular reviews to ensure effective responses to climatic events

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

48. Estimation of capital investment requirement to adapt to a hotter climate

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

49. Development of a common strategy for adaptation to climate change between the farming sectors and the insurance community

(a) Adoption of the measure: please select:
______ Traditionally adopted
______Recently adopted
______Under current consideration
______Not considered

(b) If the measure has been adopted or is under consideration, are stakeholders being consulted? Please provide the contact details of the stakeholder and their role in the measure

(c) Major challenges and obstacles encountered to adopt the measure

(d) Major opportunities, achievements and lessons learnt

Section III. Policy adaptation

50. Do you think agro-ecological measures would facilitate adaptation?
51. What do you think would be the adoption rate of such agro-ecological measures?
52. Should such measures also be part of the cross-compliance obligations or just optional?
53. Do you have suggestions for adaptation options not covered above?
54. How can we integrate adaptation into existing approaches?
55. Should there be specific measures for adaptation in CAP?
56. If you have suggestions for introducing measures to facilitate adaptation into the CAP please enter them here.
57. Would it be useful to have an EU-wide reporting and monitoring scheme on adaptation activities to provide a comprehensive overview for all Member States?

Section IV. Additional adaptation measures

58. Please describe and include any other adaptation measures that you consider important for your region and farming activity

Annex G

Questionnaire respondents

Table G.1. Questionnaire Respondents

Agroclimatic zone	Name	Organisation	Role/involvement in agriculture sector
Alpine	Josef Eitzinger	University of Natural Resources and Applied Life Sciences (BOKU)	University / Agrometeorologist
Alpine	Anja Puchta	Federal Ministry of Agriculture, Forestry, Environment and Water Management	Division Agri-environmental programmes
Alpine	Anton Reinl	Austrian Chamber of Agriculture	farmers organisation
Alpine	Gerhard Zethner	Umweltbundesamt	Agricultural expert
Atlantic Central	Dr D Viner	Natural England	Advisor
Atlantic Central	Dr John Conway	Royal Agricultural College	agriculture sector chairman for SWCCIP
Atlantic Central	Wyn Grant	Warwick University	Researcher
Atlantic Central	Michael Sayer	Sparham Estate, Norfolk	land management and farming
Atlantic Central	Roger B. Street	UKCIP-OUCE	Facilitating the identification and assessment of adaptation options
Atlantic Central	David Thompson	Natural England	Policy advisor
Atlantic Central	Jan Verhagen	Plant Research International	Research
Atlantic Central	Jo Hughes	National Farmers Union	Trade Union
Atlantic Central	Kathryn Humphrey	Defra	climate change scientific officer
Atlantic Central	Kurt Christian Kersebaum	Leibniz-Centre for Agricultural Landscape Research	Senior scientist in integrated landscape and agroecosystem modelling
Atlantic Central	Dr. Hans-Peter Ende	ZALF	Research Coordinator
Atlantic Central	Kaj van de Sandt	Ministry of Agriculture, Nature and Food Quality	policy officer Water and climate adaptation
Atlantic Central	Nathalie Guesdon	Ministère de l'agriculture et de la pêche	in charge of climate change and agriculture (mitigation & adaptation) at the Ministry of agriculture
Atlantic North	Liam Kinsella	Department of Agriculture Fisheries and Food (DAFF)	Technical Advisor to DAFF on Climate Change and Transboundary Gases and Biofuels
Atlantic North	Bernard Hyde	Environmental Protection Agency	Greenhouse Gas and Transboundary Gas emission Invnetory Compilation
Atlantic South	Teresa Avelar	Gabinete Planeamento e Polφticas - Min. Agricultura	Directora de Serv iτos de Ambiente e Ordenamento do Espaτo Rural
Atlantic South	Eduardo Rosa	Universidade de Trßs-os-Montes e Alto Douro	Teaching
Boreal	Henrik Eckersten	Swedish Univ of Agric Sciences	Research scientist
Boreal	George Bergengren	ELO	Yes
Boreal	Mattias Lundblad	Swedish Environmental Protection Agency	Agency expert
Continental North	Bernard Siska	Slovak Agricultural University	researcher in the field of climate change impacts on agriculture
Continental North	Veronika Kutilova	Association of Private Farming in Czech republic	non-governmental organization

Agroclimatic zone	Name	Organisation	Role/involvement in agriculture sector
Continental North	Jerzy Kozyra	Institute of Soil Science and Plant Cultivation	scientist - agrometeorologist
Continental North	Edita Baltrenaite	Vilnius Gediminas Technical University	researcher
Continental North	J^{n}ri Kadaja	Estonian Research Institute of Agriculture	Researcher
Continental North	Arunas Bukantis	Vilnius University	scientist
Continental North	Jiří Jungr	Ministry of Agriculture of the Czech Republic	Metodical, legislative and financial support of agriculture sector
Continental North	Kadi Lepik	Ministry of Agriculture of Estonia	Ministry
Continental North	Lubova Tralmaka	Ministry of Agriculture of Latvia	Implementation of Nitrate directive in Latvia
Continental North	Feiziene Dalia	Lithuanian Institute of Agriculture	Researcher
Continental North	Pavol Nejedlik	Slovak Hydrometeorological Institute /SHMU/	provider of agrometeorological information
Continental South	Viorel Blujdea	Forest Research and Management Institute	researcher in forestry, national focal point for UNCCD
Continental South	Sßndor Szalai	Hungarian Meteorological Service	agrometeorologist
Continental South	ELENA MATEESCU, GHEORGHE STANCALIE	NATIONAL METEOROLOGICAL ADMINISTRATION ROMANIA	provider of agrometeorological information
Mediterranean North	Vesselin Alexandrov	National Institute of Meteorology and Hydrology	assessment on climate change impacts on agroecosystems
Mediterranean North	Janez Cepljak	MINISTRY OF AGRICULTURE , FORESTRY AND FOOD (MAFF)	secretary on MAFF
Mediterranean North	simone orlandini	Department of Agronomy and Land Management - University of Florence	researcher
Mediterranean North	Valentin Kazandjiev	National Institute of Meteorology and Hydrology	Agrometeorological Forecast and Services of agriculture
Mediterranean North	Vyara Stefanova	Ministry of Agriculture and Food Supply	Manageing Authority of The Rural Development Programme 2007-2013
Mediterranean South	S.G.Zonas Desf.	MAPA	programas de desarrollo rural
Mediterranean South	Leonidas Toulios	National Agricultural Research Foundation (NAGREF)	Researcher
Mediterranean South	Mariano de Jove	Inagro SL	Land Manager

Annex H

Questionnaire results

Table H.1 Questions 8-12, 15 by zone

Agroclimatic zone		8. Have you identified previous changes in climate?	9. Have you identified an intensification of droughts or floods?	10. Have you experienced water deficits during irrigation periods?	11. Did you feel the need to make changes in your traditional practices in order to adjust to environmental conditions?	12. Have any assessments in your region been made of the response of farmers to extreme weather events during 2003 or other climate extreme years?	15. Do you attend seminars, courses, etc organized by agricultural services?
Alpine	yes	100%	100%	100%	100%	50%	75%
	no	0%	0%	0%	0%	50%	25%
	unknown	0%	0%	0%	0%	0%	0%
Atlantic Central	yes	69%	92%	62%	69%	77%	46%
	no	23%	0%	31%	15%	15%	46%
	unknown	8%	8%	8%	15%	8%	8%
Atlantic North	yes	100%	50%	0%	0%	0%	0%
	no	0%	50%	100%	100%	100%	100%
	unknown	0%	0%	0%	0%	0%	0%
Atlantic South	yes	100%	100%	100%	100%	50%	50%
	no	0%	0%	0%	0%	50%	50%
	unknown	0%	0%	0%	0%	0%	0%
Boreal	yes	67%	33%	33%	0%	0%	33%
	no	0%	0%	0%	0%	33%	33%
	unknown	33%	67%	67%	100%	67%	33%
Continental North	yes	82%	82%	55%	55%	73%	55%
	no	9%	0%	36%	27%	18%	18%
	unknown	9%	18%	9%	18%	9%	27%
Continental South	yes	100%	100%	67%	100%	100%	67%
	no	0%	0%	33%	0%	0%	33%
	unknown	0%	0%	0%	0%	0%	0%
Mediterranean North	yes	100%	75%	75%	75%	75%	75%
	no	0%	0%	0%	0%	0%	25%

