Challenges to coping strategies with agrometeorological risks and uncertainties in EUROPE

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INTERNATIONAL WORKSHOP ON AGROMETEOROLOGICAL RISK MANAGEMENT- CHALLENGES AND OPPORTUNITIES (New Delhi, India, 2006)
Outline of the talk

• Some characteristics of European agriculture
• State-of-the-art of agrometeorology in Europe
• Variability of climate
• Research challenges
• Climate change in Europe
• What has to be done?
Climate classification for Europe

Source: Köppen and de Long, 1958
Some characteristics of European agriculture

- One of the world's largest and most productive suppliers of food and fibre (in 2004: 21% of global meat production and 20% of global cereal production).
- About 80% of this production occurred in EU25.
- The productivity of agriculture is generally high, in particular in W.Europe; average cereal yields in the EU are more than 60% higher than the world average.
- The area of forests in Europe is increasing and annual fellings are considerably lower (policies today promote multiple forest services at the expense of timber production).
Changes in Agriculture in CEE

• Significant changes in land ownership structure (little private land ownership before 1989), restoration of the private ownership in CE is still not completed

• High fragmentation of the land (12 people per 10 ha) and consolidation is not completed

• Compensation schemes do not work adequately (negative environmental impact)

• Socio-economic factors (connection to own land, ageing)
EU Common Agricultural Policy has been reformed

- to reduce overproduction
- improve rural development.
- reduce environmental impacts

The European environment and agriculture

- Europe’s soil is threatened by erosion, sealing, contamination and salinisation (2 million sites are potentially contaminated)
- Water: Stress increasing in southern Europe and expected to continue (increasing tourism, irrigation and climate change)
- Water pollution from agriculture - headache in the new EU Member States — fertiliser use to increase
- Groundwater will take decades to clean up
- Prevention cheaper than clean up — changing behaviour
Drivers of European Agriculture in the next decades

– Growing demand for safe and quality food
– Growing awareness for nutrition issues and healthy food
– Increased demand for renewable energy
– Increased demand for biodegradable paper, fibres, polymers, lubricants, surfactants, solvents,
– Increased demand for bio-pharmaceuticals

Is (European) agrometeorology ready for these challenges?
State-of-the-art of agrometeorology in Europe (RA-VI)

- The position and organization of agrometeorological information systems changes from country to country.
  - Influenced by the present and near future political situation in the Region
  - It would be very difficult to outline any common European feature of the agrometeorological system.

- **Agricultural meteorology is not in a favorable position**
  - the national communities are generally not interested in a system that can promote the quantity of the food production
  - many insurance and pesticide companies have own “pararel” agrometeorological services.

- **Institutional “fragmentation”** (different types of structures, sometimes national meteorological service has no agrometeorological activity, but other service systems exist, research often detached, outdated institutions)

  Ideal model: Germany, where the national service has its own research and operational network within the federation system.
The structure of the (ideal?) agrometeorological homepage

Maracchi (2002)
Natural variability NAO
Natural variability: the North Atlantic Oscillation

Source: M. Visbeck
The North Atlantic Oscillation will intensify with increasing greenhouse-gas emissions.

Kuzmina et al. 2005
Met Office forecast: European winter 2005/06

Empirical NAO prediction
Rodwell & Folland, 2002

NAO index: difference between normalised pressure anomaly Azores - Iceland
Predicts correct sign in 2 out of 3 winters

N. Atlantic May SST anomaly associated with +ve NAO

N. Atlantic May SST anomaly 2005
Recent weather (climate change?) warnings in Europe
Heat waves
Droughts
Floods
2003 European heat wave impact on the agricultural sector

• Summer of 2003: T up to 6°C above long-term means, and precipitation deficits up to 300 mm in summer months.
• Italy: record maize yield drop of 36%
• France: corn grain crop was reduced by 30%
  fruit harvests declined by 25%.
  winter crops (wheat) yield reduction 21%
  forage production reduced on average by 30%
• Wine production in Europe was the lowest in 10 years
• The economic losses for the agriculture sector in the European Union were estimated at 13 billion Euros
• Forest area destroyed reached 650,000 hectares. Portugal lost around 6% of its forest area.
European wheat yield in 2003 (change from 2002)

% change compared to 2002
- > + 3.5
- – 3.5 to + 3.5
- – 10 to – 3.5
- – 20 to – 10
- < – 20
- Outside data coverage

