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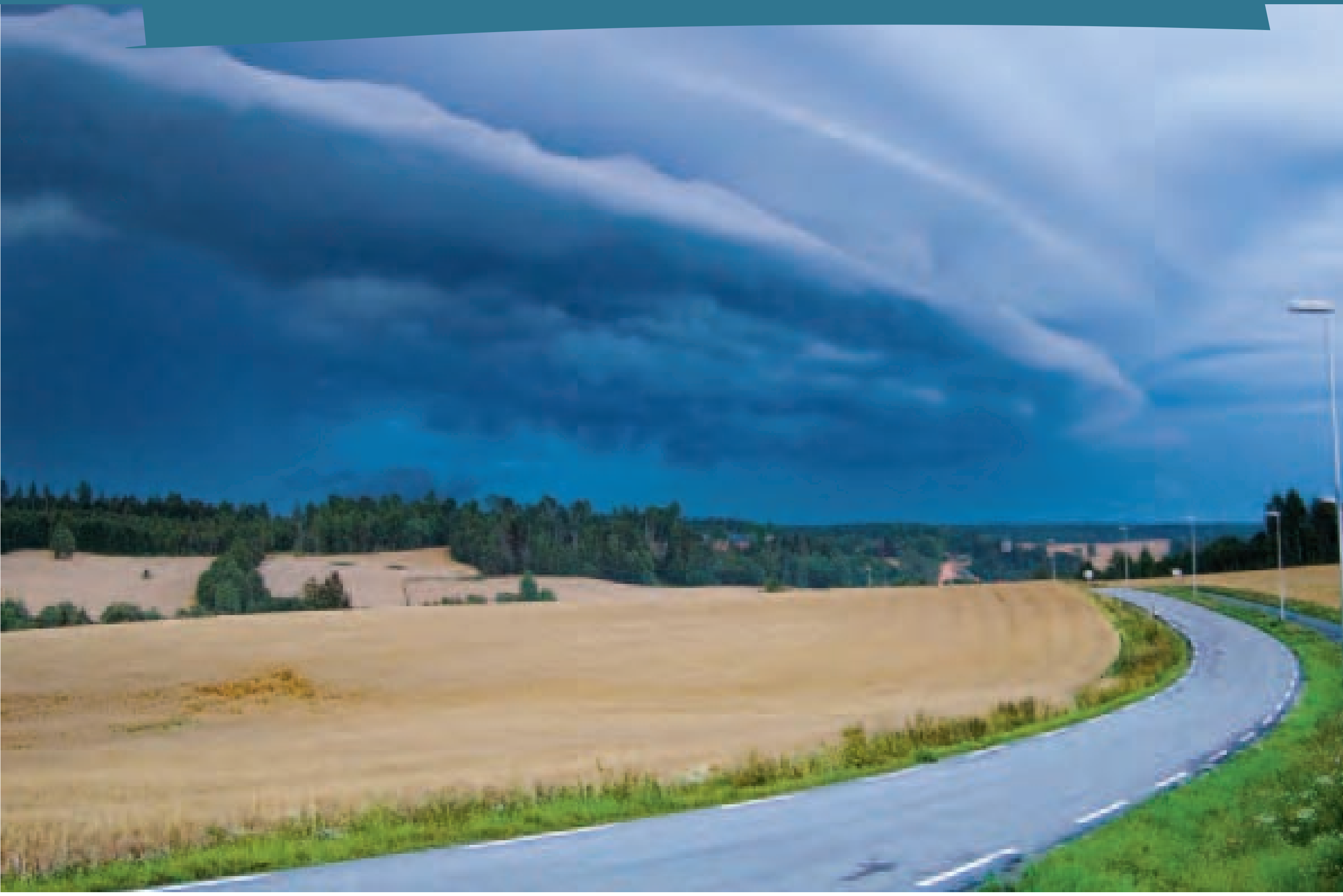

Symposium on Climate Change and Variability – Agro Meteorological Monitoring and Coping Strategies for Agriculture

Oscarsborg, Norway, June 3-6 2008

Book of abstracts

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Scientific editors: Tor Håkon Sivertsen, Arne Oddvar Skjelvåg, Simone Orlandini, Mannava V.K. Sivakumar, Josef Eitzinger, Pavol Nejedlik, Vesselin Alexandrov, Leonidas Toulios, Pierluigi Calanca, Robert Stefanski, Raymond Motha, Mduduzi Gamedze,Miroslav Trnka, Ward Smith and Jan Netland

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Preface

'The Symposium on Climate Change and Variability – Agro Meteorological Monitoring and Coping Strategies for Agriculture' is organized by the Management Committee of COST734' Impact of Climate Change and Variability on European Agriculture' and the Commission for Agricultural Meteorology (CAgM) of WMO.

The content of the symposium is closely connected to the themes of the working groups of COST734 and the term of reference of the 'WMO Expert Team on Climate Risks in Vulnerable Areas" The symposium is devoted to the very important issue of agricultural crop production and climate change. The discussion is placed in the light of agro meteorology, in Europe and in the rest of the world. The event will serve as a meeting place between meteorologists and agronomists. The cooperation between these two groups of researchers is important to find optimal mitigation and adaptation strategies with respect to impacts of climate change/variability on agriculture.

The book of abstracts for the symposium contains altogether 52 contributions. 26 of the abstracts are oral contributions, and 26 of the abstracts will be presented as posters.

The symposium venue is Oscarsborg which is located on a small island in the Oslo Fjord. We hope that you all will have a fruitful stay in Norway!

Ås, May 9, 2008
The local organizing committee at Bioforsk Plant Health and Plant Protection Division
and University of Life Science

Jan Netland

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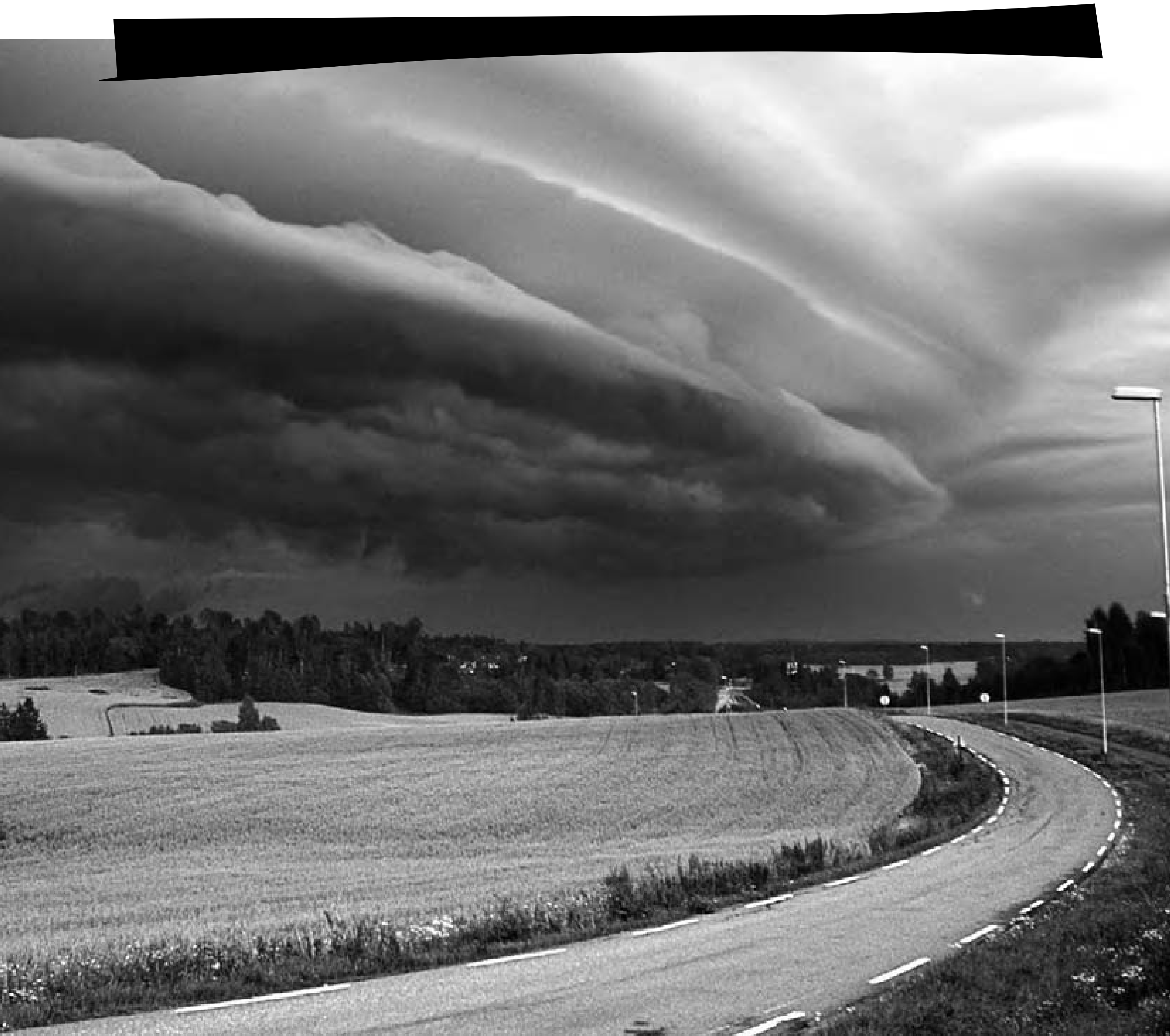
SESSION I

Agroclimatic Indices and Simulation Models



Applications of agroclimatic indices and process oriented simulation models in european agriculture

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During the past decades, in connection with the development of computers, many new software tools were developed to be used for agricultural research as well as for decision making. For example, crop and whole farm system modelling, pest and disease warning models/algorithms, models for irrigation scheduling or agroclimatic indices can help farmers significantly in decision-making for crop management options and related farm technologies. In research, models can be used to simulate and analyse the complex interactions in the soil-plant-atmosphere system for example in the important field of climate change impacts on agricultural production. All these modelled systems and their interactions include however many different kind of uncertainties and limitations, such as trends in technology and human activities, models representation of reality, lack of knowledge on system responses or lack of calibration data. Much research was done worldwide in the field of model development, model improvements or model comparisons. Also in Europe in many countries significant work was done in this field. The aims of Working group 1 of COST734 is a review and assessment of agroclimatic indices and simulation models relevant for various agricultural activities in Europe. The results of the survey are presented in this study. It includes an overview of most used agrometeorological indices and process oriented models for operational and scientific applications, an analyses of the limitations for applications and an overview of spatial applications in combination with GIS and remote sensing in Europe.

NCEP non-hydrostatic regional model and surface scheme LAPS: A dynamic scaling tool for use in agricultural models

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Characterisation of the climatic hazards for agriculture can be done using the Global Circulation Models (GCMs) and/or Regional Circulation Models (RegGCMs). The GCMs models provide credible information of climate, at least for sub-continental scales while the RegCMs are used to determine specific characteristics of the weather in mesoscale. Regardless of whether these models provide meteorological data through either long-term or short-term runs. The land surface scheme is a strong link between the underlying surface and atmosphere. Recently they have remarkably improved in the segment of the parameterisation of turbulent fluxes inside and above the tall grass canopies, making them more relevant, for example, together with agricultural models, in assessing how regional climate may affect agriculture.

This paper describes the Land-Air Parameterisation Scheme (LAPS) coupled with the NCEP non-hydrostatic mesoscale model by setting a focus on the parameterisation of processes relevant in agricultural science and practice. The scheme has seven prognostic variables: three temperature variables (foliage, soil surface and deep soil), one interception storage variable, and three soil moisture storage variables. For the upper boundary conditions the following forcing variables are used: air temperature, water vapour pressure, wind speed, short wave and long wave radiation and precipitation at a reference level within the atmospheric boundary layer. The surface fluxes are calculated using resistance representation. The soil module is designed as a three-layer model, which is used to describe the vertical transfer of water in the soil. The LAPS uses the morphological and physiological characteristics of the vegetation community for deriving the coefficients and resistances that govern all the fluxes between the surface and atmosphere. To demonstrate how the turbulent transfer coefficient inside and above tall grass canopies over a large domain represents the influence of the underlying surface on the air layer above, sensitivity tests are performed using a coupled system consisting of the NCEP non-hydrostatic mesoscale model and LAPS.

Survey of drought indices used in agrometeorology

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The paper summarises the indices used for identification of drought phenomenon in the agricultural meteorology practice. Many drought definitions and indices are known. Drought indices seem to be the simplest tools in drought analysis. The more or less well known and popular indices have been collected and compared not only with the well known simple but more complicated water balance and so called ‘recursive’ indices beside few ones use remotely sensed data, mainly satellite born information. The indices are classified into five groups, namely ‘precipitation’, ‘water balance’, ‘soil moisture’, ‘recursive’ and ‘remote sensing’ indices. For every group typical expressions are given and analysed for their performance and comparability. Taking into consideration that drought is a compound concept few drought definitions are examined together with the drought indices. As any classification the presented categories have got their limitation but the hope is that as wide review is given as it is possible using mainly meteorological data and information.

On the use of agroclimatic indices and crop simulation models for assessing the influence of climate change on the European viticulture

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The geographical distribution of vine is strictly linked to the climate, both on a global and local scale (terroir). Also, the year to year variations of wine quality are determined by climate characteristics, so that it could be anticipated as one of the most sensitive crops to the change of climate.The main tendencies of the resulting impact for the end of the century can be derived from simple analyses of the geographical distribution of vineyards in relation with mean values of the temperature between April and July (or August).

A more detailed analysis may be performed with using agroclimatic indices which have been derived for assessing the climatological potentialities of vineyards. Among them, the index of Huglin (1968), based on temperature data, has been used for mapping the change in potentialities at the European scale or estimating the change in climatic range and varieties aptitude on several French locations.