Agroclimatic zone		8. Have you identified previous changes in climate?	9. Have you identified an intensification of droughts or floods?	10. Have you experienced water deficits during irrigation periods?	11. Did you feel the need to make changes in your traditional practices in order to adjust to environmental conditions?	12. Have any assessments in your region been made of the response of farmers to extreme weather events during 2003 or other climate extreme years?	15. Do you attend seminars, courses, etc organized by agricultural services?
	unknown	0%	25%	25%	25%	25%	0%
Mediterranean South	yes	100%	100%	100%	100%	67%	67%
	no	0%	0%	0%	0%	0%	33%
	unknown	0%	0%	0%	0%	33%	0%

Table H.2 Questions 18, 50-53, 55 and 57 by zone

Agroclimatic zone		18. Do farmers have to comply with agro-environmental measures to get these payments?	50. Do you think agro-ecological measures would facilitate adaptation?	52. Should such measures also be part of the cross-compliance obligations or just optional?	53. Do you have suggestions for adaptation options not covered above?	55. Should there be specific measures for adaptation in CAP?	57. Would it be useful to have an EU-wide reporting and monitoring scheme on adaptation activities to provide a comprehensive overview for all Member States?
Alpine	yes	100%	100%	50%	50%	75%	50%
	no	0%	0%	25%	50%	25%	50%
	unknown	0%	0%	25%	0%	0%	0%
Atlantic Central	yes	69%	54%	15%	8%	15%	31%
	no	0%	0%	8%	15%	8%	0%
	unknown	31%	46%	77%	77%	77%	69%
Atlantic North	yes	100%	100%	0%	0%	0%	50%
	no	0%	0%	50%	50%	50%	0%
	unknown	0%	0%	50%	50%	50%	50%
Atlantic South	yes	100%	100%	50%	50%	100%	100%

Agroclimatic zone		18. Do farmers have to comply with agro-environmental measures to get these payments?	50. Do you think agro-ecological measures would facilitate adaptation?	52. Should such measures also be part of the cross-compliance obligations or just optional?	53. Do you have suggestions for adaptation options not covered above?	55. Should there be specific measures for adaptation in CAP?	57. Would it be useful to have an EU-wide reporting and monitoring scheme on adaptation activities to provide a comprehensive overview for all Member States?
	no	0%	0%	50%	50%	0%	0%
	unknown	0%	0%	0%	0%	0%	0%
Boreal	yes	33%	67%	0%	0%	33%	67%
	no	0%	0%	0%	0%	0%	0%
	unknown	67%	33%	100%	100%	67%	33%
Continental North	yes	64%	64%	45%	9%	64%	27%
	no	18%	0%	27%	27%	0%	0%
	unknown	18%	36%	27%	64%	36%	73%
Continental South	yes	67%	100%	100%	100%	100%	100%
	no	0%	0%	0%	0%	0%	0%
	unknown	33%	0%	0%	0%	0%	0%
Mediterranean North	yes	50%	75%	75%	25%	50%	75%
	no	25%	0%	25%	50%	25%	0%
	unknown	25%	25%	0%	25%	25%	25%
Mediterranean South	yes	100%	67%	67%	0%	67%	33%
	no	0%	0%	0%	67%	0%	0%
	unknown	0%	33%	33%	33%	33%	67%

Table H.3 Crop/animal management options 1 (Questions 21-26, by zone).

Agroclimatic zone	Crop/Animal Management Options	21. Encourage introduction of new crops that require less water	22. Encourage introduction of new crops that adapted to higher temperatures	23. Encourage changes in sowing dates	24. Provide shade and drinking water for animals at pasture	25. Develop breeds or change to breeds adapted to changed conditions, especially drought and heat resistant varieties	26. Restoring natural features such as hedgerows to help reduce erosion
Alpine	traditionally adopted	25%	25%	25%	75%	50%	75%
	recently adopted	25%	0%	25%	25%	25%	0%
	considered	25%	25%	25%	0%	25%	0%
	not considered	25%	25%	25%	0%	0%	25%
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	0%	25%	0%	0%	0%	0%
Atlantic Central	traditionally adopted	0%	0%	23%	38%	0%	8%
	recently adopted	23%	15%	8%	0%	15%	23%
	considered	8%	8%	15%	0%	15%	0%
	not considered	15%	31%	15%	23%	23%	15%
	under current consideration	23%	8%	0%	0%	0%	0%
	unknown	31%	38%	38%	38%	46%	54%
Atlantic North	traditionally adopted	0%	0%	0%	50%	0%	0%
	recently adopted	0%	0%	0%	0%	0%	50%
	considered	50%	0%	0%	0%	0%	0%
	not considered	50%	100%	100%	50%	100%	50%
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	0%	0%	0%	0%	0%	0%
Atlantic South	traditionally adopted	0%	0%	50%	0%	50%	50%
	recently adopted	50%	50%	0%	50%	0%	0%
	considered	0%	0%	0%	0%	0%	0%
	not considered	50%	50%	50%	50%	50%	50%

Agroclimatic zone	Crop/Animal Management Options	21. Encourage introduction of new crops that require less water	22. Encourage introduction of new crops that adapted to higher temperatures	23. Encourage changes in sowing dates	24. Provide shade and drinking water for animals at pasture	25. Develop breeds or change to breeds adapted to changed conditions, especially drought and heat resistant varieties	26. Restoring natural features such as hedgerows to help reduce erosion
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	0%	0%	0%	0%	0%	0%
Boreal	traditionally adopted	0%	0%	0%	0%	0%	0%
	recently adopted	0%	0%	0%	0%	0%	0%
	considered	0%	0%	0%	0%	0%	0%
	not considered	67%	67%	67%	0%	0%	0%
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	33%	33%	33%	100%	100%	100%
Continental North	traditionally adopted	9%	0%	36%	36%	9%	18%
	recently adopted	9%	18%	9%	9%	0%	27%
	considered	18%	9%	0%	0%	18%	0%
	not considered	18%	45%	36%	27%	36%	18%
	under current consideration	0%	0%	0%	0%	9%	0%
	unknown	45%	27%	18%	27%	27%	36%
Continental South	traditionally adopted	33%	33%	67%	33%	33%	33%
	recently adopted	0%	0%	0%	0%	33%	0%
	considered	33%	0%	0%	0%	0%	0%
	not considered	0%	0%	0%	67%	0%	33%
	under current consideration	33%	33%	33%	0%	33%	33%
	unknown	0%	33%	0%	0%	0%	0%
Mediterranean North	traditionally adopted	50%	25%	25%	50%	50%	75%
	recently adopted	0%	25%	25%	0%	0%	0%

Agroclimatic zone	Crop/Animal Management Options	21. Encourage introduction of new crops that require less water	22. Encourage introduction of new crops that adapted to higher temperatures	23. Encourage changes in sowing dates	24. Provide shade and drinking water for animals at pasture	25. Develop breeds or change to breeds adapted to changed conditions, especially drought and heat resistant varieties	26. Restoring natural features such as hedgerows to help reduce erosion
	considered	0%	25%	25%	0%	25%	0%
	not considered	25%	0%	0%	0%	0%	0%
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	25%	25%	25%	50%	25%	25%
Mediterranean South	traditionally adopted	67%	0%	0%	33%	0%	67%
	recently adopted	0%	0%	0%	0%	0%	0%
	considered	0%	33%	0%	0%	33%	0%
	not considered	0%	33%	67%	33%	33%	0%
	under current consideration	0%	0%	0%	0%	0%	0%
	unknown	33%	33%	33%	33%	33%	33%

Table H.4 Crop/animal adaptation management options 2 (Questions 27-32, by zone)