Source: Joint research centre (JRC) MARS project
Minimum economic cost of recent major drought events in Europe

<table>
<thead>
<tr>
<th>Period</th>
<th>Region / Countries affected</th>
<th>Economic costs (€ billion)</th>
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<tbody>
<tr>
<td>1976-77</td>
<td>Western Europe (Cost of building damage due to land subsidence in London alone estimated at € 800 million)</td>
<td>&gt; 5.0</td>
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<td>1981-82</td>
<td>Iberian Peninsula (Portugal, Spain, Southern France, Corsica, Italy)</td>
<td>&gt; 2.1</td>
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<td>1988-91</td>
<td>Mediterranean Region (Portugal, Spain, Southern France, Italy, Albania, Greece)</td>
<td>&gt; 2.1</td>
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<td>1992-94</td>
<td>Eastern Europe (Germany, Denmark, Poland, Lithuania, Hungary, Yugoslavia, Ukraine, Moldova)</td>
<td>&gt; 1.1</td>
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<td>1992-95</td>
<td>Spain</td>
<td>&gt; 3.7</td>
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<td>2000</td>
<td>Central Europe (Romania, Hungary, Poland, Bulgaria, Greece, Yugoslavia, Czech Rep, Turkey, Germany)</td>
<td>&gt; 0.5</td>
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<td>2003</td>
<td>Europe (Romania, Hungary, Poland, Bulgaria, Greece, Yugoslavia, Czech Rep, Austria, Switzerland, Italy, Germany, Belgium, Denmark, Netherlands, Norway, UK, France, Spain, Portugal)</td>
<td>&gt; 13.0</td>
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Source: DG JRC: Climate Change and the European Water Dimension (A report to the European Water Directors, 2005)
Severe droughts in the last 40 years in Slovenia

Percentage of Portugal affected by drought
(Source: Instituto de Meteorologia)
Flooding is the most common natural disaster in Europe. The total number of flood events in Europe has increased since 1974.
Use of seasonal to inter-annual climate forecasts, improved application of medium-range weather forecasts for tactical management of agriculture etc.,
European research

• DEMETER project (EU FP5) – completed Sep 2003
  – European seasonal multi-model system (hindcasts)
  – Application/impact models (also crops)
  – forecast system sensitivity studies

• EURO-SIP
  – operational real-time implementation of DEMETER

• ENSEMBLES (EU FP6 5 year project)
  – prediction/impacts seasonal to decadal (and longer) timescales
  – new representations of model and initial condition uncertainty
The seasonal forecast process

‘This forecast is produced using a combination of statistical models and complex climate models with interpretation by operational forecasters (Crown, 2005).’

- Statistical forecasting model
- Research studies (e.g. PREDICATE, COAPEC)
- What other forecasts are saying
- Analysis of current ocean observations
- Analysis of climate trends
- Monthly conference of experts (forecasting, research & comms staff)
- Skill assessed by past performance of the forecast methods
- Dynamical forecasting models (Met Office, EURO-SIP)
Choice of climatology determines the forecast message!
Statistical forecast for summer 2006 relative to 3 climatologies

July—August 2006 forecast relative to 1987–2001 climatology: Probabilities

Relative to 1987-2001 (CGCM hindcast period)
‘Most likely cold’

July—August 2006 forecast relative to 1971–2000 climatology: Probabilities

Relative to 1971-2000
‘Most likely average’


Relative to 1961-1990
‘Most likely average’
EUROSIP: Prob. 2m temp. > upper tercile

EUROSIP multi-model seasonal forecast
Prob(2m temperature > upper tercile)
Forecast start reference is 01/05/08
Unweighted mean

ECMWF/Met Office/Météo-France
JJA 2006
No significance test applied

Forecast issue date: 15/05/2008
Tellus 57A, No. 3, 21 contributions

• Evaluation of DEMETER multi-model hindcast skill
• Applications/impact models (also crop yield)
• Downscaling studies
• Sensitivity studies
Seasonal weather forecasts for crop yield modelling in Europe

By PIERRE CANTELAUBE and JEAN-MICHEL TERRES*, European Commission Joint Research Centre/Institute for Environment and Sustainability, TP 262, I-21020 Ispra (VA), Italy

(Manuscript received 30 March 2004; in final form 2 December 2004)

ABSTRACT
Within the European DEMETER project, ensembles of global coupled climate models have shown some skill for seasonal climate prediction. Meteorological outputs of the seasonal prediction system were used in a crop yield model to assess the performance and usefulness of such a system for crop yield forecasting.