The validity of this kind of projection using an empirical approach is questionable. It has been possible to compare its outputs with those of a crop deterministic model (STICS-vigne) recently set up for vine and wine production simulation. The main lines of changes in potentialities have been confirmed both for long term projections and the effect of recent warming, already very evident in wine quality. But the case study of the extreme year 2003 has shown that the Huglin index was totally wrong for describing such an event. It seems that this failure is mainly caused by the range of adaptation of the plant and its varieties to warmer temperatures (Jones, 2006), which appears larger than assessed by Huglin.

From this example, as generally anticipated, it can be confirmed that the use of agroclimatic indices, when simply computed on empirical relationships, can give valuable first-order indications for a large scale assessment, but that only models involving more detailed information on physiological processes may give more precise informations of agronomic value.

Secular trend analysis of the growing degree days in Croatia

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The simplest presentation of the air temperature impact on plants is the sum of the necessary active air temperature. It is usually measured in growing degree days (GDD) when average daily mean temperature (T_{mean} = (T_{max}- T_{min})/2) exceeds 5 °C. For this reason the GDD, for different temperature thresholds (5 °C, 10 °C, 15 °C, 20 °C and 25 °C), for the five meteorological stations in Croatia with the long-term meteorological series during the period 1901–2000 have been analysed. These stations are situated in the different parts of Croatia: Zagreb-Grič is in the central part of Croatia, Osijek in the Pannonian flat, Gospić in the mountain region, Crikvenica in the northern Adriatic coast and Hvar on the mid-Adriatic island. Growing degree days have been presented as annual values and particular for the warm season (April–September). The secular time series of GDD shows positive deviation from normal series for the period 1961–1990 for all the considered stations except Hvar for which it is negative up to the threshold of 10 °C. The analysis of the linear trend and the Mann-Kendall test indicate a significant trend of GDD annual values at the level of 0.05 for Zagreb-Grič, Crikvenica and Hvar. This statement is valid for Hvar and Crikvenica for the warm season for all the thresholds. The reason for a positive trend in GDD annual values at Zagreb-Grič lies not only in global warming, but the fast growing of the city in the last hundred years, as well. The progressive trend test for GDD annual values at Hvar, for thresholds lower than 10 °C, shows a significant increase from the early sixties of the twenty century, while for greater ones from the early eighties. The increase in annual GDD in Crikvenica happened twice: the first significant period was from the late twenties to early fifties, and the second one started in the early nineties.

Occurrence of dry and wet periods during vegetation season at selected stations of Slovakia for the period 1951-2005

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The paper brings the model computation results of relative evapotranspiration (ratio of actual and potential evapotranspiration totals) and drought index (ratio of potential evapotranspiration and precipitation totals) at 4 selected stations in Slovakia during vegetation season for the period 1951-2005. Selected stations provide information about above mentioned characteristics in relation to the altitude (Hurbanovo 115 m, Kamenica nad Cirochou 178 m, Oravská Lesná 780 m and Strbské Pleso 1360 m a.s.l.) and they also cover both drought (Hurbanovo) and wet regions of Slovakia (Oravská Lesná, Strbské Pleso). Relative evapotranspiration is an excellent measure of water supply for plants and the drought index informs about the relationship between solar energy and precipitation. Model for computation of potential and actual evapotranspiration emanates from common solution of energy and water balance equation of soil surface. The smallest vegetation season values of relative evapotranspiration were recorded in the Danube lowland in Hurbanovo. The vegetation season values varied from 35% (1990) to 89% (1965) during the investigated period. In mountain areas of Slovakia actual evapotranspiration shows only small differences from the potential one and relative evapotranspiration values during the vegetation season range in Štrbské Pleso from 84% (2003) to 100% (1958).Vegetation season values of drought index for the period 1951 – 2005 change from 0.92 (1965) to 4.05 (2003) in Hurbanovo, from 0.82 (1985) to 2.58 (1961) in Kamenica nad Cirochou, from 0.40 (1965) to 1.19 (1992) in Oravská Lesná and from 0.42 (1996, 2001) to 1.19 (1986) in Štrbské Pleso. Variability of relative evapotranspiration as well as droughty index values is decreasing with altitude above sea level. The differences in the computed extreme values of both the studied characteristics were caused by time and space variability concerning the energetic possibilities of evapotranspiration and precipitation fields on the territory of Slovakia. The statistic significance of linear trends in long–term course of relative evapotranspiration and drought index vegetation season values is analysed.

Asking some questions about the scope of mechanistic crop growth models connected to global change

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There exist several very complicated mechanistic crop growth models, like SUCROS, CERES etc. These models are constructed by modeling quantitatively physiological processes in relation to environment. Some of these models have been used for predictions and consequences of global change. The model CERES, a model for cereal crops, is delivered by IBSNAT, The International Benchmark Sites Network for Agrotechnical Transfer, University of Hawaii, Honolulu. This model contains output parameters of yield, biomass, phenological phases, soil water content etc. The input data are parameters describing the soil physics, the varieties of the cereal crop, and the weather. In addition management of fertilization and management of pests and diseases may be considered. The input weather data of interest for the present discussion are simulations, scenarios, of future climatic conditions in different countries and different regions in Europe. The type of crop production basically connected to the model CERES are technically advanced commercial production of cereals on the large agricultural scale. The outcome of any study containing this model in the present shape, will be the limits of this type of agricultural production connected to quantitative scenarios of the future climate in the different regions of Europe.

How should one attach the concepts of sustainable agriculture and global change to crop growth modeling?

How should crop growth modeling be connected to sustainable farming systems and the challenges of global change.

Has anyone tried to use crop growth models in a context of production, storage, distribution, consumption, and the treatment of waste connected to crop production.

Several ecological systems of nature contain recycling of minerals and waste products. Has anyone tried to combine crop growth models to such ecological systems?

How should the temporal and spatial scope of mechanistic crop growth models be evaluated and discussed?

Successful model prediction of frost damage in Norwegian winter wheat fields

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A Canadian model of low temperature tolerance in winter wheat was adopted and further developed for use in a maritime climate. Data from field experiments performed at three different locations in Central Norway during two winters were used to develop and parameterize the new model, FROSTOL, which simulates the course of frost tolerance, expressed as LT_{50} (the temperature at which 50% of the plants are killed), on a daily basis from sowing on, until springtime. Frost tolerance increases by hardening and decreases by dehardening and stress, the latter caused by either low temperatures, or by conditions where the soil is largely unfrozen and simultaneously covered with snow. By comparing modelled frost tolerance with actual soil temperature (2 cm depth), possible winter damages in field may be predicted. Running FROSTOL with weather records from the autumn and winter of 2006/07 showed that in February, when parts of Norway experienced a cold spell combined with strong winds, the estimated frost tolerance level had become too low for the plants to stand these low temperatures without an insulating snow cover. Plants covered with snow should, according to the model estimates, be able to survive. As spring arrived, a patchy survival pattern was seen in several winter wheat fields, and the patches with dead plants were typically found at hilltops and other places where the snow easily blows away. Hence, the model seems able to mirror changes in frost tolerance occurring in field.

Two-dimensional flow in a porous medium with general anisotropy

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We consider two-dimensional flow through a homogeneous porous medium with general anisotropy. The flow is governed by Darcy's law and depends on the spatial coordinates x and y. Darcy's law can then be formulated in two dimensions with an effective two-dimensional permeability tensor. We derive this effective permeability tensor for any 2D flow. The effective tensor has 3 independent components that replace the 6 independent components of the physical permeability tensor in 3D. There is a passive flow in the z direction perpendicular to the coordinates x and y, on which the flow depends. It will not influence the analysis whether the flow is time-dependent.

Application of weather driven crop growth models to long term experiments

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The climate change scenarios of Sweden suggest a considerable change in climate conditions during the next decades to come. There are different methodologies to assess the effects of these changes on crop yields, for instance assessments with mechanistic modelling, or by assuming regional current yield differences to be related to climatic differences and address future yield changes to changes in climatic zones. The extrapolation methods to be used need to be verified for empirical data. Yield variations in practical agriculture are influenced by several factors, and the contribution of climate is unclear. Crop yields have been measured in controlled long-term experiments since ca 1960 at different locations in Sweden. For the high fertilisation treatments weather might have been a dominant factor for yield variations. The objective of the current study is to try to predict yield variations of these experiments as a function of climate, with methodologies that can be used to assess effects of climate change. Results are not yet available. Preliminary statistical results indicate, though, that high yield of spring crops is positively correlated with high spring temperatures. We speculate that this might be related to early sowing, and that sowing date might be an important factor in determining the climate effect on yield. Possibly, this factor has not been regulated by climate in some long-term experiments, reducing their applicability to climate change studies. Further evaluations are needed.

Climate change, erosion and nutrient loss from agricultural dominated catchments in South Eastern Norway

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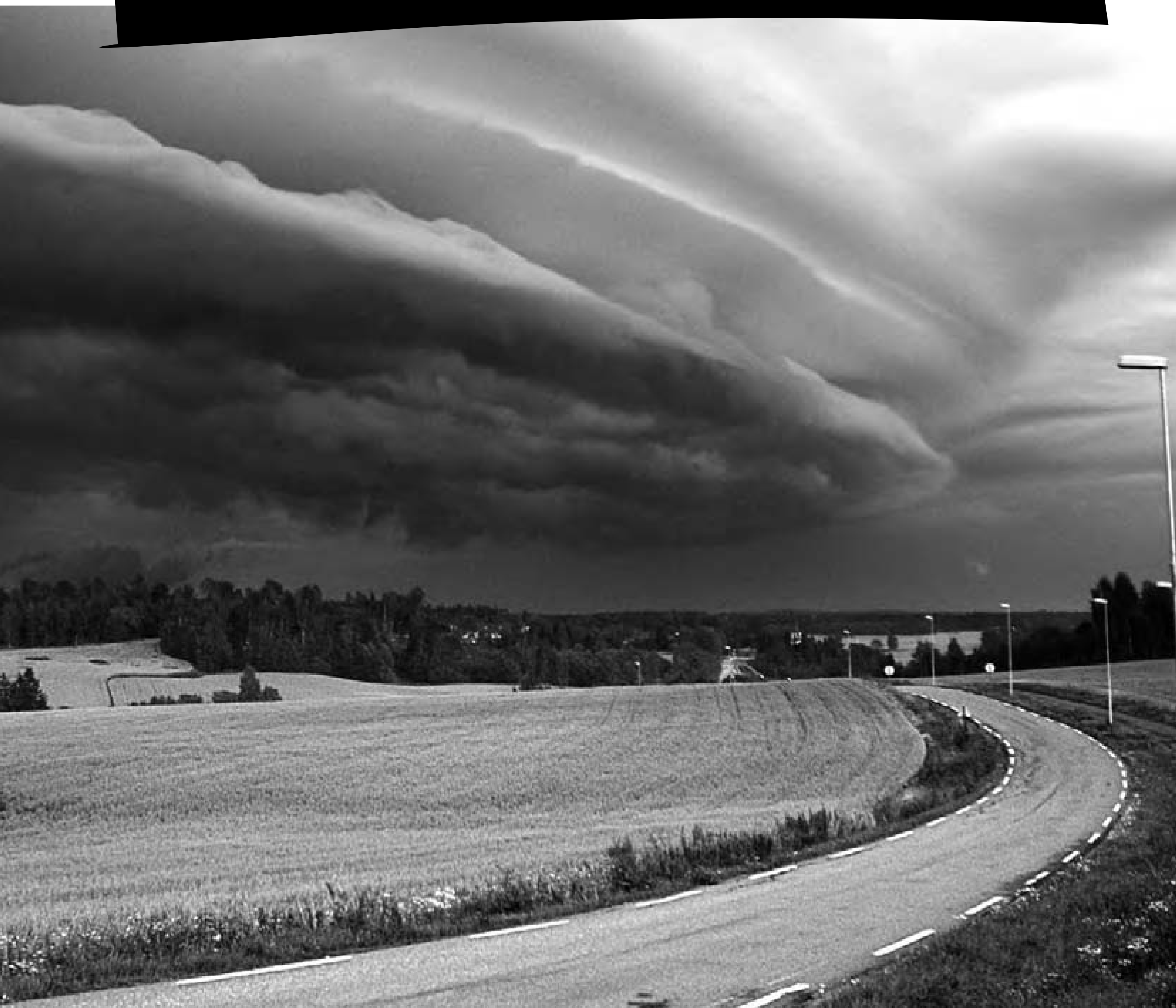
Bioforsk – Soil and environment is participating in "CLIMATE: Adapting to extreme weather in municipalities: what, how and why", a strategic research program (SIP), coordinated by CICERO. One of the objectives is to investigate the effects of extreme weather on soil and nutrient loss. The climate change scenario prediction for south eastern Norway indicates among others a wetter, milder winter. Soil and nutrient loss is mainly confined to the period from September – April as a result of rain and/or snowmelt. Winters differ with respect to temperature and amounts of snow. A winter can be characterized by means of a freezing index (FI), being the difference between the maximum and minimum on the yearly cumulative degree-days curve, its magnitude indicating the "severity" of the winter. The time difference between the dates, corresponding to the maximum and minimum value of the FI is the length of freezing period. Another characterization can be through the number of freeze/thaw cycles, a mild winter corresponding to a relative large number of freeze/thaw cycles and often with less snow, the opposite often being true for a severe winter. Consecutive freeze/thaw cycles lead to a reduction in the aggregate stability and shear strength, thereby enhancing soil and phosphorus loss. Also the release of dissolved phosphorus from plant material is enhanced by freezing/thawing. Bakken *et al*. (2004) showed that future winters probably will have less snow and a more pronounced soil frost development, this having a negative impact on the infiltration capacity. An analysis carried out on temperature data, collected by the Dept. of Mathematical Sciences and Technology (IMT/UMB), for the period 1943 – 2008 showed a large variation in the FI, with a significant decrease in recent years while at the same time a decrease in the length of the freezing period was observed. The number of freeze/thaw cycles showed a large variation in time. A negative relation between the FI and number of freeze/thaw cycles was obtained viz. a lower FI indicating more freeze/thaw cycles. Complying with the climate change scenario prediction for south-eastern Norway, i.e. milder winters (lower FI), this indicates an increase in the potential for soil and phosphorus loss from agricultural dominated catchments.