Agroclimatic zone	Crop/Animal Management Options	27. Develop farming practices that minimize susceptibility to new pests and diseases	28. Increase ground cover, by changing field design e.g. to expanded field margins	29. Enhancing the efficiency of fertilizer use	30. Developing land management practices to adapt to changes in soil properties	31. Maximising effectiveness of labour and machinery	32. Facilitate the transfer of technologies from relevant climatic zones	Average of Crop/Animal Management Options (Q21-32)
Alpine	traditionally adopted	50%	25%	75%	25%	75%	50%	**48%**
	recently adopted	25%	25%	25%	25%	0%	0%	**17%**
	considered	25%	0%	0%	0%	25%	0%	**13%**
	not considered	0%	25%	0%	50%	0%	50%	**19%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	0%	25%	0%	0%	0%	0%	**4%**
Atlantic Central	traditionally adopted	15%	0%	31%	15%	38%	8%	**15%**
	recently adopted	15%	23%	15%	0%	0%	0%	**12%**
	considered	8%	8%	15%	31%	8%	15%	**11%**
	not considered	23%	31%	8%	23%	15%	31%	**21%**
	under current consideration	0%	0%	0%	0%	8%	8%	**4%**
	unknown	38%	38%	31%	31%	31%	38%	**38%**
Atlantic North	traditionally adopted	50%	0%	0%	0%	0%	0%	**8%**
	recently adopted	0%	0%	50%	0%	0%	0%	**8%**
	considered	0%	50%	0%	50%	50%	0%	**17%**
	not considered	50%	50%	50%	50%	50%	100%	**67%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	0%	0%	**0%**
Atlantic South	traditionally adopted	50%	50%	50%	50%	50%	50%	**38%**
	recently adopted	0%	0%	0%	0%	0%	0%	**13%**
	considered	50%	50%	0%	0%	0%	0%	**8%**

Agroclimatic zone	Crop/Animal Management Options	27. Develop farming practices that minimize susceptibility to new pests and diseases	28. Increase ground cover, by changing field design e.g. to expanded field margins	29. Enhancing the efficiency of fertilizer use	30. Developing land management practices to adapt to changes in soil properties	31. Maximising effectiveness of labour and machinery	32. Facilitate the transfer of technologies from relevant climatic zones	Average of Crop/Animal Management Options (Q21-32)
	not considered	0%	0%	50%	50%	50%	50%	**42%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	0%	0%	**0%**
Boreal	traditionally adopted	0%	0%	67%	0%	0%	0%	**6%**
	recently adopted	0%	0%	0%	0%	0%	0%	**0%**
	considered	0%	0%	0%	0%	0%	0%	**0%**
	not considered	0%	0%	0%	0%	0%	0%	**17%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	100%	100%	33%	100%	100%	100%	**78%**
Continental North	traditionally adopted	18%	9%	36%	36%	45%	9%	**22%**
	recently adopted	27%	27%	45%	18%	18%	9%	**18%**
	considered	9%	18%	0%	9%	9%	18%	**9%**
	not considered	18%	9%	0%	0%	0%	27%	**20%**
	under current consideration	0%	18%	0%	0%	9%	0%	**3%**
	unknown	27%	18%	18%	36%	18%	36%	**28%**
Continental South	traditionally adopted	33%	0%	0%	0%	0%	33%	**25%**
	recently adopted	0%	33%	33%	0%	33%	0%	**11%**
	considered	0%	33%	0%	0%	33%	0%	**8%**
	not considered	0%	0%	0%	67%	0%	0%	**14%**
	under current consideration	33%	33%	33%	33%	33%	0%	**28%**
	unknown	33%	0%	33%	0%	0%	67%	**14%**
Mediterranean North	traditionally adopted	50%	25%	75%	50%	25%	25%	**44%**
	recently adopted	0%	0%	25%	0%	25%	0%	**8%**

Agroclimatic zone	Crop/Animal Management Options	27. Develop farming practices that minimize susceptibility to new pests and diseases	28. Increase ground cover, by changing field design e.g. to expanded field margins	29. Enhancing the efficiency of fertilizer use	30. Developing land management practices to adapt to changes in soil properties	31. Maximising effectiveness of labour and machinery	32. Facilitate the transfer of technologies from relevant climatic zones	Average of Crop/Animal Management Options (Q21-32)
	considered	0%	0%	0%	25%	0%	25%	**10%**
	not considered	25%	25%	0%	0%	25%	25%	**10%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	25%	50%	0%	25%	25%	25%	**27%**
Mediterranean South	traditionally adopted	0%	33%	33%	33%	33%	33%	**28%**
	recently adopted	0%	0%	33%	33%	33%	33%	**11%**
	considered	33%	33%	0%	0%	0%	0%	**11%**
	not considered	33%	0%	0%	0%	0%	0%	**17%**
	under current consideration	0%	0%	0%	0%	0%	0%	**0%**
	unknown	33%	33%	33%	33%	33%	33%	**33%**

Table H.5 Water management adaptation options 1 (Questions 33-37, by zone).

Agroclimatic zone	Water Management Options	33. Adopt suitable upland farm or land management practices so that upland areas are used to slow run off and reduce peak water flows	34. Adopt measures to reduce the impacts of extreme precipitation events	35. Encourage introduction of new management techniques e.g. requiring less water	36. Introduce measures to secure safety of livestock during extreme flooding events	37. Introduce measures to decrease sea level intrusion and salinisation of agricultural land
Alpine	traditionally adopted	25%	75%	25%	0%	0%
	recently adopted	0%	0%	50%	0%	0%
	considered	25%	0%	25%	0%	0%
	not considered	50%	25%	0%	100%	100%
	under current consideration	0%	0%	0%	0%	0%
	unknown	0%	0%	0%	0%	0%
Atlantic Central	traditionally adopted	8%	8%	8%	15%	8%
	recently adopted	8%	15%	15%	0%	0%
	considered	8%	23%	8%	0%	8%
	not considered	15%	8%	15%	23%	23%
	under current consideration	8%	0%	0%	8%	8%
	unknown	54%	46%	54%	54%	54%
Atlantic North	traditionally adopted	0%	0%	0%	0%	0%
	recently adopted	50%	0%	0%	0%	0%
	considered	0%	0%	0%	0%	0%
	not considered	50%	100%	100%	100%	100%
	under current consideration	0%	0%	0%	0%	0%
	unknown	0%	0%	0%	0%	0%
Atlantic South	traditionally adopted	50%	50%	0%	0%	50%
	recently adopted	0%	0%	50%	0%	0%
	considered	0%	0%	50%	0%	0%
	not considered	50%	50%	0%	100%	50%
	under current consideration	0%	0%	0%	0%	0%
	unknown	0%	0%	0%	0%	0%

Agroclimatic zone	Water Management Options	33. Adopt suitable upland farm or land management practices so that upland areas are used to slow run off and reduce peak water flows	34. Adopt measures to reduce the impacts of extreme precipitation events	35. Encourage introduction of new management techniques e.g. requiring less water	36. Introduce measures to secure safety of livestock during extreme flooding events	37. Introduce measures to decrease sea level intrusion and salinisation of agricultural land
Boreal	traditionally adopted	0%	0%	0%	0%	0%
	recently adopted	0%	0%	0%	0%	0%
	considered	0%	0%	0%	0%	0%
	not considered	0%	33%	0%	0%	0%
	under current consideration	0%	0%	0%	0%	0%
	unknown	100%	67%	100%	100%	100%
Continental North	traditionally adopted	9%	36%	0%	18%	9%
	recently adopted	0%	9%	27%	0%	0%
	considered	9%	9%	18%	9%	9%
	not considered	45%	18%	36%	45%	36%
	under current consideration	9%	9%	0%	0%	9%
	unknown	27%	18%	18%	27%	36%
Continental South	traditionally adopted	0%	33%	0%	33%	33%
	recently adopted	0%	0%	33%	0%	0%
	considered	0%	33%	33%	0%	0%
	not considered	33%	0%	0%	0%	0%
	under current consideration	33%	33%	33%	33%	33%
	unknown	33%	0%	0%	33%	33%
Mediterranean North	traditionally adopted	25%	75%	50%	25%	0%
	recently adopted	0%	0%	0%	0%	25%
	considered	25%	0%	25%	0%	0%
	not considered	25%	0%	0%	50%	25%
	under current consideration	0%	0%	25%	0%	0%
	unknown	25%	25%	0%	25%	50%