An innovative method for supplying seasonal forecast information to crop simulation models was developed. It consisted in running a crop model from each individual downscaled member output of climate models. An ensemble of crop yield was obtained and a probability distribution function (PDF) was derived. Preliminary results of wheat yield simulations in Europe using downscaled DEMETER seasonal weather forecasts suggest that reliable crop yield predictions can be obtained using an ensemble multi-model approach. When compared to the operational system, for the same level of accuracy, earlier crop forecasts are obtained with the DEMETER system. Furthermore, PDFs of wheat yield provide information on both the yield anomaly and the uncertainty of the forecast. Based on the spread of the PDF, the user can directly quantify the benefits and risks of taking weather-sensitive decisions.

It is shown that the use of ensembles of seasonal weather forecasts brings additional information for the crop yield forecasts and therefore has valuable benefit for decision-making in the management of European Union agricultural production.
Seasonal weather forecasts in Eui

By PIERRE CANTELAUBE and JEAN-MICHEL Centre/Institute for Environment and Sustain.

ABSTRACT

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An innovative method for supplying seasonal forecast is consisted in running a crop model from each individual year of crop yield was obtained and a probability distribution for yield simulations in Europe using downscaled DEMETER se predictions can be obtained using an ensemble multi-model in the same level of accuracy, earlier crop forecasts and obtained yield provide information on both the yield anomaly and the in the near future quantify the benefits and risk of yielding in it is shown that the use of ensembles of seasonal weather forecasts and therefore has valuable benefit for decision making production.

Probabilistic simulations of crop yield over western India using the DEMETER seasonal hindcast ensembles

By A. J. CHALLINOR1*, J. M. SLINGO1, T. R. WHEELER2 and F. J. DOBLAS-REYES3

1CGAM, Department of Meteorology, University of Reading, Reading RG6 6BB, UK; 2Department of Agriculture, University of Reading, Reading RG6 6AT, UK; 3European Centre for Medium-Range Weather Forecasts (ECMWF), Shinfield Park, Reading RG2 9AX, UK

(Manuscript received 30 March 2004; in final form 28 December 2004)

ABSTRACT

Process-based integral modelling of weather and crop yield over large areas is becoming an important research topic. The production of the DEMETER ensemble hindcasts of weather allows this work to be carried out in a probabilistic framework. In this study, ensembles of crop yield (groundnut, Arachis hypogaea) were produced for 10 2.5° × 2.5° grid cells in western India using the DEMETER ensembles and the general large-area model (GLAM) for annual crops.

Four key issues are addressed by this study. First, crop model calibration methods for use with weather ensemble data are assessed. Calibration using yield ensemble was more successful than calibration using mean yield data (the European Centre for Medium-Range Weather Forecasts (ECMWF), ERA40). Secondly, the potential for probabilistic forecasting of crop failure is examined. The hindcasts show skill in the prediction of crop failure, with more severe failures being more predictable. Thirdly, the use of yield ensemble means to predict interannual variability in crop yield is examined and their skill assessed relative to baseline simulations using ERA40. The accuracy of multi-model yield ensemble means is equal to or greater than the accuracy using ERA40. Fourthly, the impact of two key uncertainties, sowing window and spatial scale, is briefly examined. The impact of uncertainty in the sowing window is greater with ERA40 than with the multi-model yield ensemble mean. Yield heterogeneity affects model accuracy: where correlations are low on the grid scale, they may be significantly positive on the subgrid scale.

The implications of the results of this study for yield forecasting on seasonal time-scales are as follows. (i) There is the potential for probabilistic forecasting of crop failure defined by a threshold yield value; forecasting of yield tertiles shows less potential. (ii) Any improvement in the skill of climate models has the potential to translate into improved deterministic yield prediction. (iii) Whilst model input uncertainties are important, uncertainty in the sowing window may not require specific modelling.