SESSION II

Current Trends of Agroclimatic Indices and Simulation Model Output



Regions with agricultural production vulnerable to climate variability and change

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Climate is a primary determinant of agricultural productivity. The impact of climate variability on agricultural production is important at local, regional, national, as well as global scales. Any modifications of weather due to the impact of climate variability directly affect crop production. Crop yields are affected by variations in climatic factors such as air temperature and precipitation and the frequency and severity of extreme events like droughts, floods, windstorms, and hail. Global climate change will impact all economic sectors to some degree, but agricultural production is perhaps the most sensitive and vulnerable as climate is the primary determinant of agricultural productivity.

World agriculture, whether in developing or developed countries, remains very dependent on climate resources. For example, agriculture in Europe only accounts for a small part of the GDP, and the vulnerability in the overall economy to changes that affect agriculture is therefore low. However, the local effects on society might be large. There is no doubt that the question of global and regional climate variability and change as well as related impacts on agriculture is a major and important environmental issue facing the world at the beginning of the 21st century. A survey of some case studies on regions with agricultural production vulnerable to recent and projected climate variability and change is analyzed within the report. An attention is given to several European regions but regions from the other continents are also considered.

Sustainable production zoning for agroclimatic classification using GIS and remote sensing

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Agriculture is a primary production sector which is highly dependent on environmental conditions. The agroclimatic potential of agricultural areas has to be assessed in order to achieve sustainable and efficient use of natural resources in combination with production maximization. Temperature and rainfall, in terms of quantity and spatiotemporal variability, are variables which determine the type of crops suitable to a given location. Rainfall parameter can also be interpreted as availability of sufficient water required for production of given crops. These variables, in combination with soil type and geomorphology also determine areas where high levels of production are appropriate, avoiding the threat of degrading the natural resources. In the current work, zones indicating water availability are combined with topographic features and soil types in order to identify areas for sustainable production. Firstly, Aridity Index (AI) and Vegetation Health Index (VHI) are used in order to define zones adequate for sustainable farming according to water limitations. As crop growth is affected by water supply, these zones are named Water Limited Growth Environment (WLGE) zones. AI represents climatic aridity and is expressed by the ratio between rainfall and potential evapotranspiration (Unesco, 1979). AI determines the adequacy of rainfall in satisfying the water needs of crops. VHI represents agricultural drought and is used to express the presence of moisture and thermal stresses, which affect crop growth and final yield. The two indices are computed on monthly time steps for twenty hydrological years, from October 1981 to September 2001. VHI is derived from NOAA/AVHRR data while in AI computations both satellite and conventional field data are used. Afterwards, WLGE zones are combined with soil maps and a Digital Elevation Model (DEM) of the area under investigation in order to define zones appropriate for sustainable production. The soil types were digitized according to fertility (appropriate or not for agricultural use) and desertification limitations. The study area is the aquatic district of Thessaly, located in Central Greece. The current application resulted in the definition of sustainable production zones by means of parallelepiped supervised classification using the two indices, the soil maps and the DEM. These zones can be in further use for agroclimatic classification.

On availability of the new climate models numerical experiments to reproduce historical climatic variations: Can the climate change scenarios applied in the 4th IPCC report be ranked by their accuracy?

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Any forecasting of agroclimatic assessment should be based on estimations of future regional climate changes caused by global warming. In the initial stage of Russian researches on possible global warming impact on agriculture the paleoanalogue scenarios usually were applied. About 20 years ago the well known Russian climatologist Mikhail Budyko recommended to use as such scenarios: the paleoclimatological territorial reconstructions the Holocene, Riis-Wuerm Interglacial, and Pliocene Optimums. Later with the fast development of climatic models, it became clear that it is very improbable to wait a further progress of paleoreconstructions; virtually for principal scientific difficulties and because of extremely high labour input to such work. Therefore this approach in the forecasting climatology, despite of its doubtless importance, has conceded a place to new one based on the climate change scenarios generated by GCMs.

Obviously, the model scenarios regularly developed are based on the climate models runs which differ from each other, sometimes rather considerably. Therefore it is quite natural that users of such scenarios try to find out, what model among others could be considered as the more reliable, and whether the impact estimates calculated using that model are most accurate among others estimates.

Unfortunately, on search in scientific literature the independent estimates have not appeared directly. For this purpose the authors of the paper have carried out and continue to carry out special research on the reliability of climatic models in reproducing historical variation in some climatic characteristics. Estimates of the accuracy of such reproductions by 22 climate models recommended in 4th IPCC Report from year 2007 have been obtained, and they are ranked according to their performance in some geographical regions. In this investigation the results of each model run have been tested by their accuracy in reproducing climate dynamics in the past historical periods in all climatic regions of the continents as defined by Koeppen.

By using the same methodology, the model estimates of future climate parameters were applied in time trends of all Koeppen regions of the world, and further analysed for ranking of performance. The designed rank-series characterizing the total of model scenarios inter-accuracies will be presented and discussed.

The materials given in this paper are from the investigations carried out within the frames of Project N° 06-05-64643-a supported by the Russian Fund of Basic Research.

Current trends of agroclimatic indices applied to grapevine and olive tree in central Italy

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The increase of greenhouse gases in the atmosphere is causing wide changes in atmospheric events with critical impacts on vegetations. Temperature increases will lead to several consequences: longer growing season but, at the same time, faster physiologic plant growth, and therefore smaller final production; greater risk of pathogenic attacks and greater request for irrigation water. About grapevine, the more delicate growth phases, such as the very early ones, will be even more and more vulnerable with climate changes. In particular, late frost risks will increase. A quality problem could arise, from the faster plant growth that will lead to lower grape quality. Besides, high maximum temperatures during summer months may cause an excessive fruit ripening, against fruit quality.

Olive trees are quite resistant to high summer temperature and drought, but the increase of extreme conditions can be responsible of physiological stresses, such as the reduction of photosynthetic efficiency. Others critical phases are wintering and late frost in relation with the anticipation of bud break. Moreover high temperature and dry condition in October can be critical for the optimum olive oil synthesis inside the fruits.

On such background, this study covers some aspects of the analysis of the impacts of climate variability and change on grapevine and olive oil responses, based on historical climate data and agroclimatic indices. On the more statistical point of view, a linear regression trend was fitted to each time series by using least square regression. Simple statistical trends, in fact, such as linear trends are useful for investigating changes in climatic patterns and the slope of regression provides pictures of changes that have occurred at any location over an extended period of time. In order to make the statistic analysis stronger, the Mann-Kendall non-parametric test was also applied to each time series to look for statistically significant trends. To detect variability patterns, the modification of inter annual variability was calculated for each index, using the moving deviation by decades; in its turn the values of moving standard deviation were submitted to linear regression analysis for evidence of trends. Finally, due to a slight cooling in Europe observed in the Mediterranean region during the seventies, trends of indices were also calculated for different sub periods.

Trend analysis of long series of agroclimatic parameters in Spain

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In this study, the results of a research aimed at the analysis of time trends of different agroclimatic parameters based on the data from a set of selected climatological stations over Spain are presented.

In particular, a study of the time trends of frosts days and minimum temperatures in a set of stations located in areas of economic interest in agriculture in Spain (fruit trees mainly) has been carried out as an application of climatology to the insurance sector. The study was mainly focussed on the frequency of cold spells that could cause damage in sensible crops. We wanted to answer the questions: Is there any trend in minimum temperatures in the sensible season for fruit trees? Are there changes in the dates of the last frost day in springtime?.

As the month of March is the crucial month for the cultivars of interest (flowering occurs mainly in this month in the areas of our study), the study of trends in time series of minimum temperatures was carried out for this month. A common period of 36 agricultural years (1970-71 to 2005-06) was applied using daily data for minimum temperatures in all the areas of interest. A simple test of trend detection was applied to all these series, and in every case a slightly positive trend was revealed. In some areas the minimum temperatures trend study was extended to the month of February, and surprisingly the positive tendency was less than that of Mars or inexistent.

Different statistical tests were also applied to the date of the last frost day in several of the areas under study, and in all cases there was a trend that such a date occurs earlier. Nevertheless, it is remarkable that there is no decrease in the total number of cold spells through the year, and so it is that the occurrence of frost days in Mars in the agricultural years of 2003-04 and 2004-05 in several areas (in Levante and Andalucia), which were free or almost free of frost in springtime (period from the first of March to May) in the previous ten or fifteen years.

The results of the trend analysis for other parameters like reference evapotranspiration ETo and a drought index (SPI) will also be shown.

Testing different CO_2 response algorithms against a FACE crop rotation experiment and application for climate change impact assessment on different sites in Germany

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To assess the impact of climate change on agricultural production agro-ecosystem models are widely used. Especially in regional studies the effect of elevated CO_2 on crop biomass and yield formation had not been considered in most cases, although several approaches were described in literature.

Different algorithms describing CO_2 response on crop growth and crop water use efficiency have been selected and intregrated in the soil-crop model HERMES. The approaches are different in complexity and parameter requirement. Their suitability to explain crop growth responses and soil water dynamics observed in a six year agricultural crop rotation (winter barley, sugar beet, winter wheat) under elevated atmospheric CO_2 level (FACE experiment; Weigel and Dämmgen, 2000) was tested to decide, which approach would be best applicable for regional climate change scenarios.

All algorithms were able to describe an observed increase in above-ground dry matter for all crops in the rotation with different amount of effort for calibration. Increasing water use efficiency with rising CO_2 was also reflected. A combination of a semi-empirical Michaelis-Menten approach describing a direct impact of CO_2 on photosynthesis and a Penman–Monteith approach with a simple stomata conduction model for evapotranspiration yielded the best simulation result expressed by model performance indicators. The results of the simulations will be shown in comparison to measured data from the 6 year FACE experiment.

Scenario simulations with and without CO_2 effect will be presented for different sites in Germany for the present and future situation of the A1B scenario using statistically downscaled climate change scenarios from the WETTREG model. Beside the productivity aspect, model results on groundwater recharge, nitrogen leaching and nitrogen use efficiency will be presented.

Designing of the new regression models of crop productivity year-to-year anomalies based on the AVHRR satellite vegetation monitoring information

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Development and modernization of crop productivity prediction techniques based on weather conditions is still the most urgent problem of modern agrometeorology. In spite of the fact that advanced mechanistic models of crop growth have been widely used in prediction of climate change impacts, the statistical models remain one of the basic instruments used for these purposes. When designing such models surface input weather information is commonly used. In some cases a combinations of meteorological parameters expressed as agrometeorological indices are used as predictors.

About 25 years ago the first satellite systems for surface vegetation monitoring were designed. The development of such systems has resulted in continuous series of satellite data for relatively long periods (more than 20 years) have become available. As a first approximation, such long series can be considered as sufficient for designing of statistical crop productivity models, but the use of satellite information in vegetation indices in agrometeorological prediction techniques has been questioned. So far many researchers have been devoted to the use of satellite information, but still the development of forecasting models remains rather urgent.

The poster presentation will discuss estimation of the efficiency of using satellite monitoring data on crops state dynamics for development of new statistical models, based on multivariate algorithms for selection of the best regressions formulae. Such an approach will be free from many a priori hypotheses, earlier limiting the selection of the statistically most real models.

The materials of this presentation are from the investigations carried out in the frames of Project N° 06-05-64643-a supported by the Russian Fund of Basic Research.

Session II: Posters

Satellite climatic and biophysical data for warning purposes for European agriculture

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In this paper, the contribution of space satellite-derived data for warning purposes in agriculture due to climate variability and change is discussed. Climate variability and change is a global issue, which must be addressed with global models and global data are needed as input to these models. Earth observation from space has a unique capacity to provide such global data sets continuously and consistently not only on this level, but also on the national and local levels and the use of alert and warning systems must be based on such data.

Some of the climate and biophysical variables essential for understanding and monitoring the climate system and the impact on agriculture can be efficiently observed from space since this technology enables their systematic, global and homogeneous measurement. Climate and agriculture research is generally based on data collected for other purposes, primarily for weather prediction. To make these data useful for climate impact and warning studies, it is usually necessary to analyze and process the basic observational raw data and integrate them into models.

In the frame of COST734, satellite data records, e.g. series of observations over time that measures variables believed to be associated with climate variation and change, were surveyed among European countries, based on a specific questionnaire. The analysis and the presentation in tables of the data records which have been developed from operational satellite observations, present the status of satellite climate and biophysical data for warning purposes for agriculture, in Europe. Among European countries there is a great inhomogenity concerning climate and biophysical data received from satellite sensors or collected as satellite-derived ready products. Some of them are currently collecting satellite data for years and these data records could be useful for models for climate change impact studies. The main variables that are collected in operational or experimental way are land surface temperature and NDVI. Some examples of satellite images, as referred in the questionnaire answers are also presented.

Climate indices for overwintering of forage grasses in Norway in relation to climate change

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Climate scenarios for Norway indicates an increase in air temperature especially during the winter and for some regions an increase in precipitation especially in autumn. Temperature and precipitation are important factors for hardening and overwintering of perennial crop plants. We used climate indices to assess potential impacts of climate change on the overwintering abilities of forage grasses. The indices were based on similar indices for Canadian conditions, developed further by using the SnowFrostIce model, which supplies daily values for snow depth, soil frost and surface ice cover. The indices reflect the risk of winter injuries related to cold intensity, duration of snow cover and ice encasement. Indices were calculated for three locations representing differences in climate: Sola (58° 53' N 5° 38' E, 7 m a.s.l.) on the SW coast, Løken (61° 7' N 9° 4' E, 525 m a.s.l.) in the SE inland, and Tromsø (69° 39' N 18° 55' E, 100 m a.s.l.) on the N coast.