Agroclimatic zone	Water Management Options	33. Adopt suitable upland farm or land management practices so that upland areas are used to slow run off and reduce peak water flows	34. Adopt measures to reduce the impacts of extreme precipitation events	35. Encourage introduction of new management techniques e.g. requiring less water	36. Introduce measures to secure safety of livestock during extreme flooding events	37. Introduce measures to decrease sea level intrusion and salinisation of agricultural land
Mediterranean South	traditionally adopted	67%	33%	33%	33%	33%
	recently adopted	0%	0%	33%	0%	33%
	considered	0%	33%	0%	33%	0%
	not considered	0%	0%	0%	0%	0%
	under current consideration	0%	0%	0%	0%	0%
	unknown	33%	33%	33%	33%	33%

Table H.6 Water management adaptation options 1 (Questions 38-41, by zone)

Agroclimatic zone	Water Management Options	38. Alter conservation practices for dry summers	39. Adopt more effective use of irrigation	40. Increase in irrigation area and or water volume	41. Adopt water re-use technology	Average of Water Management Options (Q33-41)
Alpine	traditionally adopted	50%	25%	25%	0%	**25%**
	recently adopted	0%	25%	0%	0%	**8%**
	considered	0%	25%	25%	0%	**11%**
	not considered	50%	25%	50%	100%	**56%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic Central	traditionally adopted	15%	23%	8%	8%	**11%**
	recently adopted	0%	15%	8%	0%	**7%**
	considered	0%	0%	8%	0%	**6%**
	not considered	15%	8%	8%	23%	**15%**

Agroclimatic zone	Water Management Options	38. Alter conservation practices for dry summers	39. Adopt more effective use of irrigation	40. Increase in irrigation area and or water volume	41. Adopt water re-use technology	Average of Water Management Options (Q33-41)
	under current consideration	15%	0%	15%	0%	**6%**
	unknown	54%	54%	54%	69%	**55%**
Atlantic North	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**6%**
	considered	50%	0%	0%	0%	**6%**
	not considered	50%	100%	100%	100%	**89%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic South	traditionally adopted	0%	0%	0%	0%	**17%**
	recently adopted	50%	0%	0%	50%	**17%**
	considered	0%	50%	100%	0%	**22%**
	not considered	50%	0%	0%	50%	**39%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	50%	0%	0%	**6%**
Boreal	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	0%	0%	0%	0%	**0%**
	not considered	33%	67%	67%	0%	**22%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	67%	33%	33%	100%	**78%**
Continental North	traditionally adopted	9%	18%	9%	18%	**14%**
	recently adopted	18%	18%	36%	9%	**13%**
	considered	18%	9%	18%	9%	**12%**
	not considered	27%	27%	18%	36%	**32%**
	under current consideration	0%	9%	0%	0%	**4%**
	unknown	27%	18%	18%	27%	**24%**
Continental South	traditionally adopted	33%	0%	33%	0%	**19%**
	recently adopted	0%	33%	0%	0%	**7%**

Agroclimatic zone	Water Management Options	38. Alter conservation practices for dry summers	39. Adopt more effective use of irrigation	40. Increase in irrigation area and or water volume	41. Adopt water re-use technology	Average of Water Management Options (Q33-41)
	considered	0%	33%	33%	33%	**19%**
	not considered	0%	0%	0%	33%	**7%**
	under current consideration	0%	33%	33%	33%	**30%**
	unknown	67%	0%	0%	0%	**19%**
Mediterranean North	traditionally adopted	25%	50%	50%	25%	**36%**
	recently adopted	0%	0%	0%	0%	**3%**
	considered	0%	0%	25%	25%	**11%**
	not considered	25%	0%	0%	25%	**17%**
	under current consideration	0%	0%	0%	0%	**3%**
	unknown	50%	50%	25%	25%	**31%**
Mediterranean South	traditionally adopted	33%	33%	0%	33%	**33%**
	recently adopted	0%	33%	0%	0%	**11%**
	considered	33%	0%	0%	33%	**15%**
	not considered	0%	0%	67%	0%	**7%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	33%	33%	33%	33%	**33%**

Table H.7 Controlling/monitoring adaptation options (Questions 42-45, by zone)

Agroclimatic zone	Controlling/Monitoring Options	42. Monitoring the changes on biodiversity that may occur due to changes in agricultural crops	43. Monitoring new pests and diseases	44. Monitoring changes in soil properties	45. Information systems to raise awareness of the changes and possible risks and opportunities	Average of Controlling/ Monitoring Options (Q42-45)
Alpine	traditionally adopted	50%	75%	50%	0%	**44%**
	recently adopted	25%	25%	0%	25%	**19%**
	considered	25%	0%	25%	75%	**31%**
	not considered	0%	0%	25%	0%	**6%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic Central	traditionally adopted	0%	15%	15%	8%	**10%**
	recently adopted	23%	0%	8%	0%	**8%**
	considered	8%	8%	0%	15%	**8%**
	not considered	0%	8%	15%	0%	**6%**
	under current consideration	15%	8%	0%	8%	**8%**
	unknown	54%	62%	62%	69%	**62%**
Atlantic North	traditionally adopted	0%	50%	50%	0%	**25%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	100%	50%	50%	0%	**50%**
	not considered	0%	0%	0%	100%	**25%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic South	traditionally adopted	0%	50%	0%	0%	**13%**
	recently adopted	50%	0%	0%	50%	**25%**
	considered	0%	50%	50%	50%	**38%**
	not considered	50%	0%	50%	0%	**25%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Boreal	traditionally adopted	0%	0%	67%	0%	**17%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	0%	33%	0%	0%	**8%**

Agroclimatic zone	Controlling/Monitoring Options	42. Monitoring the changes on biodiversity that may occur due to changes in agricultural crops	43. Monitoring new pests and diseases	44. Monitoring changes in soil properties	45. Information systems to raise awareness of the changes and possible risks and opportunities	Average of Controlling/ Monitoring Options (Q42-45)
	not considered	33%	0%	0%	0%	**8%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	67%	67%	33%	100%	**67%**
Continental North	traditionally adopted	45%	55%	45%	18%	**41%**
	recently adopted	9%	18%	9%	27%	**16%**
	considered	9%	9%	9%	0%	**7%**
	not considered	9%	0%	9%	18%	**9%**
	under current consideration	0%	0%	0%	9%	**2%**
	unknown	27%	18%	27%	27%	**25%**
Continental South	traditionally adopted	0%	33%	33%	33%	**25%**
	recently adopted	0%	33%	33%	0%	**17%**
	considered	0%	0%	0%	0%	**0%**
	not considered	67%	0%	0%	33%	**25%**
	under current consideration	33%	33%	33%	33%	**33%**
	unknown	0%	0%	0%	0%	**0%**
Mediterranean North	traditionally adopted	25%	50%	75%	25%	**44%**
	recently adopted	25%	0%	0%	25%	**13%**
	considered	25%	25%	0%	0%	**13%**
	not considered	0%	0%	0%	0%	**0%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	25%	25%	25%	50%	**31%**
Mediterranean South	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	33%	67%	33%	67%	**50%**
	not considered	33%	0%	33%	0%	**17%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	33%	33%	33%	33%	**33%**

Table H.8 Structural/Financial adaptation options (Questions 46-49, by zone)

Agroclimatic zone	Structural/Financial Options	46. Permanent changes in farm structure, such as buildings, irrigation systems, heating or cooling structure	47. Establishing business plans with regular reviews to ensure effective responses to climatic event	48. Estimation of capital investment requirement to adapt to a hotter climate	49. Development of a common strategy for adaptation to climate change between the farming sectors and the insurance community	Average of Structural/ Financial Options (Q46-49)
Alpine	traditionally adopted	50%	25%	25%	25%	**31%**
	recently adopted	0%	0%	0%	25%	**6%**
	considered	25%	0%	0%	50%	**19%**
	not considered	25%	75%	75%	0%	**44%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic Central	traditionally adopted	15%	0%	0%	0%	**4%**
	recently adopted	0%	8%	0%	8%	**4%**
	considered	23%	0%	0%	15%	**10%**
	not considered	0%	15%	23%	0%	**10%**
	under current consideration	8%	0%	8%	8%	**6%**
	unknown	54%	77%	69%	69%	**67%**
Atlantic North	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	0%	0%	0%	0%	**0%**
	not considered	100%	100%	100%	100%	**100%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Atlantic South	traditionally adopted	50%	0%	0%	0%	**13%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	0%	50%	0%	50%	**25%**