The implications of the results of this study for yield forecasting on multi-decadal (climate change) time-scales are as follows. (i) The skill in the ensemble means suggests that the perturbation, within uncertainty bounds, of crop and climate parameters, could potentially narrow out some of the errors associated with mean yield prediction. (ii) For a given technology trend, decadal fluctuations in the yield gap parameter used by GLAM may be relatively small, implying some predictability on those time-scales.
Evaluation of downscaled DEMETER multi-model ensemble seasonal hindcasts in a northern Italy location by means of a model of wheat growth and soil water balance

By V. MARLETTI*, I. E. ZINONI†, L. CRISCIUOLO†, G. FONTANA†, S. MARCHESI†, A. MORGINO‡, M. VAN SOETENDEAL†, E. COTTO† and U. ANDERSEN†
Emilia-Romagna, Bologna, Italy; †Institute of Meteorology and Hydrology, Modena, Italy; ‡Danish Meteorological Institute, Copenhagen, Denmark

(Manuscript received 31 March 2004; in final form 14 October 2004)

ABSTRACT

In this paper we explore the new possibilities for early crop yield assessment at the local scale arising from the availability of dynamic crop growth models and downscaled multi-model ensemble seasonal forecasts. We compare the use of the latter with other methods, based on crop growth models driven by observed climate data only. The soil water balance model developed and used at ARPA Emilia-Romagna (CIFERMA) was integrated with crop growth routines from the model WASD M. Some validation runs were then carried out and we worked with independent field data that the new integrated model satisfactorily simulated above-ground biomass and leaf area index. The model was then used to test the feasibility of using downscaled multi-model ensemble seasonal hindcasts, coming from the DEMETER European research project, in order to obtain early (50, 60 and 80 days before harvest) yield assessments for winter wheat in northern Italy. For comparison, similar runs with climatology instead of hindcasts were also carried out. For the same purpose, we also produced six simple linear regression models of final crop yields on within season (end of March, April and May) storage organs and above-ground biomass values. Median yields obtained using downscaled DEMETER hindcasts always outperformed the simple regression models and were substantially equivalent to the climatology runs, with the exception of the June experiments, where the downscaled seasonal hindcasts were clearly better than all other methods in reproducing the winter wheat yields simulated with observed weather data. The crop growth model output dispersion was almost always significantly lower than the dispersion of the downscaled ensemble seasonal hindcast used as input for crop simulations.

Within the Eur seasonal climate to assess the pl
An innovation consists in using of crop yield models simulating predictions that can be used to provide to the user community.
It is shown that forecasts and production.

The implications of the results of this study for yield forecasting on multidecadal climate change time scales are as follows. (i) The skill in the ensemble means suggests that the perturbation, within uncertainty bounds, of crop and climate parameters, could potentially manage some of the errors associated with mean yield prediction. (ii) For a given technology trend, decadal fluctuations in the yields gap parameter used by GLAM may be relatively small, implying some predictability on these time-scales.

search topic: probabilistic
2.25° × 2.25° annual crops, ensemble
3.2 data (the missing one for produc
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*BLAS-REYES†
Institute of Agriculture, Forecasts (ECMWF),

By PIERRE CANT Centrale

Centrale
ARPA crop modelling results (wheat in Italy)

Vittorio Marletto

- 72 ensembles (4 models (x9) x2) downscaling replicates
- WOFOST based crop model observed data to 31st March and onwards with DEMETER hindcasts to harvest date (end June)
- Box (IQR) whiskers (10th & 90th percentiles)
- Observed weather simulation (control) solid triangle
- Climatology based run hollow circle.
Met Office decadal forecast system (DePreSys): Forecast of global annual mean $T_s$

7 model multi-model installed at ECMWF
- includes Met Office decadal forecast system (anomaly assimilation)
- realistic GHGs, aerosols

Predict 0.36+/-0.23°C (5-95%) warming for the coming decade (Unless a major volcanic eruption occurs!)
Challenges to coping strategies with Climate change in Europe

Preparedness as a coping strategy!!!
Spremembe temperature zraka (°C) v obdobju od 1970 do 2000

Warming trends 1970-2000

-1,7  0  0,5  1  3  No data
Climate scenarios for Europe: relative to 1961-1990 (4 GCMs, 4 SRES)

Temperature Change (°C)

Precipitation Change (%)

Potsdam Institute for Climate Impact Research

Mitchell, Hulme et al. 2004 (in review).
PRUDENCE model projections of changes in European climate by the end of this century
European sub-areas (http://prudence.dmi.dk/)