The climate data were refinements of dynamically downscaled precipitation and temperature scenarios IPCC SRES A2 and B2 (both 2071-2100) and control period scenario (1961-1990) provided by the Hadley Centre (UK) (www.met.no). The indices were calculated for A2 and B2 scenarios and the control period. Compared with control period (CP), according to A2, the average winter (Dec-Feb) temperature will increase by 2.5, 3.0 and 3.2 °C at Sola, Løken, and Tromsø, respectively, whereas the precipitation as rain will increase by 72, 20, and 39 mm.

The calculated length of the growing season increased dramatically at all sites; 81, 39, and 66 days for Sola, Løken, and Tromsø, respectively, for the A2 scenario. All sites showed an increase in temperature sum (base 0 °C): 1126, 782, and 844 for Sola, Løken, and Tromsø respectively. At all sites, the length of the hardening period decreased, and the hardening period in Tromsø approached the current values at Sola.

Snow cover at Sola amounts to a few days each year in CP. However, at Tromsø the duration of snow cover was dramatically reduced (120 days); at Løken the reduction was 30 days. There was reduced risk of injuries due to frost at Løken and Tromsø, however, at Sola a slightly increased risk of frost after growth start in spring was predicted. The risk of ice encasement injuries was reduced at all sites. All in all, the indices indicate that overwintering will be at least as good in the future as today. The increases in length of growing season and temperature sum indicate that at least one extra grass harvest can be taken at all sites.

The SnowFrostIce model is currently being incorporated in a crop model to gain further insight of the hardening processes of forage grasses. We will recalculate the indices when more refined scenarios become available from the NorClim project.

Comparison between piecewise linear and flat steps statistical methods for the long period agroclimatological discontinuity analysis

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During the recent decades the perception to live an anomalous meteo-climatological phase, far different from the "climatic normal" has increased. The "climatic normal" actually is defined from WMO as the statistical analysis (average and extreme values) of the data recorded during the last 30 years. For this reason it is important to have a correct definition of "climatic change" and a specific analysis of the variables that describe it, such as temperature and precipitation. In fact the behaviour of past and future climate trends is frequently approximated using linear functions, while in the last years evidence has become more evident that climate evolution is characterized also by changes that occur abruptly.

In sufficiently long historical data sets, break-points identify and separate homogeneous climatic periods, that can be analyzed by linear trend analysis. However, it is not useful to apply a simple linear regression analysis to long periods with climatologically non homogenous data.

In this case study, meteorological variables from the period 1956-2004 have been used to compare a piecewise regression and a flat-step method to identify abrupt changes in climatic regime and better describe linear trends. The two methods have been used respectively to identify the starting moment of a new climatic trend, and the average values describing subsequent stationary climatic phases.

The application of these statistical methods to global circulation indices and phenological proxy data sets can be very useful to point out their correlation to the recorded meteorological variables. In this way a different and more intelligible expression of climatic trends may be possible, leading to a better comprehension of the complexity and variability of the climatic system.

Summarizing a questionnaire on agroclimatic trends in Europe.

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Some of the European systems and sectors have shown particular sensitivity to recent trends in temperature and precipitation. The major goal of this work is to summarize a questionnaire on trends in agroclimatic indices and crop model outputs in Europe. This questionnaire was developed and disseminated by Working Group 2 of the COST734 Action 'Impacts of Climate Change and Variability on European Agriculture – CLIVAGRI". The first part of the survey is related to the availability of long-term historical meteorological and agrometeorological data, its temporal and spatial resolution, area coverage, etc. The second part is dedicated on the various meteorological models applied in selected European countries – numerical weather models, global and regional climate models, weather generators. A special attention in this survey is paid to data homogenization tests, techniques and software. Finally, the answers based on the statistical methods for analyses of meteorological and simulation model outputs related to time series, for respective European countries, are listed and summarized.

Agro-ecosystems monitoring using spectral vegetation indices and agro-meteorological data in Romania

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Remote sensing techniques play an important role in crop identification, acreage and production estimation, disease and stress detection, soil and water resource characterization. Spectral indices of vegetation, based on satellite observations in the visible and near-infrared wavebands are widely employed as quantitative measures of the biomass or vegetative vigor.

This paper assess the suitability of vegetation indices derived from the TERRA-Moderate Resolution Imaging Spectroradiometer (MODIS) sensor and SPOT-VEGETATION (VGT) sensors for agro-ecosystems monitoring and hydrological/thermal stress impact assessment; these include vegetation classical indices (e.g. multi-year NDVI values) and complex indices (e.g. LAI, Modified soil advanced vegetation index – MSAVI, Vegetation crop index - VCI). The MODIS/ VEGETATION bases are able to provide consistent, spatial and temporal comparisons of global vegetation conditions that can be used to monitor the Earth's terrestrial photosynthetic vegetation activity for crops phenology, change detection, and biophysical derivation of radiative and structural vegetation parameters.

In the case of the Normalized Differenced Vegetation Index (NDVI) S10 data set (ten-day synthesis), derived from SPOT – VEGETATION, the primary satellite data processing comprises: the creation of the subset for Romanian territory and their conversion into a dedicated reading format; georeferencing of each image; checking the quality for vegetation indices by comparing an analysis with the agrometeorological and biophysical in situ crop parameters, in the test areas; creation of the yearly data series using "layer stacking"; exportation in GIS the environment; agricultural areas extraction using SPOT – land cover grid.

Time-series of MODIS 250 m Vegetation Index datasets hold considerable promise for large-area crop mapping in an agriculturally intensive region such as the Romanian Plain, given their global coverage, intermediate spatial resolution, high temporal resolution (16-day composite period), and a cost-free status. However, the specific spectral-temporal information contained in these data has to be thoroughly explored, and their applicability for large-area crop-related land use/land cover classification is relatively unknown.

The objective of this research is to investigate the specific applicability of the time-series MODIS 250 m Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI) datasets for crop-related land use/land cover classification in Romania. A combination of graphical and statistical analyses were performed on a 12-month time-series of MODIS EVI and NDVI data from several cropped field sites across agricultural area from Romania. Both VEGETATION and MODIS derived vegetation indices datasets were found to have sufficient spatial, spectral, and temporal resolutions to detect unique multi-temporal signatures for each of the region's major crop types (corn, soybeans, and winter wheat). Each crop's multi-temporal vegetation indices signature were consistent with its general phenological characteristics and most crop classes were spectrally separable at some point during the growing season. The multi-temporal EVI and NDVI data tracked similar seasonal responses for all crops and were highly correlated across the growing season.

Example are also presented from of the crop vegetation state monitoring, using remote sensing and agro-meteorological during the agricultural year 2006-2007, considered extremely droughty because the intensity, duration and development.

Maize crop vegetation state evaluation using radiative transfer models in Romania

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The monitoring of agricultural crops performances and accurate prediction of crop yields require high quality information on the state of the vegetation. Relevant information may be retrieved through remote measurements, using satellite sensors in the solar reflective spectrum. The main task is to estimate the vegetation parameters using physical models based on the description of radiance transfer in the canopy. These models provide the relationship between the radiation incoming from the sun and the – according to the bidirectional reflectance distribution function (BRDF) – directionally scattered radiation at the location of the observer given some structural and spectral properties of the vegetation/ soil medium.

The paper presents the connections between the biophysical parameters of a crop vegetation canopy (e.g. maize), the reflected radiation flux in different spectral channels and the geometrical and radiometrical factors that characterize the interaction processes in the atmosphere-vegetation-soil system. The derived radiative product outputs from modeling like: spectral signature characteristics, LAI, FPAR, moisture or thermal stress indices are useful for the vegetation state monitoring of the agricultural crops.

In order to estimate the maize crop parameters from multi-spectral optical satellite data, the SAIL+PROSPECT coupled model, based on radiative transfer theory has been used. The model input data are obtained from ground measurements, satellite images and simulated data (gathered in different natural conditions).

The ground measurements consist of: photograph series with a 300d Canon DSLR camera with 15 mm fish-eye lens; biochemical parameters (chlorophyll concentration, leaf water content, dry matter content and brown pigment content) and agro-meteorological parameters (soil moisture, soil temperature, precipitation amount). The processing of photos was made using the CAN-EYE software (INRA, Avignon). The technique to derive the canopy architecture variables (leaf area index (LAI), average leaf inclination (ALA), clumping factor, average gap fraction, etc.) is based on a look-up-table (LUT) technique.

The SAIL model calculates the directional reflectance on top of the canopy as a function of structural and spectral properties of the vegetation canopy. The vegetation canopy is considered as a homogeneous layer characterized by leaf area index (LAI), leaf angle distribution (LAD), as well as radiance and transmittance of the leaves. The azimuth angles of the leaves are assumed to be randomly distributed while their zenith angles obey the LAD. Other input parameters of the SAIL model are soil reflectance, diffuse part of the incoming radiation, azimuth angle of the observer with respect to the azimuth angle of the sun, zenith angle of the observer, and zenith angle of the sun.

The PROSPECT model provides reflectance and transmittance of fresh leaves over the whole solar domain or leaf physiological and structural data (content of chlorophyll a and b, the specific water content, the specific dry matter a structure parameter). The reflectance and transmittance of leaves calculated with the PROSPECT model are used as input parameters for the SAIL model.

The model was tested on several test-sites for the maize crop non-irrigated. The model results proved to be very useful in correlation with satellite derived products to estimate the crop vegetation state and to identify the areas exposed to some risk diseases (e.g. aflatoxine risk contamination of maize crops, during droughty years with high-temperature coupled with deficit water-stress).

The methodology presented in this paper can serve as a basis for validating medium and high resolution satellite products.

Crop growth under future atmospheric CO_2 concentrations: results from the German Free Air Carbon Dioxide (FACE) experiment

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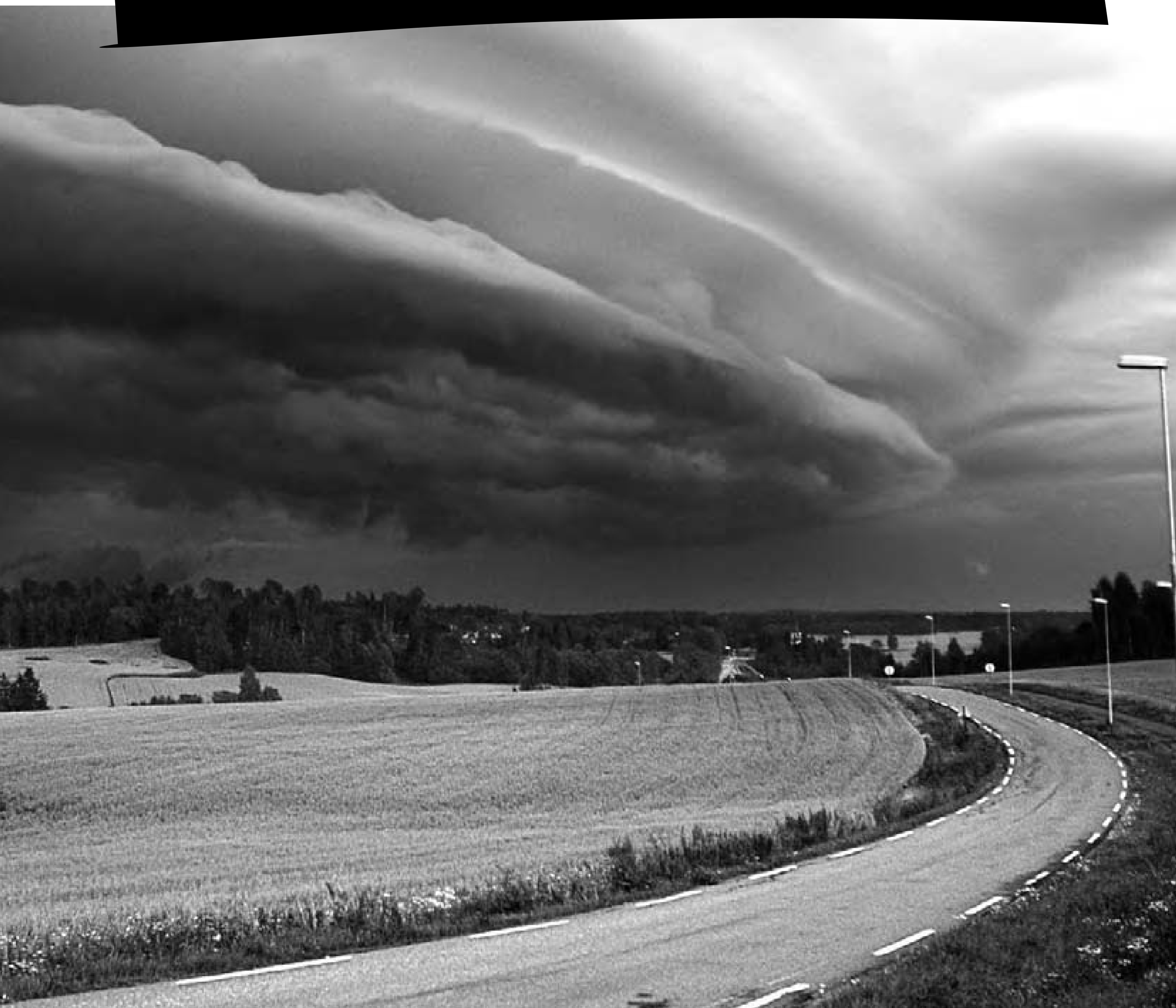
Along with overall climate change effects the increasing concentration of atmospheric CO_2 ([CO_2]e) will have significant direct impacts on agricultural crops and agroecosystems. For example, [CO_2]e is known to stimulate photosynthesis and to reduce leaf transpiration and significant interactive effects of [CO_2]e with elevated temperatures and drought have been observed. Thus, a proper assessment of the direct effects of [CO_2]e ("CO_2 fertilization") on crop growth is crucial for any assessment of potential effects of future climate change on food and fibre production.