Agroclimatic zone	Structural/Financial Options	46. Permanent changes in farm structure, such as buildings, irrigation systems, heating or cooling structure	47. Establishing business plans with regular reviews to ensure effective responses to climatic event	48. Estimation of capital investment requirement to adapt to a hotter climate	49. Development of a common strategy for adaptation to climate change between the farming sectors and the insurance community	Average of Structural/ Financial Options (Q46-49)
	not considered	50%	50%	100%	50%	**63%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	0%	0%	0%	0%	**0%**
Boreal	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	0%	0%	0%	0%	**0%**
	not considered	0%	0%	0%	0%	**0%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	100%	100%	100%	100%	**100%**
Continental North	traditionally adopted	27%	9%	0%	9%	**11%**
	recently adopted	27%	9%	18%	9%	**16%**
	considered	18%	18%	9%	18%	**16%**
	not considered	9%	18%	27%	9%	**16%**
	under current consideration	0%	9%	9%	18%	**9%**
	unknown	18%	36%	36%	36%	**32%**
Continental South	traditionally adopted	0%	0%	0%	0%	**0%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	33%	33%	33%	67%	**42%**
	not considered	33%	33%	33%	0%	**25%**
	under current consideration	33%	33%	33%	33%	**33%**
	unknown	0%	0%	0%	0%	**0%**
Mediterranean North	traditionally adopted	25%	25%	25%	25%	**25%**
	recently adopted	0%	0%	0%	0%	**0%**
	considered	25%	0%	25%	25%	**19%**

Agroclimatic zone	Structural/Financial Options	46. Permanent changes in farm structure, such as buildings, irrigation systems, heating or cooling structure	47. Establishing business plans with regular reviews to ensure effective responses to climatic event	48. Estimation of capital investment requirement to adapt to a hotter climate	49. Development of a common strategy for adaptation to climate change between the farming sectors and the insurance community	Average of Structural/ Financial Options (Q46-49)
	not considered	25%	50%	25%	25%	**31%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	25%	25%	25%	25%	**25%**
Mediterranean South	traditionally adopted	0%	0%	0%	33%	**8%**
	recently adopted	33%	33%	0%	0%	**17%**
	considered	33%	33%	0%	33%	**25%**
	not considered	0%	0%	67%	0%	**17%**
	under current consideration	0%	0%	0%	0%	**0%**
	unknown	33%	33%	33%	33%	**33%**

Annex I

Adaptation to risks and opportunities

Table I.1. Assessment of adaptation measures with priority and timescale

Adaptation Measure	Adaptation Action	Adaptive capacity	Technical feasibility	Potential cost	Ancillary benefits	Cross-sectoral implications	Timescale
RISKS							
Crop area changes due to decrease in optimal farming conditions							
Capacity building	Livelihood diversification	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Capacity building	Strengthen local capacity to reduce sensitivity	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Choice of crop	Changing cultivation practices	Moderate	High	High	May increase variety and choice of fruit locally	May contribute to improving nutritional status of locality	Long-term - Only needed as traditional production declines significantly
Refrigeration	Conversion of ambient storage to refrigerated stores	High	High	High		Will increase energy use	Mid-term - Technology exists
Irrigation	Irrigation	High	High	Moderate		Sources of water will need to be identified and may lead to conflict with other users	Short-term - Water collection needed first
Input of agro-chemicals	Additional aphicide application	High (easily fit into production cycle)	High (low tech)	Low	Enable sector to keep up with changing market advantages elsewhere in the world (Defra, 2002)		Long-term - Already practiced and easily fits into production cycle

Adaptation Measure	Adaptation Action	Adaptive capacity	Technical feasibility	Potential cost	Ancillary benefits	Cross-sectoral implications	Timescale
Input of agro-chemicals	Increased need for cutworm control	High (easily fit into production cycle)	High (low tech)	Low	Enable sector to keep up with changing market advantages elsewhere in the world (Defra, 2002)		Long-term - Already practiced and easily fits into production cycle
Irrigation and water harvesting	Increased irrigation of maincrop potatoes	High	High	Moderate	May also improve ware quality through scab control	Will increase demand for water and potential for conflict with other users	Mid-term - Needs water collection first
Input of agro-chemicals	Extra aphicide application in winter	High	High	Low	Increased risk of reducing water quality		Mid-term - Easily fits into production cycle
Input of agro-chemicals	Fewer aphicide applications in summer	High	High	Low			Mid-term - Easily fits into production cycle
Change in cropping	Industry level: Movement of wheat to more favourable areas	High, but suitable soil types needed to maintain yield	High	High			Mid-term - Only applicable as limit moves north
Choice of crop	Change of cropping mix	Moderate, suitable alternative crops need to be identified	Moderate	Low			Long-term - Only applicable when significant decline is seen

Adaptation Measure	Adaptation Action	Adaptive capacity	Technical feasibility	Potential cost	Ancillary benefits	Cross-sectoral implications	Timescale
Choice of crop	Switching to alternative crops	Moderate, Suitable alternative crops need to be identified	Moderate	Low	May lead to increased biodiversity		Long-term - Only applicable when significant decline is seen
Choice of crop	Industry level: Loss of early potato production advantage and shift to alternative crop	Moderate, suitable alternative crops need to be identified	Moderate	Low			Long-term - Only applicable when significant decline is seen
Industry research	Industry level: Increase in wheat breeding investment	Moderate	Moderate	Moderate	May also be able to improve wheat quality		Short-term - Industry research needed
Industry research	Climate change resilient crops	Moderate	Moderate	Moderate			Short-term - Industry research needed
Economic	Insurance	High	Moderate	High			Short-term
Soil management	Extensification: enhance carbon management and zero tillage	High	Moderate	Moderate			Mid-term
Crop management	Precision agriculture: improve soil and crop management	High	Moderate	Moderate			Mid-term
Industry research	Intensify research efforts and an enhanced training	High	Moderate	Moderate			Short-term

Crop productivity decrease							
Crop management	Change in crops and cropping patterns	Moderate	Moderate	Moderate		Economic diversification	Mid-term
Research	Industry research	High	Moderate	Moderate			Short-term
Crop management	Increased input of agro-chemicals	High	High	Moderate			Mid-term
Water management	Irrigation	High	High	Moderate		Sources of water will need to be identified and may lead to conflict with other users	Short-term - Rainfall collection needed first
Economic	Agricultural insurance	High	Moderate	High			Short-term
Crop management	Crop planting diversification	Moderate	Moderate	Moderate		Economic diversification	Mid-term
Planning	Design of regional adaptation plans	High	Moderate	Low			Short-term - Requires partnership
Capacity building	Livelihood diversification	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Capacity building	Strengthen local capacity to reduce sensitivity	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Increased risk of agricultural pests, diseases, weeds							
Choice of crop	Use new pest resistant varieties	Moderate, resistant varieties need to be identified or bred	Moderate	Moderate	If resistant varieties can be identified it should maintain biodiversity	Less risk of reduced water quality from pesticide leaching	Short-term - Needs investment in new breeds

Temperature control	Use of thermostats and rapid cooling	High, but only for protected crops	High (financial capital, market security and low energy price needed)	Moderate	None	Will increase energy use and may also increase GHG emissions	Mid-term - Does not compliment mitigation unless renewables used
Input of agro-chemicals	Develop sustainable integrated pesticides strategy	Moderate	Moderate	High	If a successful strategy can be developed then it may preserve or enhance biodiversity		Short-term - Needs partnership and strategy development
Crop husbandry	Natural predators	Low, natural predators need to be identified	Low	Low		Less risk of reduced water quality from pesticide leaching	Mid-term - Some natural predators known already (transferable from other zones)
Animal welfare	Vaccination of livestock and wild population to reduce disease spread	High	Moderate	Moderate (farm level costs)		Could lead to issues with organic certification	Mid-term - Vaccines transferable from other zones
Crop quality decrease							
Temperature control	Thermal screens	High	High	Moderate	May reduce evapo-transpiration and drought stress		Mid-term - Technology exists
Temperature control	Use of thermostats and rapid cooling	Very limited, only for vines grown under protection	High (financial capital, market security and low energy price needed)	Moderate		Will increase energy use	Long-term - Limited use
Increased risk of floods							
Flood defence	Develop contingency plans	High	High	Low		Wider community benefits	Short-term - Requires partnership