Series of high-resolution climate change scenarios for 2071-2100
Alpine region:
Change in seasonal mean 2m T by the end of this century

Min  Ensemble  Max

DJF  MAM  JJA  SON
Alpine region:
Change in seasonal precipitation by the end of this century

PRUDENCE model projections
Precipitation change [%]
Modelled suitability for grain maize cultivation during the baseline (1961-1990) and future (2071-2100)

7 RCM scenarios driven by HadAM3 (SRES A2)
6 GCM-A2 scenarios
24 scenarios from 6 GCMs
4 SRES scenarios
A1FI, A2, B1, B2

Green: suitable area for the baseline
Red: expansion common under all scenarios and
Blue: the uncertainty range of the respective scenario group
Grey: unsuitable under all scenarios.
Changes in NPP (%) (2071-2100)-(1961-1990) simulated by LPJ-GUESS driven by different RCM-generated climate scenarios.

<table>
<thead>
<tr>
<th>RCM</th>
<th>GCM</th>
<th>Emission Scenario</th>
<th>SW</th>
<th>SE</th>
<th>E</th>
<th>W</th>
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<tbody>
<tr>
<td>RCAO</td>
<td>HadAM3H</td>
<td>A2</td>
<td>8.4</td>
<td>13.6</td>
<td>19.3</td>
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<td>48.3</td>
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<td>RCAO</td>
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<td>B2</td>
<td>7.9</td>
<td>15.3</td>
<td>17.7</td>
<td>20.1</td>
<td>35.4*</td>
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<td>ECHAM/OPYC</td>
<td>A2</td>
<td>-4.8*</td>
<td>10.0*</td>
<td>9.7*</td>
<td>16.8*</td>
<td>44.3*</td>
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<td>RCAO</td>
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<td>11.2</td>
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<td>HIRHAM</td>
<td>HadAM3H</td>
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<td>HadRM3H</td>
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<td>CLM</td>
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<td>REMO</td>
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<td>A2</td>
<td>13.0</td>
<td>26.4**</td>
<td>28.0**</td>
<td>29.2</td>
<td>44.3*</td>
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</tbody>
</table>

Mean: 10.20 17.93 18.20 25.08 45.71

* = Lowest value for each sub-region; ** = Highest value for each sub-region.
Mediterranean: increased fire risk

Example Spain

% change in 90\textsuperscript{th} percentile of 10-metre wind speed

\rightarrow Increased wind speed intensity in core of Europe north of Alps
Ensemble mean soil moisture changes

Spring A2

Summer A2

Spring B2

Summer B2
## Expected impacts of climate change in Europe during this century

<table>
<thead>
<tr>
<th>Sectors and systems</th>
<th>Impact</th>
<th>Area</th>
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<td>North</td>
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<td>Water resources</td>
<td>Floods</td>
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<td>Forest, grasslands and shrublands</td>
<td>Forest NPP</td>
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<td>Northward/inland shift of tree species</td>
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<td>Natural disturbances (e.g., fire, insects)</td>
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<td>Change of stability of forest ecosystems</td>
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<td>Agriculture</td>
<td>Suitable cropping area</td>
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<td>Agricultural land area</td>
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<td>Summer crops (maize, sunflower)</td>
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<td>Winter crops (winter wheat)</td>
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<td>Air pollution: ozone</td>
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Coping strategies for climate change: Is Europe prepared for rapid or abrupt climate change?
Vulnerability to abrupt climate change in Europe

Nigel Arnell\(^1\), Emma Tompkins\(^2\), Neil Adger\(^2\) and Kate Delaney\(^1\)

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Report to ESRC Environment and Human Behaviour Programme
Project RES-221-25-0011

Tyndall Centre Technical Report 34
November 2005
Rapid and abrupt climate change and abrupt climate change impacts (low probability, high impact)

3 types of abrupt climate change
- Collapse of the thermohaline circulation
- Accelerated climate change
- Collapse of the West Antarctic Ice Sheet
Change in average annual runoff, assuming A2 emissions and accelerated climate change.
Change in average annual runoff,