Current information on how arable crops in Europe might respond to [CO_2]e is mainly based on studies performed with isolated plants under optimized growth conditions, i.e. under conditions which may result in misinterpretations of the size of the CO_2 fertilization effect. A large-scale Free Air CO_2 Enrichment (FACE) experiment (550 ppm CO_2) was therefore carried out from 1999 to 2005 in an arable C3-crop rotation (winter barley , sugar beet , winter wheat) at Braunschweig, Germany under conditions of local farm practice. The objectives were to assess effects of [CO_2]e on crop performance and on related agro-ecosystem properties. The presentation will briefly describe the objectives of the FACE experiment and report the overall key findings related to [CO_2]e effects on canopy CO_2 and H_2O fluxes, leaf area index, biomass and yield after 6 years of experimentation.

SESSION III

Developing and Assessing Future Regional and Local Scenarios of Agroclimatic Conditions



Analysis of European drought risk under current and future climatic conditions based on regional climate scenarios

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Drought is undoubtedly one of the major threats to agricultural production, and the possibility to develop projections of drought occurrence at the regional and continental scale is a necessary step toward the definition of suitable adaptation strategies for the agricultural sector. In deriving drought projections from regional climate scenarios, the capability of climate models to reproduce the key feature of the hydrological regime should be examined. In addition, from a risk analysis standpoint there is a pressing need to quantify uncertainties in the projections and provide probabilistic assessments of the impacts of climate change.

In this contribution I examine European drought risk under current and future climatic conditions based on regional climate scenarios issued from the PRUDENCE archive. I adopt a general methodology but the investigation is restricted to the Alpine region. I first consider the models' performance in reproducing daily precipitation statistics and discuss the implication of model biases for the assessment of drought conditions under present climatic conditions. I then discuss uncertainties in the projections of temperature and precipitation for the ensemble of PRUDENCE scenarios and apply these results to obtain a probabilistic assessment of drought occurrence.

Climate change mitigation, adaptation and sustainability in agriculture

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Sustainability conveys the idea of a balance between human needs and environmental concerns. A common theme amongst definitions of sustainability is that sustainable agricultural systems remain productive over time. They should provide for the needs of current, as well as future generations, while conserving natural resources. The enhancement of environmental quality and careful use of the resource on which agriculture depends is viewed as a requisite for sustained agricultural productivity. The notion that sustainable agricultural systems maintain output in spite of major disturbances, e.g. such as those caused by projected climate change, is relevant to vulnerable areas especially in the semi-arid and sub-humid regions of developing countries.

According to the Fourth Assessment Report of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) released in 2007, semi-arid regions of Asia, Africa and Latin America are likely to warm during this century and freshwater availability is projected to decrease. Agricultural productivity in tropical Asia is sensitive not only to temperature increases, but also to changes in the nature and characteristics of monsoon. In the semi-arid tropics of Africa, which are already having difficulty coping with environmental stress, climate change resulting in increased frequencies of drought poses the greatest risk to agriculture. In Latin America, agriculture and water resources are most affected through the impact of extreme temperatures and changes in rainfall.

Climate change mitigation strategies which include interventions to reduce the sources or enhance the sinks of greenhouse gases have a marked management component aiming at conservation of natural resources such as improved fertilizer use, improved ruminant digestion, use of water harvesting and conservation techniques. These strategies are equally consistent with the concept of sustainability. Adaptation strategies include initiatives and measures to reduce the vulnerability of agroecosystems to projected climate change, such as changing varieties, altering the timing or location of cropping activities, improving the effectiveness of pest, disease and weed management practices, making better use of seasonal climate forecasts etc. It is essential to develop and integrate Agriculture Mitigation and Adaptation Frameworks for Climate Change into sustainable development planning at the national and regional levels to cope with the projected impacts of climate change.

Some perspectives on agricultural GHG mitigation and adaptation strategies with respect to the impact of climate change/ variability in vulnerable areas

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It is recognized that agricultural activities have an effect on net greenhouse gas emissions (GHG) and soil carbon dynamics which influence climate change and variability. Worldwide agriculture is responsible for about 13 percent of the total anthropogenic emissions. The scientific community has placed considerable effort on developing ways to mitigate this effect through improvements in agricultural management practices. Improved practices such as greater N use efficiency, implementation of less intensive tillage, change in crop rotation, improved feed quality for better digestibility, improved manure management, better water management of rice paddies and biofuel/bioheat production are commonly employed as a means to mitigate GHG emissions and enhance soil sustainability. It is controversial whether or not some strategies (ie. biofuel production) will help mitigate GHG emissions and their potential must be analyzed on a regional basis. Inversely, climate change can have a wide range of effects on agricultural systems and we must adapt to these changes to ensure that agricultural production is not only maintained but is increased to support a growing world population. Adaptation strategies may range from a change in crop cultivars to accommodate drought or shifts in temperature to extreme measures such as a total change in land use away from agriculture production. In some areas shifts in crop zones are expected whereby cool season crops may be replaced by warm season crops and new cropping zones may open up for production. All of these adaptation scenarios will influence GHG emissions. Production of bioenergy crops, particularly lignocellulosic crops and bioheat crops can in some cases provide a means to both mitigate net CO_2 emissions and adapt to a changing climate and world energy needs. In this paper we explore mitigation and adaptation strategies that could help deal with a changing climate in areas of the world that are most impacted by climate change. Pertinent research from various sources is reviewed and examples are provided using IPCC climate change scenarios to demonstrate the effect that mitigation and adaptation strategies may have on GHG emissions.

Developing an adaptation strategy for sustainable agriculture

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Agriculture is one of the most important economic sectors of society. Agricultural production continues to expand into forest and virgin lands as well as marginal crop areas, with food supplies attempting to keep pace with the ever-increasing world population. Environmental damage is increasing, including erosion, salinity, desertification, deforestation, threats to biodiversity, and water scarcity. Simultaneously, climate change/variability is having a profound influence on agroecosystems, posing serious threats to food security, human health, and protection of the environment. Thus, comprehensive agrometeorological adaptation policy guidelines, focusing on preparedness, mitigation and adaptation measures to support sustainable agricultural development, are needed to cope with the impacts of climate change/variability.

The adaptation strategy refers to a general plan of action for addressing the impacts of climate change and climate variability, including extremes. The key to developing adaptation policy and measures is to recognize the existing vulnerability to climate change/variability. The adaptation strategy requires a combination of coordinated policies and measures with the primary objective of reducing the overall vulnerability. Policies refer to the primary objectives, together with the means of implementation, as with the goal to strengthen food security, for example. Measures are focused actions aimed at specific issues. They can be individual interventions or packages of related measures. Each of these measures may contribute to the local, regional and national goal of food security.

Improving the capability of communities, governments or regions to deal with climate vulnerabilities will improve their ability to deal with future climate change. Adaptation policy can not be an effective “stand alone” strategy, but should be incorporated into a broader policy objective. For example, adaptation to climate change should be a part of a broader socio-economic policy such as agricultural, forest, water resources, natural resources or coastal-zone management policy.

The adaptation strategy must focus on information, capacity-building, financial resources, institutions, and technology. These priorities will be discussed in detail. Important priorities include: strengthening capacities in the technical and planning disciplines most relevant to understanding potential climate impacts as well as devising response strategies; financial resources which are of utmost importance to guide action plans from the drawing boards to local implementation; and, poorer countries that will require resources to improve capacity, undertake specific adaptation measures, and cope with impacts as they occur.

Discussing the concepts of 'sustainability', 'sustainable agriculture' and 'allodial farm'

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Some ideas connected to the scope of scientific work in agronomy and agro meteorology and the scope of the scientific principle are outlined. Then the concepts of 'sustainability' and 'sustainable agriculture' are presented, and the content of different definitions of these concepts is discussed. Especially the idea of sustainability as conservation of important relations is discussed.

Then the concept and principle of an allodial farm or free farm, connected to Norwegian law and Norwegian traditions is presented and the history of the present law is briefly outlined. Also traditions for passage of farms from one generation to the next generation in a few other European countries are mentioned.

Then the concept of allodial farm is connected to the challenges of global change of Northern Europe, and the existing ideas of commercial agriculture.

The following idea is discussed: 'The idea of changing the focus in agricultural production from maximizing the crop yield to keeping the ecological system of the farming and the local area sound and in shape'. Man is an organism like other organisms. He ought to take care of his surroundings and the other species, to take care of a totality of biological systems on the Earth. Probably no god or gods will take care of him if he does not succeed in doing this. The content of the concepts of adaptation and mitigation connected to global change is also finally mentioned.

Climate change effects in perennial weeds at high latitudes

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The aim of this study was to reveal whether a projected climate change can affect autumn growth of the perennial weeds *Elytrigia repens, Cirsium arvense* and *Sonchus arvensis* at high latitudes. In September and October 2004 and 2005 plants were placed in six environments (manipulated field climate conditions) which consisted of elevated CO_2 (550 ppm) and an increase in temperature of 2-2.5 °C in open top chambers (OTCs), or an increase in both factors, a control in the OTCs and outdoor controls with and without shading (30%) at Særheim (58°47'N, 5°41'E). The plants in 2004 were older (planted 26 May 2004) than the plants in 2005 (planted 30 June and 1 August 2005).

Every fortnight during the experimental period growth characteristics were assessed. Preliminary results indicated that, in spite of a large variability in the plants, characteristics related to leaf growth were most influenced by one or more of the altered climatic factors. In *E. repens*, for instance, leaf area increased with rise in temperature, CO_2 (only 2004) and with shading. The leaf area of *C. arvense* increased with increasing temperature and shading (the latter only in 2004). *S. arvensis* withered down in early autumn, but this withering was delayed in young plants, and especially with the combination increased temperature and CO_2 in 2005. Plant biomass (above ground and below ground dry weight (DW)) was less influenced by environment, but in 2005 we found e.g. an effect of CO_2 on below ground DW of *E. repens.* The ratio between below vs. above ground DW (called root:shoot ratio) increased during autumn in all species in both years and was not influenced by environment in 2004, but in 2005 there was an interaction with planting time and environment of *E. repens* and *S. arvensis*. It was a tendency that the youngest plants of *S. arvensis* and *C. arvense* at elevated CO_2 concentration and the lowest temperature had the highest root:shoot ratio.

In this study *E. repens* grew later in autumn, and is thus easier to control, than *C. arvense*. A global warming, resulting in increased and prolonged autumn growth, can make also *C. arvense* easier to control in autumn, but possibly also result in larger weeds the next growing season. *S. arvensis* is difficult to control chemically or mechanically in autumn due to early withering and dormancy in the propagating roots. The large variability in the plant material in this study makes the results realistic when relating to field conditions.

New sources of high resolution climate change scenarios for impact studies in agriculture

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Global Circulation Models (GCMs) can reproduce climate features on large scales, but their accuracy decreases when proceeding from continental to regional and local scales because of the lack of resolution. This is especially true for surface fields, such as precipitation, surface air temperature and their extremes, which are critically affected by topography and land use. However, in many applications, particularly related to the assessment of climate-change impacts, the information on surface climate change at regional to local scale is fundamental. To bridge the gap between the climate information provided by GCMs and that needed in impact studies, several approaches have been developed. A few of recent and ongoing projects are based on the principles of so-called dynamical downscaling, i.e., nesting of a fine scale limited area model (or Regional Climate Model, RCM) within the GCM. This approach is more correct from a physical point of view, but much more demanding on computer resources, than another quite popular approach of statistical downscaling, i.e., identification of statistical relationships between large-scale fields and local surface climate elements.

In the regions with complex terrain features (as e.g. in Central and Eastern Europe, but other regions as Scandinavia as well) the need for high resolution studies is particularly important. A resolution sufficient to capture the effects of these topographical and associated land-use features is necessary. Simulations for FP6 Integrated Project ENSEMBLES with resolution 50 and 25 km for whole Europe will be shown based on reanalysis runs. For specific regions like Central and Eastern Europe, especially with emphasis to agriculture impacts, even higher resolution is of great importance to capture necessary details in this region characterized by the northern flanks of the Alps, the long arc of the Carpathians, and smaller mountain chains and highlands in the Czech Republic, Slovakia, Romania and Bulgaria that significantly affect the local climate conditions. That is why 10 km resolution has been introduced in new projects CECILIA and CLAVIER being solved based on the 4th call of EC FP6.

For climate change scenarios the transient runs covering whole period of 1950-2050 (2100) from the couples of 14 RCMs and 6 GCMs (just selected combinations) in 25 km resolution for whole Europe will be available from ENSEMBLES Project, moreover, with probabilistic information considering individual couples as ensemble members. The weights for this procedure will be based on individual RCMs and GCMs assessment using reanalysis and control runs results, respectively. With respect to resources necessary for this simulation, only GHG scenario A1B experiment will be performed to get these high resolution climate change simulations. Based on selected runs from ENSEMBLES experiment, regional climate modelling studies in targeted areas of Central and Eastern Europe at a resolution of 10 km are run in CECILIA Project to assess the local impacts of A1B scenario in time slices for mid of century (2021-2050) and end of the century (2071-2100). Similarly, the CLAVIER Project covers the targeted region of Eastern Europe up to resolution of 10 km, in some cases using A2 and B1 scenarios as well, either in time slices or transient runs.

AgriCLIM – software package for assessment changes in agroclimatic conditions – results and planned use in COST734

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There has been a number of studies investigating the relationships between meteorological variables and crop yields (or other parameters e.g. quality) using field experiments, regional statistical data or crop models of various complexity. However as most of the studies have focused on the crop development and productivity, they have paid only limited attention to changes in the frequency of potentially damaging events and agroclimatic conditions in general. The main aim of this presentation is to introduce a software package AgriCLIM developed for efficient comparison of changes in agroclimatic conditions between regions and different scenarios of future development. In order to highlight the software possibilities, both for the COST Action 734 community as well as other users, three case studies have been carried out.

The authors investigated the effect of climate change on the selected agrometeorological characteristics with a pronounced influence on the overall site suitability for crop production including: (i) length of growing season and interannual variability of this parameter; (ii) probability of occurrence of late/early frosts; (iii) number days suitable for sowing during spring/autumn sowing windows; (iv) number of days suitable for harvesting during harvest period; (v) snow cover presence/absence during days with Tmin < -5 °C and -15 °C; (vi) number of days during anthesis with daily maximum temperature over 32 and 35 °C and (vii) changes in the soil water balance during key parts of the growing season.