Flood defence	Create wetlands	Moderate	Moderate	Moderate	Water storage potential	Potential biodiversity benefits	Short-term - Requires partnership
Flood defence	Enhance flood plain management	Moderate	Moderate	Moderate	Water storage potential	Potential biodiversity benefits	Short-term - Requires partnership
Flood defence	Hard defences	Moderate, hard defences are less appropriate to river managemen t	High	High	Bring more land into production	Wider community benefits	Short-term - Requires partnership
Flood defence	Increase drainage	High	High	Low		Wider community benefits	Short-term
Rainfall interception capacity	Move towards farmers as ‘custodians’ of floodplain lands (Defra 2002) with appropriate compensation	Moderate, policy needs to strike balance between crop production and flood managemen t	High	High	May increase habitats for wildlife	Will reduce flooding risk for all sectors	Short-term - Requires policy development and partnership
Rainfall interception capacity	Reduce grazing pressures to protect against soil erosion from flash flooding	Low	Low, soil erosion associated mainly with arable farming	Low			Long-term - Limited use - Already practiced
Rainfall interception capacity/Soil management	Contour ploughing	Moderate	High	Low			Long-term - Already practiced

Rainfall interception capacity	Increase woodland and hedgerow area of farmland	High	High	Moderate	Likely to increase biodiversity	Will increase landscape value and may promote farm tourism	Mid-term - Requires maturity time
Soil management	Addition of organic material (OM) clay soils which are difficult to work in wetter conditions	Low, the only effective ways to increase OM are to put down to grass or add very large amounts of OM	Most arable farms do not have ruminants that can consume the grass	Low			Long-term - Limited use
Economic	Insurance of buildings and contents against flooding	Moderate		High (in high flood risk areas)			Long-term - Policies already in place
Increased risk of drought and water scarcity							
Change in cropping	Shifting crops from areas that are vulnerable to drought	Limited as there may not be enough land	Limited	Large as may lead to drought-prone farms being abandoned	May provide opportunities for farms in drought-free areas	May lead to land becoming derelict, reduce scope for farm tourism	Short-term - To avoid land abandonment
Water use	Set clear water use priorities	High	High	Low	Resource efficiency	Wider community benefits	Short-term
Water use	Increase water use efficiency	High	High	Low	Resource efficiency	Wider community benefits	Short-term
Water harvesting	Increase rainfall interception capacity	High	High	Variable, depending on scale of intervention	Alternative water supply	Reduces competition for a finite resource	Short-term

Water Management	Water audits	High	High	Low			Mid-term -Already used in other sectors
Rainfall interception capacity	Improving in field drainage and soil absorption capacity	Low	Moderate	Moderate			Mid-term - More natural measures should be tried in the short term
Rainfall interception capacity	Reduced run-off via contoured hedgerows and buffers	Moderate	Moderate	Low	Will reduce the risk of poor water quality	Will reduce risk of localised flooding. Will increase biodiversity.	Mid-term - hedgerows and buffers take less time to mature
Rainfall interception capacity	Introduce grass into arable rotations	Low, specialised nature of agriculture means that arable farms often have no ruminant livestock	High	Moderate	May reduce the risk of poor water quality	May increase biodiversity	Long-term - Limited use (depends on farming type)
Rainfall interception capacity	Woodland planting	Moderate	High	Moderate	May reduce the risk of poor water quality	May increase biodiversity	Short-term - takes time for trees to mature
Rainfall interception capacity	Recreate wetlands	Low	Moderate	Moderate	May provide new habitats for wildlife, particularly wading birds.	May greatly increase the potential for farm tourism.	Short-term - Takes time for ecosystem development
Tillage and time of operations	Use of precision farming could help in the adaptation to decreased water availability	Low, to a large extent such practices are already adopted	Low	Low	May provide new habitats for wildlife, particularly wading birds.	Reduce risk of conflict with other water users	Mid-term - Already practiced

Water harvesting	Installation of small scale water reservoirs on farmland	High	High	Moderate			Short-term - Needs (greater) funding - Requires planning permission - Already summer drought pressure
Water Management	Re-negotiation of water abstraction agreements	High	High	High, may have severe impact on farm incomes			Short-term - Requires partnership
Water Management	Water charging/ tradable permit schemes to promote efficient use of prescribed (reduced) sources	High	High	High, may have severe impact on farm incomes			Short-term - Required EU wide policy
Time of operations	Changing/cutting grazing regime for grassland						Long-term - Already practiced
Increased irrigation requirements							
Water harvesting	Investing in equipment that helps reduce the severity	High, large amounts of water may be harvested	Good	Moderate (average cost for reservoir in UK is £250K, with 40% funding available, NFU, 2005)	Will reduce pressure on other water supplies	Will reduce risk of conflict with other water users and build stronger relationships with water authorities. Planning and environmental constraints may make installation difficult (NFU, 2005).	Short-term - Needs (greater) funding - Requires planning permission - Already summer drought pressure

Irrigation and water harvesting	Technical improvements in advanced irrigation equipment	Moderate, advanced equipment may not always be appropriate	Good	Moderate	Will reduce pressure on other water supplies	Will reduce risk of conflict with other water users	Mid-term - Irrigation already practiced
Irrigation and water harvesting	Trickle Irrigation	Moderate, only applicable to permanent crops	Good	Moderate	Will reduce pressure on other water supplies	Will reduce risk of conflict with other water users	Long-term - Limited use
Irrigation and water harvesting	Spraying at night to reduced evapotranspiratio n	High, but may not be as effective as other measures	High	Low			Mid-term - Already practices
Irrigation and water harvesting	Separation of clean and dirty water	High	High	Moderate	Will reduce volumes of effluent and risk of reducing water quality		Mid-term - Equipment already available
Water harvesting	Installation of small scale water reservoirs on farmland	High	High	Moderate			Short-term - Needs (greater) funding - Requires planning permission - Already summer drought pressure
Water quality deterioration							
Equipment	Investing in aerating ploughing equipment that minimises the adverse effects of waterlogging	Low	Moderate	Moderate	Greater crop and forage growth	Minimal	Mid-term - More research and development needed - Grants needed once available

Research	Industry research into practices that minimise the adverse effects of waterlogging	High	Moderate	Moderate			Short-term
Research	Develop less polluting inputs	High	High	Low		Potential biodiversity benefits	Short-term
Optimisation of fertilizers input	Reduced N outputs from soil through enhanced efficiency of fertilizer use	Low, in the current climate farmers watch inputs carefully	High	High, further reductions in yield will reduce income and profit. Precision farming techniques need high capital investment	None	Reduced agrochemical inputs may improve image of farming	Mid-term - Technology/ practice exists already
Soil erosion, salinisation, desertification							
Capacity building	Livelihood diversification	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Capacity building	Strengthen local capacity to reduce sensitivity	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Capacity building	Intensify research efforts and enhanced training	High	High	Moderate	Enhanced profitability	Diversification of employment prospects	Short-term
Choice of crop	Change in cropping	Moderate, suitable alternative crops need to be identified	Moderate	Low			Long-term - Only applicable when significant decline is seen