A2 emissions accelerated climate change
<table>
<thead>
<tr>
<th>Water</th>
<th>“Conventional” climate change</th>
<th>THC collapse</th>
<th>Accelerated climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public supply and demand</td>
<td>● Increase in winter runoff, decrease in summer</td>
<td>● Reduction in total runoff of at least 30% for at least 30 years</td>
<td>● Reduction in total runoff of at least 40% by 2050</td>
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<td>- <em>river flows and recharge</em></td>
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<td>● Shift to snow-dominated regimes: lower flows in winter</td>
<td>● Increased range in flows through the year, with lower summer flows</td>
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<td><em>demand</em></td>
<td>● Increase in peak demands</td>
<td>● Reductions in peak demands</td>
<td>● Large increase in peak demands</td>
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<td>Irrigation</td>
<td>● Increase in demand</td>
<td>● Reduction in demand</td>
<td>● Large increase in demand</td>
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<td>Floods</td>
<td>● Increase in risk of winter flooding</td>
<td>● Shift from winter to spring snowmelt flooding</td>
<td>● Increase in risk of winter flooding</td>
</tr>
</tbody>
</table>
Coping strategies for climate change: mitigation versus adaptation
Share of the EU-15 agricultural sector in total greenhouse gas emissions (2002)
Production of renewable energy from agricultural sources (EU-15)

- Primary energy cereal straw: 17% (380 ktoe)
- Primary energy agricultural biogas: 3% (57 ktoe)
- Primary energy short rotation forestry: 13% (281 ktoe)
- Primary energy ethanol crops: 10% (216 ktoe)
- Primary energy biodiesel crops: 57% (1,292 ktoe)

EEA Report, No 6/2005
Greenhouse gas emissions

Emissions of greenhouse gases per capita, 2002

Emissions of greenhouse gases per GDP, 2002

Distance to Kyoto target, linear target path, 2002
Late Lessons, Early Warnings:

2002 European Environment Agency Assessment:
• asbestos and asbestosis
• BSE in cattle
• CFCs and the depletion of stratospheric ozone
• collapse of Atlantic fish stocks
• PCBs
• etc.
What is the “precautionary principle”?

It is better
(and likely less costly)
to be safe
than sorry
Precautionary principle in the UK

Greater stress on water resources by 2050

- Scotland
  - Loss of biodiversity
  - Poor housing stock
- North West
  - Upland biodiversity
  - Industry
- Northern Ireland
  - Sea routes
  - More arable farming?
- West Midlands
  - Effect on regeneration
  - Transport disruption
- Wales
  - Heritage & agriculture
- South West
  - Tourism, water & fisheries
- North East
  - Coastal flooding
- Yorkshire & Humber
  - Coastal flooding
- East Midlands
  - River flooding followed by reduced river flows
- East of England
  - Coastal flooding
  - Water shortages
- South East
  - Flood risk & water resources
12 Late Lessons from early warnings

1. Respond to ignorance as well as uncertainty
2. Research and monitor for “early warnings”
3. Search out and address gaps in scientific knowledge
4. Identify and reduce interdisciplinary obstacles to learning
5. Ensure that real-world conditions are fully accounted for
6. Systematically scrutinize and justify “pros” and “cons”
7. Promote robust, diverse and adaptable solutions
8. Use local knowledge as well as all relevant specialist expertise
9. Take account of wider social interests and values
10. Maintain regulatory independence from economic and political special interests
11. Reduce institutional obstacles to learning and action
12. Avoid paralysis by analysis
2006 WMO and UNCCD initiative

Drought Management Centre for South-Eastern Europe (DMCSEE).

• An operational centre for drought preparedness, monitoring and management;
• Drought monitoring and forecast products
• Strengthening the technical and scientific capacity for drought preparedness, monitoring and management
• Exchange of knowledge, experience and best practices
Main tasks of DMCSEE

- To collect, compile, process, analyse, interpret, assess and validate relevant data on drought events
- Timely drought forecasts in the subregion;
- New applications and techniques
- Climate monitoring and modelling activities for diagnostic analysis and forecasting;
- Dissemination of appropriate products to end users;
- Specialized training and exchange programmes on drought issues
- Subregional awareness-raising campaigns
Final thoughts

• Europe needs improved agrometeorological services, not just for coping with drought and climate change, but also for protecting the environment and biodiversity and for ensuring sustainable development.

• Mitigation and adaptation to the adverse effects of climate variability and climate change is of high priority for all European countries.

• Europe needs the recognition that drought is becoming a “normal” feature of many natural, economic, and social environments.