The study area included key agricultural regions in Northeastern Austria (22 weather stations) and Denmark (10 stations) as well as whole Czech Republic (111 weather stations) providing large variability of climate conditions. The database included daily records of maximum and minimum air temperature, precipitation, solar radiation, air humidity and mean daily wind-speed that underwent thorough quality control and homogenization prior to its use using the AnClim software package. Based on the 1961-2000 observations 99 years long synthetic weather series were prepared by the stochastic weather generator M&Rfi both for the present and future climate. In order to highlight the uncertainty in the future characteristics of agroclimate a wide range of GCMs and two emission scenarios were used.

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Current capabilities in the analysis of climate risks and adaptation strategies in critical areas

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Risk is generally considered to be a product of consequences and likelihood - what can happen, and what are the odds of it happening. Both of these factors are important in determining whether and how we address specific risks. Uncertainty is a critical factor in assessing both climate risks and the effectiveness of different policy strategies. Each climate risk is identified by its own natural characteristics, including geographical area, time of the year it is most likely to occur and its severity.

A number of tools and methods are employed for analyzing those risks. These include agro-climatic indices, statistical and econometric analysis and mathematical models. In addition there are community based participatory tools such as climate risk maps, community history, focus group meetings and historical transect, matrix rankings, seasonal calendars and vulnerability indices etc. This study delineate on these tools and their capabilities to assess the risks in the critical areas of crop production. A huge amount of climatic, land use and agricultural data are required in employing these methods. A major problem of the present tools is that methods and tools have widely varying spatial scales. Climate information needs to be scaled down to the local level, and participatory risk information needs to be scaled up to higher levels of aggregation.

Present study reports on whether prevailing methods and tools for risk analysis and risk reduction planning can be put to use for climate change adaptation, how climate risks can be identified and managed through adaptation options and do current methods and tools for disaster risk reduction require adjustments in the light of climate change? Local adaptation practices and those practices introduced by national development, research and extension organizations need to be collected from the respective organizations and evaluated at different levels. Different agronomic, water and policy management adaptation strategies will also be discussed.

The impact of climate change on the water balance of Belgian crops

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The yearly water balance in Belgium amounts to an average surplus of 238 mm (1972-2001), with a shortage from end of May to October and a surplus from October to March. During most years the summer shortage is compensated for with the soil moisture reserve in the soil. The predictions of climate change in Belgium are, apart from a rise in temperature, an increase in winter precipitation and a decrease in summer precipitation. This further shift in rainfall patterns is likely to effect the water balance of different crops.

The impact of climate change on moisture availability is closely related to the effect that an increased CO_2 concentration has on photosynthesis and transpiration. Although the resulting effect on water use efficiency is considerable it is often neglected for reasons of uncertainty related to rainfall predictions. In this study the changes in water use efficiency are incorporated when simulating the water balance and biomass.

The water balance was simulated using a daily dynamic biomass model accounting for improved water use efficiencies and growth reduction by drougth stress. Crop water parameters were taken from the FAO method for crop water modelling. Based on multi-criteria analysis (e.g. goodness of fit in hindcasting) of all ensembles of European RCM predictions carried out in the framework of the PRUDENCE project, a low, a medium, and a high time series valid for Belgium (Ukkel) were identified as inputs to the model. Biomass fractions (in terms of yield loss in case of water stress), water balance deficit and surplus (drainage, run-off) were simulated for eight different crops (winter wheat, fodder maize, grain maize, sugarbeet, potatoes, spring cauliflower, autumn cauliflower, grass) on three different soils (loamy sand, loam, polder clay) and for both historical and three climate change time series of weather variables.

The results demonstrate that the effects of climate change for Belgium result in water deficits and subsequent yield losses up to 24% particularly for summer crops with a shallow rooting depth (sugarbeet, potato) with the highest stress for the high climate change time series and the lowest deficits or no stress for the historical time series. For winter wheat the results for the water balance during the winter demonstrate a surplus increasing from the historical climate data to the high climate change scenario. However, drought stress during the ripening stage in the summer may still cause a yield loss of up to 0.6% in a high climate change scenario.

New assessment of potential productivity for maize vegetation with respect to projected climate changes in Hungary

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A new procedure is introduced to estimate the potential crop yield, which considers accumulated climate anomalies of four climate characteristics and a set of soil characteristics. The climate variables are: precipitation, temperature, sunshine duration and the so-called xero-thermal index, derived in various periods of the year. The climate characteristics are combined in a strongly non-linear and multi-variable manner to estimate the so-called climate multiplier. Constant soil estimators multiplied by the climate multiplier derive the ecological point estimators which, in turn, are scaled to provide the potential plant production. The actual production can only approach this potential value from below, as a result of nutrient input and other aspects of agricultural technology.

The authors verified their assessment procedure for actual maize production in the 19 administrative counties of Hungary, using 31 year time series (1976-2006). The value of the procedure is confirmed by the 0.64-0.85 correlation coefficient (0.75, on average) and by the plausible value (0.5-0.7) of the actual vs. potential production ratio, with small inter-annual variations. The quantitative relationships are later used to estimate how the expected potential changes of the local climate can modify maize production in Hungary. PRUDENCE Project model runs are used for regional scenarios, scaled to the years 2030 and 2055. The result is a considerable decrease of the potential maize production. In case of the most unfavorable scenario, the difference reaches several tens of percent during the longest time span, which is half a century. Besides this climate change application, other computations regarding spatial characterization of the ecological potential, and to evaluate yield expectations of the ongoing vegetation period are briefly demonstrated, too. The presented estimation procedure is also elaborated for some other major crops of Hungary.

Effect of climate change on growth potential in the mountainous region of Southeast Norway

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As the temperature climate ameliorates, cultivation will be possible at higher altitudes than today, thus opening considerable areas in Southeast Norway for increased food production. We have explored the potentials and possible problems by extending fodder production to higher altitudes in a future climate. Our empiric basis are results from series of field experiments with fodder crops in the mountainous region of Southeast Norway, contemporary weather records, and soil characteristics. These data were processed through the COUP – ENGNOR crop modelling system, where the COUP model calculates soil moisture and crop water budget based on daily values for global radiation, temperature, precipitation, relative air humidity, and wind speed. These data were used as input variables for simulations of plant production by the ENGNOR model. Observed yields at different altitudes were used to model calibration for the actual area. Extrapolations into future climates were based on regionally downscaled climate scenarios.

The mineral soil in the area is largely loamy sand of morainic origin. The annual normal air temperature in the region is about 0 °C, and the annual precipitation ranges between 400-600 mm. The growth start with the present climate is on average around the middle of June, and the season lasts until the middle of September, about 80-100 days. The snow cover lasts on average 5-7 month in the region, and around half of the year has a mean air temperature below 0°C. The downscaled Hadley A2 scenario indicates only minor changes in the precipitation, whereas the air temperature will increase by 2-3 °C, implying a lengthening of the growth season by approximately 1½ months.

The improvement of the seasonal temperature climate expected has a considerable positive effect on future plant production potential, even though the occurrence of growth reducing drought periods will be somewhat more frequent. These estimated favourable effects were assessed against a prospectively impaired winter survival of the most productive perennial fodder crops. The main problems identified were warm spells and risks of ice sheet formation on the grass fields during winter, the extent of which can be predicted by the COUP model.

Some questions connected to global scenarios of climate change

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Climate change scenarios provide alternative plausible future climate for the planet, each being an example of what might happen under a particular set of assumptions. Scenarios are not specific predictions or forecasts. Scenarios provide starting points for examining questions about the uncertain future climate.

Some of the main processes connected to exchange of energy of the atmosphere of the planet usually are connected to radiation of short wave and long wave electromagnetic radiation. The global albedo of the short wave radiation is one important parameter, and the processes connected of the greenhouse gases water vapour and carbon dioxide in the atmosphere are extremely important elements of future scenarios.

The total amount of output of fossil carbon into the atmosphere is of importance as well as the natural cycle of the carbon. Also there exist several important positive feedback systems. The amount of water vapor in the atmosphere is connected to the temperature of the air, or to be more specific the saturation vapour pressure of the water in the air is increasingly dependent on the temperature of the air. Usually a warm atmosphere then will contain more water vapour than a cold atmosphere, and this will make the atmosphere even warmer because water vapour is the most important greenhouse gas connected to long wave radiation.

The ice cover of the Arctic and Antarctic regions as well as the glaciers in the high mountainous areas on the Earth are important for keeping the albedo of the short wave radiation of globe high. When the glaciers and the ice cover are melting, the albedo is decreasing and the consequence seems to be even more melting of ice.

The ultimate worst case scenario seems to be that the ice cover and the glaciers of the planet melt down and the oceans receive all this water.

The present situation seems to be like this:

- The total energy of short wave radiation, received by the planet: 100 units
- Planetary albedo: 30%
- Total energy connected to the water cycle. 21 units
- Amount of yearly precipitation totally: 1000mm
- Average residence time of a water molecule in the atmosphere: 10 days
- Total volume of ice on the planet: 33 x 106 km^3 (~ 60 m of sea level equivalent)
- Total amount of CO_2 in the atmosphere: 385 ppm

In order to understand the content and the challenge of the different scenarios I would like to know the value of the following parameters (every 5th year) of the scenarios:

- Albedo
- Total energy connected to the water cycle
- Amount of yearly precipitation totally
- Average residence time of a water molecule in the atmosphere
- Total mass of ice on the planet
- Total amount of CO_2 in the atmosphere

Expected effects of regional climate change on the soil moisture regimes in central europe and central US

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Soils exert an important control mechanism on water fluxes in the landscape and in many parts of the world soils act as the most important water reservoir mitigating the effects of rainfall variability. Soil moisture and temperature regimes are inherently more stable and quantifiable than their atmospheric counterparts and are essential in determining the environmental conditions of any region. In order to easily estimate the soil moisture and temperature regime at a given site, or within a selected region, a software SoilClim was developed, tested, and applied in two markedly different regions of the Northern Hemisphere. The tool was tested using daily values of soil moisture, soil temperature, reference (ETr) and actual evapotranspiration (Eta) estimated by the model from routinely observed atmospheric variables. These were compared with observations across multiple sites in Austria, the Czech Republic, and Nebraska.

After the successful evaluation, SoilClim was run both in Central Europe and in Nebraska with the climatic data corresponding to the conditions expected under future climates taking into account two Global Circulation Models (ECHAM and HadCM) and assuming the B1 and A2-SRES emission scenarios with low and high climate sensitivity for time slices of 2025, 2050 and 2100. It was found that under the present climate only a fraction of the territory of Central Europe is situated within the dry tempudic soil moisture regime, with high drought risk being confined to a small area. However, under a changing climate, a notable increase of the areas with a high probability of dry events was noted as well as sharp reduction of perudic (very-wet) mountainous areas that are essential for sustainable river flow. We found an especially alarming rate of these shifts in the soil climate characteristics taking place within decades rather than centuries. In the case of Central US (High Plains region) the eastward expansion of drier soil moisture regimes up to several hundred kilometers is to be expected. The predicted changes in the soil climate regimes are closely related to drought impacts (e.g. decrease of crop yields, damage to forest stands, low stream flow and reservoir levels, etc.) or changes in the dynamics of key soil processes (e.g. rate of carbon sequestration or mineralization) and should be a part of a complex climate change impact assessment.

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Sustainable strategies for spring barley production

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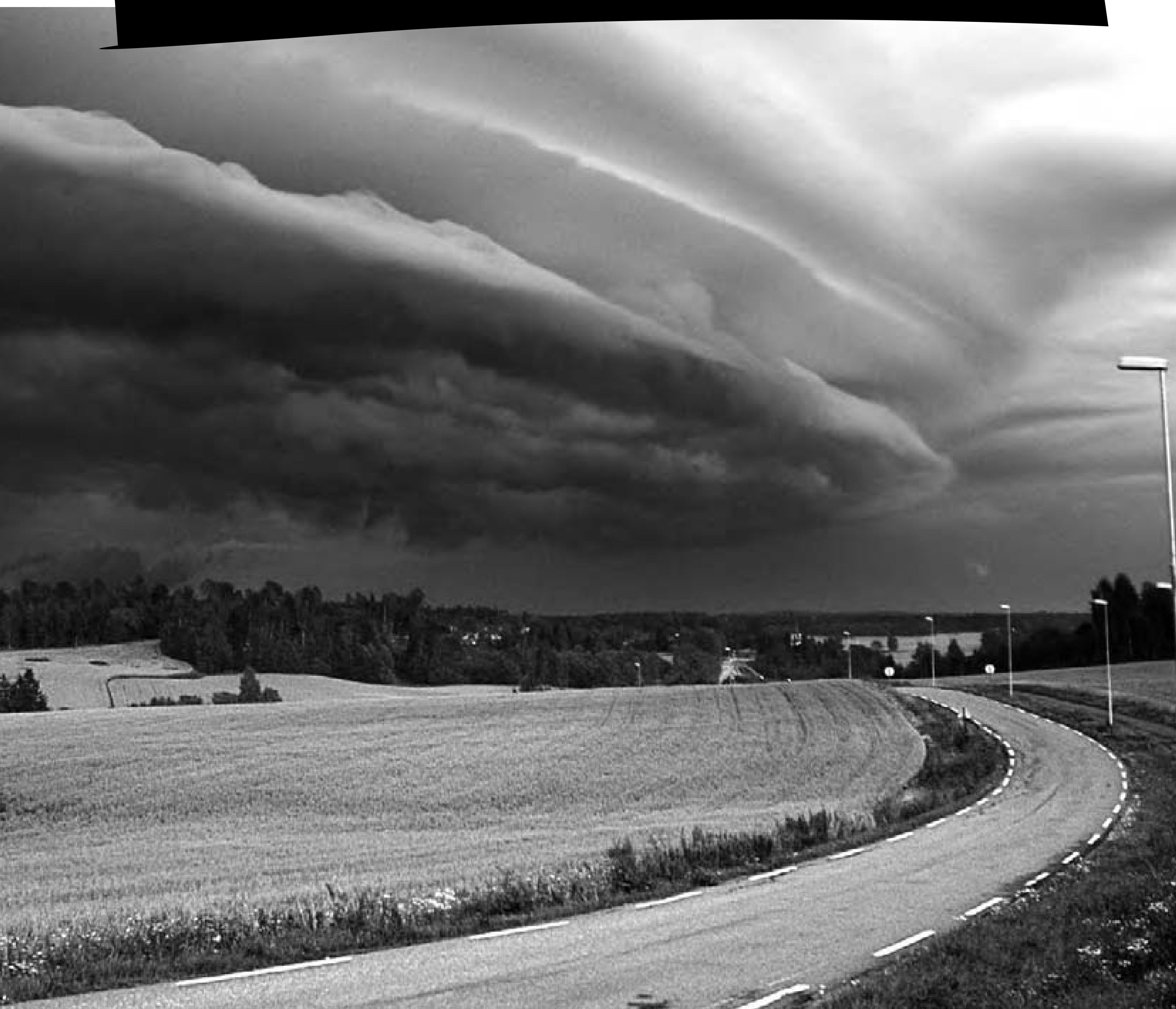
Crop growth models are efficient tools to assess the farm economic, socioeconomic and environmental effects of new technologies, regulations and future climate changes. In particular, crop growth models are useful for examining farm management strategies for crop production that have not been tested in field experiments. In this study, the DAISY crop growth simulation model has been used to investigate if yield and quality of spring barley will be affected by climate changes. The simulations are based on soil type data and climatic conditions at the Danish research field site in Askov. More than fifty treatments involving different time of sowing, irrigation strategies and nitrogen applications have been tested for each year from 1971 to 2004. In this way the response functions for water and nitrogen have been revealed and different strategies for the future production of spring barley have been identified.