Change in cropping	Allocate fields prone to flooding from sea level rise as set-aside	Limited to the extent to which such schemes remain operative	Moderate	High, due to reduced agricultural production	May provide new habitats for wildlife, particularly wading birds.	May greatly increase the potential for farm tourism.	Mid-term - Already EU policy structure in place to facilitate
Crop husbandry	Change fallow and mulching practices to retain moisture and organic matter	High	Good	Low			Mid-term - Already carried out
Crop husbandry	Use intercropping to maximise use of moisture	Good – will increase farm level efficiency	Good (no new technology needed)	Low	Diversification	May affect biodiversity if field margins change	Mid-term - Already carried out
Flood defence	Create wetlands to stop pollution	Moderate	Moderate	Moderate	Water storage potential	Potential biodiversity benefits	Short-term - Requires partnership
Crop husbandry	Alter row/plant spacing to increase root extension to soil water	Good – will increase farm level efficiency	Good (no new technology needed)	Low	Diversification	May affect biodiversity if field margins change	Mid-term - Already carried out
Equipment	Investing in aerating ploughing equipment that minimises the adverse effects of waterlogging	Low	Moderate	Moderate	Greater crop and forage growth	Minimal	Mid-term - More research and development needed - Grants needed once available
Research	Industry research into practices that minimise the adverse effects of waterlogging	High	Moderate	Moderate			Short-term

Loss of glaciers and alteration of permafrost							
Water management	Compensatory water capture and storage systems	High	Low	High		Wider community benefits	Short-term - Requires complex planning
Structural stability	Repair, maintenance and structural underpinning of buildings and infrastructure.	High	Low	High		Maintaining tracks and roads	Short-term - Preventative work will reduce costly repair
Deterioration of conditions for livestock production							
Animal husbandry	Moving herds from waterlogged fields	Limited, farm may not have alternative fields	High	Low	Will reduce damage to soil structure	May improve image of farming and increase tourism	Mid-term - Practice exists already
Rainfall interception capacity	Improving field drainage	Moderate	High	High, may also reduce grass yields	May increase length of grazing period	Will reduce water retention by soils and increase flood risk	Short-term - High cost, will need funding/grants
Aerating equipment	Investing in machinery that minimise the adverse effects of waterlogging	Low	Moderate	Moderate	Greater crop and forage growth	Minimal	Mid-term - More research and development needed - Grants needed once available
Animal husbandry	Decline in number of native breed livestock and introduction of more drought tolerant breeds	Low, such breeds may be less productive	High	Moderate			Mid-term - Some known breeds from outside Europe, but may required further research

Animal welfare	Increase amount of wallows for outdoor pigs to protect them from the sun	High	High	Low		If natural shelter, will increase biodiversity.	Short-term - Structures require planning permission, trees need time to mature to provide adequate shelter
Animal welfare	Change breeding and shearing patterns for sheep production	High	High	Low			Mid-term - Already practiced
Animal welfare	Windbreak planting to provide shelter for animals from extreme weather	High	High	Low		If natural shelter, will increase biodiversity.	Mid-term - Hedgerows easily planted
Animal welfare	Woodland planting	High	High	Moderate	May increase biodiversity and farm incomes from woodland products	May improve landscape and increase potential for farm tourism	Short-term - Trees need time to mature
Animal husbandry	Supplemental feeding	High	High	Moderate	May be able to reduce protein intake and hence reduce N excretion and pollution from livestock manures		Long-term - Already practiced
Grazing practice	Balance of grazing and cutting	High	High	Low			Long-term - Already practiced

Sea level rise							
Flood defence	Hard defences	High	High	High		Will also protect other sectors	Short-term -Requires partnership between authorities/land owners/local residents
Flood defence	Alternative drainage systems	High	High	High		Will also protect other sectors	Short-term -Requires partnership between authorities/land owners/local residents
Change in cropping	Set aside of land for buffer zones	Limited to the extent to which such schemes remain operative	Moderate	High, due to reduced agricultural production	May provide new habitats for wildlife, particularly wading birds.	May greatly increase the potential for farm tourism.	Mid-term - Already EU policy structure in place to facilitate
Change in cropping	Alternative crops	Low	Low - Limited by salt tolerance	Low		Potential for energy crops	Mid-term
Capacity building	Livelihood diversification	Moderate	Moderate	Moderate	Enhanced profitability	Diversification of employment prospects	Mid-term
Research	Into other options for management of salt water intrusion	Moderate	Low (new area of research)	High (requires hard engineering)			Short-term - New area of research
OPPORTUNITIES							
Crop distribution changes leading to increase in optimal farming conditions							
Increase crop production	Extend arable farming to new areas	Moderate	Moderate	High		May reduce biodiversity	Mid-term - Only applies as limit moves north

Increase crop production	Introduce more productive varieties	High	Moderate, the potential will be limited by soil type	Low, can be achieved with existing infrastructure	Will increase farm income	Suggestion: increase crop production	Mid-term - Immediate economic benefits
Crop husbandry	Grow quicker maturing varieties to maximise yields	Moderate, limited by soil	Moderate, requires research	Moderate, Needs considerable investment			Mid-term - Immediate economic benefits
Choice of crop/Industry research	Investment in energy crops, short-rotation coppice and miscanthus	Moderate, infrastructur e required	Moderate	Low	Will reduce net GHG emissions	Creation of new jobs in the energy sector	Short-term - Requires research
Crop productivity increase							
Increase crop production	Extend arable farming to new areas	Moderate	Moderate	High		May reduce biodiversity	Mid-term - Only applies as limit moves north
Increase crop production	Introduce more productive varieties	High	Moderate, the potential will be limited by soil type	Low, can be achieved with existing infrastructure	Will increase farm income	Suggestion: increase crop production	Mid-term - Immediate economic benefits
Crop husbandry	Grow quicker maturing varieties to maximise yields	Moderate, limited by soil	Moderate, requires research	Moderate, Needs considerable investment			Mid-term - Immediate economic benefits
Choice of crop/Industry research	Investment in energy crops, short-rotation coppice and miscanthus	Moderate, infrastructur e required	Moderate	Low	Will reduce net GHG emissions	Creation of new jobs in the energy sector	Short-term - Requires research
Choice of crop/Industry research	Frost resistant varieties	High	High	Low			Short-term - Research required to develop varieties
Choice of crop/Industry research	Drought resistant varieties	High	High	Low	Will reduce demand for irrigation	Will reduce risk of conflict with other sectors	Short-term - Research required to develop varieties

Forest productivity increase							
Forest Management	Move away from monoculture	High	Moderate	Moderate	Opportunity for new habitats	Potential biodiversity benefits	Short-term
Forest Management	Continuous cover forests with mixed stands of native species	Moderate	Moderate	Moderate	Opportunity for new habitats	Potential biodiversity benefits	Short-term

Improved water availability							
Increase crop production	Extend arable farming to new areas	Medium	Medium	High		May reduce biodiversity	Mid-term - Only applies as limit moves north
Increase livestock production	Extend livestock farming to new areas	Medium	Medium	High		May reduce biodiversity	Mid-term - Only applies as limit moves north
Increase crop production	Substitute higher-yielding cereal crops, e.g. wheat for barley	High	High, can be grown with existing equipment	Low			Mid-term - Immediate economic benefits
Improvement of production in greenhouses							
Temperature control	Use ground heat sources when required	Moderate	Moderate	High	Decreased heating costs		Long-term
Improvement in livestock productivity							
Increase livestock production	Increase stocking rate	Moderate	Moderate	Moderate	Will increase farm income	May reduce biodiversity	Mid-term - Immediate economic benefits
Increase livestock production	Extend livestock farming to new areas	Moderate	Moderate	High	Will increase farm income	May reduce biodiversity	Mid-term - Only applies as limit moves north

Animal husbandry	Increased ventilation in housing/dairy parlours/transportation	Moderate	Moderate	High			Mid-term

Annex J

Workshop agenda, attendees and minutes

Results from the consultation workshop on the integration of adaptation to climate change in the EU Common Agricultural Policy

4th October 2007, DG AGRI

Introduction

Historically, the CAP has provided significant incentives to encourage self-sufficient production across the Union. These incentives have been a major determinant of farmers' behaviour, reducing the relevance of market prices to many farmers.

Successive reforms of CAP have switched market intervention to direct payment. In 2003, further reform led to a realignment of production as a result of decoupling direct payments, while providing farmers with greater flexibility to react to market (economic) and environmental (agronomic) signals.

The decoupling of subsidies from production gives farmers the flexibility to adapt their production decisions, based on agronomic criteria. This change may provide the foundations for farm-level adaptation strategies. Policy makers have also provided a new focus on climate change. Climate change objectives have already been integrated into the rural development policy framework for 2007-13, and climate change adaptation is a recognised priority in the strategic guidelines for rural development.

However, there is also a possibility that future changes to CAP may expose farms to other climate change risks. For example, the loss of area-based subsidies combined with market stochasticity leading to both less secure and less predictable farm income. Farming could become more vulnerable as climate change affects production.

This third task aims to provide an analysis of the potential contribution (and constraints) of the CAP, and options to include policy measures to tackle and adapt to the impacts of climate.

According to the activities proposed for the last task of this project, a consultation process with experts on the issue of climate change and its impacts was carried out in two phases:

- Development of questionnaire to be sent to experts all over the project area and compilation of results.
- Validation of results for the analysis of the most significant impacts and proposal of adaptation measures. First approach to the integration of adaptation measures in the CAP.

Based on the results f this consultation process the ability or inability of existing CAP instruments to deliver the adaptation options identified will be assessed (the strengths and weaknesses). The potential for modifications of the CAP will also be considered as well as the potential for the evolving CAP to undermine adaptation measures.

Workshop Agenda and Attendees

Agenda

The workshop will present and discuss the outputs of the various components of the project: analysis of impacts and risks; assessment of adaptive measures; and options for integration of the adaptation considerations into the CAP.

It will also provide a forum to consider adaptation issues in farming more widely and the potential role of the EU in developing and delivering adaptation policy for the agriculture sector. Invited ‘experts’ will help facilitate discussion.

09.00 Registration and coffee.

09.30 Welcome and introductions. Mike Harley, AEA Project Leader

09.45 EU policy context for the project. Maria Fuentes-Merino, EC Project Officer

09.55 Aims and objectives of the project. Mike Harley

10.00 Risks and opportunities from climate change by geographical area. Ana Iglesias, UPM

10.25 Adaptation measures and actions in EU member states. Nikki Hodgson, AEA

11.00 Role of CAP in adaptation to climate change. Paul Fisher, AEA

11.25 Summary of project findings and introduction to interactive sessions. Mike Harley

11.30 Open discussion of project outputs.

12.00 Lunch

13.30 Projected impacts of climate change on European agriculture.

14.15 Measures and actions to help European farmers adapt to climate change.

15.00 Tea.

15.30 Policy measures to address impacts and enable adaptation in European agriculture.

16.15 Recommendations for further action.

16.45 Close of Workshop.

Participants

Table 1. List of workshop participants

Country	Organisation	Area of expertise	Expert
France	Ministry of Agriculture	National agriculture	Nathalie Guesdon
Italy	Director of Interdepartmental Centre for Bioclimatology / head of COST	Bioclimatology	Simone Orlandini
Poland	Institute of Soil Science and Plant Cultivation - State Research Institute	Agrometeorology	Dr. Jerzy KOZYRA
Ireland	Irish EPA	Technical Advisor on Climate Change/Farm specialist	Liam Kinsella

Austria	University of Vienna	Researcher	Gerhard Kubu
UK	RSPB	Biodiversity	Gareth Morgan
Netherlands	Plant Research International	Coastal defence	Dr. Jan VERHAGEN
Netherlands	Ministry of Agriculture, Nature and Food Quality	National agriculture	Kaj van de Sandt
Lithuania	Lithuanian Institute of Agriculture	Researcher	Saulius Marcinkonis
Sweden	Swedish Board of Agriculture	National agriculture	Johan Wahlander

European Commission attendees:
Maria Fuentes Merino – DG Agri
Beatriz Velázquez - DG Agri

Project team attendees:
Ana Iglesias – UPM
Marta Moneo – UPM
Mike Harley – AEA
Paul Fisher – AEA
Nikki Hodgson – AEA
Keesje Avis – AEA

Results from the workshop

Validation of the results from: Impacts of climate change on agriculture (see presentation 'Task 1 Impacts presentation_Ana Iglesias UPM')

In order to validate the results obtained through the detailed literature review carried out for the development of the impact assessment, a matrix was set up including the identified agro-climatic zones and the most significant risks and opportunities. The participants could evaluate which of them were most important to their respective areas and also include other aspects that had not been previously considered.

The following table summarizes the results of the consultation process:

Table 2. Validation of the results of the impact identification

	Climate variability	Temp. stress	SLR	Expansion of agr. area	Env.l conflicts	Other
Boreal					**-**	**- Temp increase during winter -, 0 Pests and diseases**
Atlantic N-C	**- - - -**		**-**	**+ +**	**- -**	**0 Pests and diseases**
Atlantic S	**-**				**- -**	**- - Winter variability 0 Pests and diseases**
Continental	**- -**	**-**	**-**		**-**	**- - 0 Pests and diseases**
Mediterranean	**- 0 0**	**-**			**- - 00**	**- - Extreme events 0 Pests and diseases**
Alpine	**- - 0**	**-**		**+ +**	**- -**	

Legend: - Risk, + Opportunity, 0 Policy need

Conclusions

- Some impacts like climate variability or the appearance of environmental conflicts are generalised to most of the areas, while others like Sea level rise or the expansion of agricultural area are more area-specific.

- For those common risks, proposed policies will probably be better accepted by society as people can easily appreciate the impacts by themselves.
- Increase of lake's water level or saline intrusion are not sufficiently reflected in the report. These are the most significant risks derived from SLR in the Boreal area.
- There is a clear limitation of the analysis of risks and policies with the scenarios proposed as time scales are so different for the two aspects.
- When considering potential impacts caused by N leaching in the future we should not assume poor management, even if there is a higher need for fertilizers, leaching does not necessarily have t increase that much if management is adequate.
- Increases in soil organic matter, turns soils from CO_2 sinks into CO_2 emitters.
- Farmers in most of the regions have already appreciated climate change and have adapted their activities to the observed changes in some way.
- Structured soils will eventually be more resistant to changes and impacts than non-structured soils in alpine or boreal areas.
- There is great uncertainty associated to the evaluation of risks and opportunities
- Europe will suffer gradual changes with local variability that should be accounted for

Validation of the results from: Adaptation measures for climate change (see presentation 'Task 2 Adaptation measures_Nikki Hodgson AEA')

For the validation of results of the adaptation measures identified, again the most significant risks were displayed with the included adaptation measures and the experts proposed alternative measures not included in the analysis.

Table 3. Proposed alternative adaptation measures

Main Risk	Proposed measures
Flooding	Dykes/local dams Local storage (farm ponds) Cropping patterns Energy crops for flood retention Set aside of areas frequently flooded Creation of wetlands Insurance might prevent necessary changes to be adopted
Drought	Strict use of ONLY available water Water charging Water planning Groundwater storage Establishment of water rights Irrigation Soil quality management Conservation tillage
Higher temperature	Knowledge transfer Not necessarily implies more pesticide use Change of crop management dates Optimization of farm system (supported by policy)
SLR	Hard flood defence Salinity management Change of cropping pattern Change to fish farming

Additional measures	Improve farmer's education: Increase scope of FAS (biological farming), vocational training for young farmers, transfer of R&D to end-users, requirements for new farmer's education. Improvement of climate modelling Integrate Climate Change in CAP Coordination between European policies (WFD; CAP; Nitrates, Soils) Links between adaptation and mitigation aspects Remove the biofuels target (price increases, water competition, NOx production) Progress in technologies (2nd generation technologies) Changes in cropping patterns Economic evaluation of measures Water and soil management measures Livestock management Establishment of CC indicators to trigger policies or actions Water policy is not determinant for every regions Control on the conversion of pastures to agricultural land Insurances (evaluate adequate way of implementation: private companies, government…) Coordination with the Soil Framework Directive

Integration of adaptation measures in the CAP (see presentation 'Task 3 CAP_Paul Fisher AEA')

Suggestions made by the experts:

- Modification of SAS for the creation of an ecological international network and for water resource management (flood storage, flood defence…)
- Article 69 gives some flexibility to member states to direct their funds to the development of adaptation practices or regulations.
- The farm advisory service currently does not include adaptation

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