The present study indicates that spring barley yields and needs for nitrogen decreases with warmer climate and less precipitation in the growing season. However, the study also shows that irrigation will mitigate the changes. If irrigation is allowed and sufficient water is available, both spring barely yield and need for nitrogen is significantly increased. There is a high and positive correlation between a high climate related yield potential and the need for irrigation and nitrogen. From an environmental point of view an increased use of nitrogen and water could cause negative environmental impacts. In this matter, the profitability of different strategies for fertilization and irrigation of spring barley has been assessed. Moreover, the possibility of using more sustainable strategies, encouraged by nitrogen and water quotas as well as tax regulation, has been studied. If the irrigation is restricted to years with significant water stress in the period of ripening, the overall use of water is moderate, but the marginal economic effect per unit of water may increase significantly.

Our study shows that climate-related variability in the yield potential makes it difficult to foresee and apply the right amount of nitrogen in the first place. An additional nitrogen application (site-dressing) may be a solution, although the effect of site-dressing heavily depends on subsequent rainfall. Because of the positive correlations between the need of irrigation and nitrogen, additional application of nitrogen, followed by sprinkler irrigation may be an efficient strategy. So far it is concluded that the effects of climate change in spring barley may be mitigated by an increased, controlled and sustainable use of nitrogen and irrigation water.

SESSION IV

Risks and Foreseen Impacts on Agriculture



Status of coping with climate risks in agriculture, rangelands, forestry and fisheries in critical areas

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Croplands, pastures and forests that occupy 60 percent of the Earth's surface are progressively being exposed to threats from increased climatic variability and, in the longer run, to climate change. Increasing changes in air temperature and rainfall and resulting increases in the frequency and intensity of drought and flood events have long-term implications for the viability of these ecosystems.

As climatic patterns change, so also do the spatial distribution of agroecological zones, habitats, distribution patterns of plant diseases and pests, fish populations and ocean circulation patterns which can have significant impacts on agriculture and food production.

Agricultural risk plays a predominant role in the vulnerability profile of developing countries. Nearly three-fourths of the world's 1.3 billion people who are living on less than $1 per day depend on agriculture for their livelihoods and are concentrated in the rural areas of low-income countries. Adverse weather, disasters associated with natural events, and commodity price fluctuations threaten agricultural livelihoods and can perpetuate cycles of poverty.

In rural areas of developing countries people are aware that with every year comes the chance that drought, hail, floods, frost, and other climate events may happen; and some of these events could be extreme. In order to mitigate the year to year variations of climate, farmers seed different varieties of the same crop in the same area, seed in different altitudes, practice land rotation, seed associated crops (maize and peas for example) and practice agro forestry. They also have their own bio indicator system to determine if it will be a rainy or a dry year, although in recent years this system has not proved reliable. This means that people take care, in their own way, of both small and large risks while government tries to take care of extreme and low frequency risks associated with El Niño for example.

In many regions the use of weather and climate forecasts is reducing the negative impacts on agriculture and fisheries. The use of weather based insurance is being adopted by developing countries as a risk transferring mechanism. More resistant crop varieties to climate extremes are beginning to be grown, and so on. Nevertheless, these and other efforts still cannot be employed unilaterally. The reason appears to be the result of a lack of intra- and inter-institutional cooperation to use comparative advantages of working together to manage climatic risks, the need to join modernity with ancestral practices as well as that there has been no clear message formulated by policy makers aimed at the farm level.

Climate forecasts for user communities in agriculture, rangelands, forestry and fisheries

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Climate affects the lives of all living beings on earth. Every system is vulnerable to climate, and the impact of climate extremes can cause devastating damage to people and their economies and environment. This vulnerability, however, varies from region to region, and is a function of many factors, such as the geographic location, resiliency, capacities (economic, technical and financial), social capital, political environment, and livelihood security.

Climate variability and change carry significant implications for the sustainability of agricultural productivity and food security, especially in the developing countries. Hence to promote more active application of seasonal climate forecasts, a project entitled "Climate Forecasts for User Communities" was established, using case studies from each of the six WMO regions. This was agreed to by the CAgM Implementation/Coordination Committee; however the project has, thus far, not proceeded beyond this concept stage.

Despite this, significant progress has been made in several countries and regions towards tailoring climate forecasts for users in primary production and natural resource management. In Australia and the South Pacific (RA-V), significant advances have been made with the production of seasonal forecast tools aimed at the rural sector. The "Water and the Land" project (http://www.bom.gov.au/watl) specifically tailors products towards those in agriculture. This project provides the end user with products across a range of timescales (not just climate ones), and has been constructed based upon user feedback surveys. These surveys have resulted in a new set of seasonal forecasting products, including probability of exceedance outlooks and, for times when seasonal outlooks have low skill, "rainfall ranges" graphs which show users a range of possible scenarios for the coming year or growing season.

In the South Pacific, the Bureau of Meteorology's AUSaid funded "Pacific Islands – Climate Prediction Project" (http://www.bom.gov.au/climate/pi-cpp) has pilot projects aimed directly at using seasonal forecasting techniques to improve sugarcane production in Fiji, squash pumpkin yield in Tonga, and cabbage production in Samoa. The Agricultural Production systems SIMulator (APSIM) crop model has been adopted for the Fiji sugarcane industry, with the aim of increasing the understanding of the inter-linkages between climate variability (including on intra-seasonal, seasonal and interannual timescales), regional climate change and farm scale inputs, and how all these factors combine to impact upon the productivity of sugarcane in Fiji. Climate outlook training and guidance is also being provided for those in fisheries, as heavy rainfalls can impact upon stock levels particularly through the effects of increased freshwater runoff. Nine participating Pacific Island Countries have been involved with this project.

In Africa (RA-I) Climate Outlook Forums continue to operate in the three organized sub-regions; namely Southern African Development Community (SADC) having the Southern Africa Regional Climate Outlook Forum (SARCOF), The Greater Horn of Africa (IGAD)'s ICPAC which is held annually in September to develop and disseminate a consensus Regional Rainfall Outlook for October to March and covers all member states. A similar Forum is conducted in the East and Greater Horn of Africa Region (IGAD) and it also takes place around the same time annually. PRESAO, a Regional Climate Outlook Forum (RCOF) activity dedicated to West Africa, is coordinated by the African Centre of Meteorological Application for Development (ACMAD), Niamey, Niger

These outlook forums have continued to contribute positively to the agricultural sector, though with limited progression to be user friendly for the agricultural sector as it is based on probabilities which have made it difficult for users to interpret these forecast appropriately and also for use by agricultural modelers for crop production estimation using agricultural production models i.e. water balance models. Another challenge of these outlooks is the lack of specific requirements of users such as amount, onset date, wet/dry spells. More and more sectors that are aware of theses products, have since joined the initiators of the programme and are also using this Climate Forecasts amongst which is the Water Sector.

The other regions of WMO also have formalized Climate Outlook Forums from which a Consensus Regional Outlook Forecasts for their regions and the members states partaking in the region. These outlooks are; the Climate Outlook Forum for Central America, Western Coast of South America Climate Outlook Forum (WCSACOF), Southeast of South America Climate Outlook Forum (SSACOF), and the Forum on Regional Climate Monitoring, Assessment and Prediction for Regional Association II, Asia (FOCRAII).

All these forums have served as vehicles through which projects on Climate Forecasts for user community have been piloted either at country or regional level.

Scenarios of future cereal production, ecological and economical consequences evaluated by simulation models using downscaled GCM scenarios for two regions in Norway

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Global warming is expected to enhance agricultural production in northern Europe, but the effect will vary between regions regarding both the economic and environmental performance. We have used a cluster of models to investigate such economic and environmental consequences of climate change for two regions in Norway, Østlandet and Trøndelag (about 59° and 63° N).

Heat and water transport in the soil plant system was simulated with COUP, which is a one-dimensional model driven by daily values of air temperature, relative humidity, wind speed, precipitation and cloudiness. The simulated soil temperature, soil moisture, and water runoff was used as input for the SPN model, which integrates the SOILN_NO model with the dynamic plant growth model KONOR for simulation of spring cereals. The denitrification algorithm of the DAYCENT model was integrated for simulation of N_2O emission.

The model clusters were anchored to the two regions by calibration exercises, using data of field experiments on representative soils. Economical optimal N fertilizer levels were estimated based on the simulated yield responses to fertilizer N for the different climate scenarios and current prices for nitrogen fertilizers and grains.

Future climate scenarios were regionally downscaled from the global simulations Hadley A2 (year 2071-2100) and Max Planck ECHAM 4/OPYC3 (year 2020-2049).

HadleyA2 predicted an increased frequency of summer drought for Southeast Norway whereas ECHAM 4 did not. A faster decline in soil organic C content and a slight increase in the emission of N_2O were predicted. Predicted yields of present Norwegian cultivars were dramatically lowered. The simulations demonstrated that introduction of cultivars that mature substantially later is necessary to improve yields and economic gross margins. Such cultivars should be characterized by reaching maturity at a substantially higher day-degree sum than any cultivar presently used in Norway.

Consequences of climate change on maize micro climate in Hungary

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The influences of global climate change on radiation balance and elements of microclimate of maize were studied by using the simulation model of Goudriaan, connected to the average July weather in Keszthely, Hungary. Eight scenarios were made, an increase of CO_2 content until doubling the content was included in the scenarios. The period 1961-1990 was considered for the basic run. We also quantified weather variation of recent years on the basis of the period between 1997 and 2006. The other five scenarios were developed by down scaling the IPCC (2007) report (A2 and B2) to Hungary, and by taking into account more serious weather changes (up to +9 °C in July).

Plant and soil characteristics of the individual scenarios were chosen on the basis of analogy from the past 30 seasons being extensively used in construction of weather scenarios. For evaluation of the results of the model runs, we used paired t-test. The chosen significance level was at 5%.

It was a real surprise, that the ratio of latent heat to sensible heat decreased by only 4.8% when doubling CO_2 concentration. The largest ratio of sensible to latent heat occurred in the case containing the highest warming and largest decrease of precipitation.

Each approach increased both the canopy air temperature and plant temperatures in maize depending on the degree of warming-up. The changes already occurring in the environmental factors in the past decade increased the canopy air temperature at canopy level by 0.6 °C. So far, the presence of plant canopy, however, mitigated the degree of warming-up, likely owing to the shading effect of the canopy.

The rate of photosynthesis was reduced only above 6 °C increase of air temperature. Water shortage counteracted the positive influence of elevated CO_2 on carbon assimilation. The stomatal conductance was also changed significantly in all scenarios. The elevated CO_2 content did increase the stomatal resistance in the maize crop.

Based on results from this study local level information has become available for potential users, and the results can be used to prepare for mitigation of adverse impacts of projected changes.

Simulation of rapeseed yields under climatic change in Finland

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Finland is the only country in which summer turnip rape (*Brassica rapa* L.) is predominant over summer oilseed rape (*Brassica napus* L.) as an oil crop. Recently, however, farmers show increased interest in growing oilseed rape. Its cultivated area has increased rapidly and climate change is expected to further strengthen its position. It has been hypothesized that, in the first place, current turnip rape cultivars are sensitive to increased temperatures during seed set and seed filling, and therefore are outperformed by oilseed rape in relatively warmer years. But the relative importance of the yield-influencing factors is not yet sufficiently understood. In order to identify and disentangle the factors causing yield variations of modern turnip and oilseed rape varieties under current and future climatic conditions, a crop modeling approach has been applied that analyzes yield–determining and –limiting factors in a systematic way.

Potential and water-limited yields have been analyzed for summer turnip rape and oilseed rape at Jokioinen in Southwestern Finland. To this end the crop growth simulation model WOFOST, a centre-piece of the EU crop growth monitoring system (CGMS) was applied. We calibrated the model using comprehensive experimental data sets and observations from MTT experimental station Jokioinen, and ran it with modified crop parameters for enhanced atmospheric CO_2 concentrations, and three different climate change scenarios.

Modelling results for turnip rape for the period between 1975-2006 suggest that growth duration varied considerably among years, fitting well with observations. Duration of the reproductive phase has become considerably shorter during recent years. For the 20th of May planting at Jokioinen, potential yields ranged between 2.3 and 3.9 t ha^{-1}, while water-limited yields varied from 0.9 to 3.5 t ha^{-1}. Variations in soil physical characteristics, increased moisture deficits (early summer drought) and higher temperatures during seed-filling had the strongest negative impact on biomass and economic yields, while the effect of time of planting was moderate. Similar results were obtained for summer oilseed rape. Increased temperatures of 2 to 2.5 °C and 4 to 4.5 °C reduced growth duration on average by 12 and 21 days, respectively. Shortened growth duration especially affected the reproductive phase, and reduced yields considerably. Enhanced atmospheric CO_2 could not compensate for climate change-induced yield losses.

Climate change is expected to have marked negative impacts on rapeseed yields, if no appropriate adaptation measures are taken. Improved crop management practices guided by crop growth modelling in combination with breeding of new cultivars that are less sensitive to temperature and moisture stress and more disease resistant seems promising to reduce current yield gaps and better cope with climate-change induced production risks. Differences in temperature sensitivities between salient turnip and oilseed rape cultivars were not explained and require further research.

Drought analyses of agricultural landscape as influenced by climatic conditions in the Slovak Republic

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The moisture balance evaluation was based on datasets of daily mean, maximum and minimum air temperatures, solar radiation, wind speed, water vapour pressure and precipitation from 55 meteorological stations during the period 1975-2004. Penman-Montheith formula was applied for calculation of reference crop evapotranspiration. Crop water requirement was calculated according to procedures recommended by FAO.

For calculations we used mean values of water field capacity, wilting point and soil depth represented in a grid of 10 x 10 km.

Number of days with maximum temperature (T_{max}) > 30 °C was calculated for evaluation of stress. Weather stations used were Hurbanovo for Danubian lowland, Kuchyňa for Záhorie lowland, Bolkovce for South Slovakia Basin, and Milhostov for Eastslovakian lowland. These were considered as representative meteorological stations for individual regions of Slovakia.

Crop adaptation to climate changes and meteorological adversities-agrometeorological and agronomic aspects

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Macroclimatic characteristics of all regions are showing significant changes, particularly in the last decades. The parameters more representative of these variations are air temperature and rainfall regime, and the occurrence of natural disasters has increased substantially. The analysis of 118 years of monthly minimum and maximum air temperatures at Campinas-SP (22º54'S/47º05'E) shows an increase up to 1.5 ºC for the minimum and 1.2 ºC for the maximum air temperature. This paper describes briefly some of the agrometeorological and agronomic techniques that can be used, alone or in a complementary way to mitigate extreme meteorological events and to face the challenge of global warming on agriculture. Agrometeorologically, some of the techniques that can be used are: i) Early Warning System, methodologies should be encouraged and enhanced to monitor and to predict extreme events such as dry-spell; drought; frost; hurricanes; ii) Weather Data collection and use, to enhance the use and modernization of AWNWS to give support to farmers' decision process and extension services; iii) Irrigation Management, to develop irrigation schedules based on agrometeorological information to face dry spells and drought situations; iv) Planting Time; to determine the best planting time for annual crops based on crop weather demand, and meteorological risks; v) Crop Zonation, based on new scenarios of climate, indicate the new species, and the risks they are associated with.

In relation to the agronomic techniques to reduce the negative effects of climate some that can be used are: i) Direct Planting; to reduce substantially the surface evaporation, and the losses of CO_2 from the soil to the atmosphere; ii) Use of Adapted Crops, in this case the use of crops adapted to more severe climate extremes should be enhanced, as for example in drought prone areas, drought tolerant cultivars should be used; iii) Planting Density, in areas where the scarcity for water will increase, the use of less plants per square meter, may help to reduce crop losses due to dry spells; iv) Plant Breeding, crop geneticists should develop new crop varieties, considering the adaptation to extreme climatic situations, and specially the traits of drought tolerance or high/low temperature tolerance. Some complementary techniques should also be evaluated, considering the combination of crop response to climate constraints and soil. For sure many others can be listed, but this paper tries to point out agronomic techniques which may help overcome the challenges of the negative scenarios indicated. This is not the task of only one person or only one institution, but rather that of a group of specialists and institutions. Furthermore, it is extremely important that researchers and specialists in the areas of agronomy, agrometeorology, meteorology, and others, should be involved in the study of crop adaptation to climate change and global warming.

Crop yields and agroclimatic conditions in central Europe between 2020 and 2050

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Central Europe is located between East and South European climate change hot-spots where its impact is thought to become visible sooner or will be more pronounced (or both). Despite the fact that agriculture is by no means a dominant activity in the region it remains an essential part of the economy (and landscape) and in most cases is based on the performance of few crops such as spring barley and winter wheat. It is obvious that production stability and quality would be influenced under changed climatic conditions and that these changes will differ between regions. However, the magnitude of the change in the agrometeorological conditions and crop productivity (both positive and negative) is not fully known due to the large differences between individual global circulation models (GCM) and SRES scenarios. In order to assess trends and magnitude of crop yields and key agrometeorological indicators we applied dynamic crop models CERES-Barley and CERES-Wheat in combin ation with the newly developed tool AgriCLIM for the region including the main agricultural regions in the Czech Republic and Austria. In order to estimate uncertainty in future crop production a number of GCMs provided from the Fourth Assessment Report (4AR) was used (ECHAM, HadCM, NCAR-PCM, CSIRO and GFDL) applying pattern-scaling technique and a set of SRES scenarios. The scenario values were used to set up boundary parameters of the future climate over Central Europe (including CO_2 levels required as an input for the crop model). In order to estimate future yields more realistically both medium and long-term trends in grain productivity between 1918 and 2007 (due to technological advancement) as well as the effects of autonomous adaptation strategies were taken into account. The latter included optimization of fertilization and sowing dates, changing basic parameters of the cultivar and finally measures to increase soil water accumulation during winter that precede sowing. Overall the higher altitudes (between 400-700 m a.s.l) of the region seem to benefit more from the changing agrometeorological conditions whilst in the lowlands new types of stress factors (e.g. high temperature during anthesis or absent snow cover during winter) are emerging.

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Current perceptions on climate change impacts and adaptation for arable crops in Europe

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The studies on anthropogenic climate change performed in the last decade over Europe indicate consistent increases in projected temperature and different patterns of precipitation with widespread increases in Northern Europe and rather small decreases over southern Europe. These changes in climate patterns are expected to greatly affect all components of the European agricultural ecosystems (e.g. crop suitability, yield and production, livestock, etc.).

The development in national grain yields for wheat in the period 1961 to 2006 for countries in Europe shows that yields in Northern Europe are limited by cold temperatures, whereas yields in Southern Europe are limited by high temperatures and low rainfall. Yields increased considerably during the period 1970 to 1990 in all countries with the highest absolute increases in Western and Central Europe. The yield increases have levelled off considerably during the past 10-20 years. There is in recent years a tendency in many countries to lower yields and increased yield variability. A preliminary analysis shows that the yields in several European countries in recent years correlated well with the mean temperature during the main part of growing season with observed yield reduction in warmer years.

Grain yields in maize have been increasing over the period 1961-2006 in both Central and Southern Europe. The yields increases seem to be continuing in Belgium and Germany, even in recent years, where wheat yield increases have been levelling off. This has also resulted in a steadily increasing grain maize area in these countries. The yield of grain maize in France and Italy have not increased in recent years, and this is most likely due to warmer climate and a higher frequency of droughts, which reduce the water available for irrigation, and since maize is predominantly an irrigated crop in these countries this has impact on both maize yields and the area cropped with maize.

In order to gather information on perceived risks and foreseen impacts of climate change on agriculture in Europe we designed a set of qualitative and quantitative questionnaires that were distributed to lead experts in 26 countries. There were two types of questionnaires distributed to the COST 734 members and other experts: i) country based overview questionnaires and ii) climate regions specific quantitative questionnaires. Europe was divided into 13 Environmental zones (EZ). In total we had 16 complete national reports and 50 responses for specific EZ from 26 countries. The questionnaires provided both country and EZ specific information on the: 1) Main vulnerabilities of crops and cropping systems under present climate; 2) Estimates of climate change impacts on the production of nine selected crops; 3) Possible adaptation options as well as 4) Adaptation observed so far. In addition we also focused on the overall awareness and presence of warning and decision support systems.

The results show farmers across Europe are currently adapting to climate change, in particular in terms of changing timing of cultivation and selecting other crop species and cultivars. The responses in the questionnaires show a surprisingly high proportion of negative impacts of climate change on crops and crop production throughout Europe, even in the cool temperate North European countries

Impacts and adaptation to climate change in cropping systems (IMPACTS)

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Anthropogenic climate change is expected to produce largely positive effects for agricultural productivity in Northern Europe through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation. However, crop yield and yield quality are determined not only by direct effects of climate on crop development and growth, but also by indirect effects through enhanced cycling of carbon and nitrogen (N) in soil, increased risks of pests and diseases, and increased variability due to summer droughts and wet conditions during autumn affecting harvesting conditions and yield quality. The net effect on harvested yield, quality and farm profitability will also be determined by adaptation measures taken to moderate effects of climate or take advantage of possible positive effects. Adaptations will take place at both the farm and society level, where effects at society level mostly relate to indirect effects of climate change on environmental impacts of agricultural production, including nitrate leaching and pesticide use.

The IMPACTS project will address the relationships between the direct and indirect effects of climate change on cropping systems. A combination of experimental, data mining and modelling approaches will be applied. Existing data sets will be used to analyse the importance of climate and climate variability on crop yield and quality. The ability of a range of crop simulation models to simulate the effect of climate change will be determined and the results will be used for improving the FASSET crop simulation model. Controlled experiments will be carried out to support and test FASSET, where analytical data are particularly required. One experiment will focus on the effects of higher winter temperatures on growth and N uptake of catch crops and winter cereals in autumn. Other experiments will be used to analyse and simulate the effects of climate change on occurrence of pests and diseases. Responses of crop, N cycling and N leaching to a range of climate change scenarios for 2020, 2050 and 2080 will subsequently be simulated. The results obtained will be used in combination with two economic models for analysing the effectiveness of adaptation options on economic viability of farming systems under the environmental constraints posed by the need to reduce N leaching and pesticide use.

Field crop losses caused by weather conditions in Poland

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The main source of losses in agricultural production is caused by the year–to–year variability of meteorological conditions. Many authors propose that the variability of the yields in the last few decades has become greater, which means there is an increased risk in agriculture. The objective of this work was to study the variability of crop losses, which were caused by the unfavourable weather conditions over the last fifty-two years in Poland.

For an evaluation on the impact of weather conditions on the crop yield in Poland, prognostic statistical-empirical models (IPO) were used. In these models, the concept of the so-called weather index (WI) that is linearly related to the expected yield is used. The WI is a multiple function of meteorological elements aggregated in decade and monthly periods. The WI expresses the yield variability in Poland that is influenced by various weather factors, and can be used for the prediction of expected yields in a particular year using meteorological data. An analysis of individual partial indices constituting the WI makes it possible to identify which meteorological element is responsible for the yield losses in a particular year.

The work has revealed that crops in Poland have been damaged by various weather phenomena: by frosts and by long-lasting snow cover, by droughts and by excessive rainfalls. The greatest crop losses appeared in 1980 caused by the wet and cool year, and in 2006 caused by the drought conditions. It has been shown that yield variability of major crops in Poland increased during the last few decades with the exception of sugar beet and rape yield. The analysis indicated that the role of droughts has increased in the last few decades in Poland.

The impact of climate change on soil hydrology and degradation: an assessment of vulnerabilities on Irish agriculture

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Soil formation and soil erosion are natural process, occurring over geological time. Given the slow rate of soil formation, soil erosion of more than 1 t/ha/yr represents an irreversible process on a time scale of several decades. There is widespread evidence however that accelerated erosion, especially by water, is presently occurring in vulnerable areas of Europe due mainly to inappropriate agricultural practices. Losses of topsoil of 20-40 t/ha occur in southern Europe in association with individual storms every two or three years and extreme events can result in the removal of more than 100 t/ha. Presently, soil erosion problems in northern Europe are less serious due to less intensive rainfall and gentler topographical gradients on average. Global climate change however is likely to change this. Downscaling from most global climate models project that increased annual rainfall amounts will occur in future years in areas of northern Europe, including Ireland. Furthermore, increased intensity is likely to be a feature of these changed rainfall regimes, both in winter and summer. Such scenarios suggest that the identification of areas that are vulnerable to soil erosion should be undertaken with a view to ultimately develop measures to control any emerging problems.

As Irish population increases and settlement expansion sterilizes large tracts of highly productive agricultural land, and as new transport arteries reach inexorably into the rural hinterlands, soil resources more than ever before face new threats. Existing research on soils in Ireland has thus far not encompassed considerations of climate change as the required climatic scenarios have not been developed at a sufficiently high resolution. Recent advances in downscaling of global climate models mean that increasingly confident future climate scenarios can be provided for Ireland. It is now clear from these that substantial changes in soil moisture and temperature are commencing which will have implications for many aspects of Irish soils. Consequently, by researching the likely impact of climate change on Irish soils, national agencies can be provided with the high resolution spatial information they require to enable them to focus policies on vulnerable areas. Therefore the central question this research addresses is to assess likely changes in soil characteristics, hydrology and functioning in Ireland as a result of projected climate change. The main objectives in which the work is under progress are:

- To develop an understanding and quantification of the resistance and resilience of Irish soils to changes in climate as projected from ensemble combinations of the best currently available downscaled global climate models
- To assess the likely impact of climate change on soil functional parameters over a range of spatial and temporal scales
- To assess erosion risks in response to changing precipitation regwimes
- To assess the impact of climate change on the organic and nutrient content of all major Irish soil types

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