
A global water model is used to analyse the impacts of climate change and socio-economic driving forces (derived from the A2 and B2 scenarios of IPCC) on future global water stress. This work extends previous global water research by analysing not only the impact of climate change and population, but also the effects of income, electricity production, water-use efficiency and other driving forces, on water stress. Depending on the scenario and climate model, water stress increases (between current conditions and the 2050s) over 62.0-75.8% of total river basin area and decreases over 19.7-29.0% of this area. The remaining areas have small changes. The principal cause of decreasing water stress (where it occurs) is the greater availability of water due to increased annual precipitation related to climate change. The principal cause of increasing water stress is growing water withdrawals, and the most important factor for this increase is the growth of domestic water use stimulated by income growth. (Population growth was a much less important factor and irrigated area was assumed to remain constant.) To address the uncertainty of water stress estimates, three different indicators of water stress were computed and compared. The overlap area of their computation of "severe stress" in the 2050s was large (approximately 23 x 10(6) km(2) or 56-73% of the total "severe stress" area). This indicates a moderate level of agreement and robustness in estimates of future water stress.

At the same time the indicators disagreed in many other areas, suggesting that work is still needed to elaborate general indicators and concepts of water stress.

KEY: GLOBAL; WATER MODEL; A2; B2


It is expected that a change in climatic conditions due to global warming will directly impact agricultural production. Most climate change studies have been applied at very large scales, in which regions were represented by only one or two weather stations, which were mainly located at airports of major cities. The objective of this study was to determine the potential impact of climate change at a local level, taking into account weather data recorded at remote locations. Daily weather data for a 30-year period were obtained for more than 500 sites, representing the southeastern region of the USA. Climate change scenarios, using transient and equilibrium global circulation models (GCM), were defined, created and applied to the daily historical weather data. The modified temperature, precipitation and solar radiation databases corresponding to each of the climate change scenarios were used to run the CERES v.3.5 simulation model for maize and winter wheat and the CROPGRO v.3.5 model for soybean and peanut. The GCM scenarios projected a shorter duration of the crop-growing season. Under the current level of CO2, the GCM scenarios projected a decrease of crop yields in the 2020s. When the direct effects of CO2 were assumed in the study, the scenarios resulted in an increase in soybean and peanut yield. Under equilibrium 2 x CO2, the GCM climate change scenarios projected a decrease of maize and winter wheat yield. The indirect effects of climate change also tended to decrease soybean and peanut yield. However, when the direct effects of CO2 were included, most of the scenarios resulted in an increase in legume yields. Possible changes in sowing data, hybrids and cultivar selection, and fertilization were considered as adaptation options to mitigate the potential negative impact of potential warming.

The article discusses the economic impacts of climate change on agriculture. The author presents summaries of the key findings from agricultural researches on impacts of climate changes based on IPCC Assessment Reports from 2001 to 2007. Related literature on policy implications on agriculture and climate changes include the companion paper by Rose and McCarl and discussions on greenhouse emissions by Schneider and Kumar. Uncertainties and limitations of the current data are also presented by the author on impacts of climate change and agriculture.


Due to their reliance on rain-fed agriculture, both as a source of income and consumption, many low-income countries are considered to be the most vulnerable to climate change. Here, we estimate the impact of climate change on food security in Tanzania. Representative climate projections are used in calibrated crop models to predict crop yield changes for 110 districts in Tanzania. These results are in turn imposed on a highly disaggregated, recursive dynamic economy-wide model of Tanzania. We find that, relative to a no-climate-change baseline and considering domestic agricultural production as the channel of impact, food security in Tanzania appears likely to deteriorate as a consequence of climate change. The analysis points to a high degree of diversity of outcomes (including some favorable outcomes) across climate scenarios, sectors, and regions. Noteworthy differences in impacts across households are also present both by region and by income category.


In this paper we use two alternative methods to assess the effects of climate change on the quality of wines from the vineyards of the Mosel Valley in Germany. In the first, structural approach we use a physical model of solar radiation to measure the amount of energy collected by a vineyard and then to establish the econometric relation between energy and vineyard quality. Coupling this hedonic function with the physics of heat and energy permits a calculation of the impact of any temperature change on vineyard quality (and prices). In a second approach, we measure the effect of year-to-year changes in the weather on land or crop values in the same region and use the estimated hedonic equation to measure the effect of temperature change on prices. The empirical results of both analyses indicate that the vineyards of the Mosel Valley will increase in value under a scenario of global warming, and perhaps by a considerable amount.


As a result of climate change, and in particular rainfall changes, agricultural production is likely to change across the globe. Until now most research has focused on areas which will become unsustainable for agricultural production. However, there are also regions where climate change
might actually improve conditions for growth. In the western Pampas region of Argentina, average annual rainfall has increased by 100-200 mm over the last 70 years, mainly during summer. Wheat is grown during winter, primarily on stored soil water and the main factor limiting plant production in this area is rainfall. Using the well tested simulation model APSIM-NWheat, we studied whether recent climate change has potentially opened new opportunities for wheat cropping in Argentina. Simulation results indicated that the additional rainfall in the Pampas of Argentina has increased the achievable yield (defined as the yield limited by solar radiation, temperature, water and nitrogen supply) of wheat in the currently cropped region, but less than expected based on the large amount of additional rainfall. The higher achievable yield from additional rainfall could potentially allow an expansion of profitable wheat cropping into currently non-cropped areas, where the achievable wheat yield increased in average from 1 t/ha to currently 2 t/ha. However, the poor water-holding capacity of the sandy soils which dominate the region outside the current cropping area limits the systems ability to use most of the increased summer rainfall. Nevertheless, the current higher achievable yield indicates a suitability of the region for cropping, which will slightly decline or remain unchanged depending on summer rainfall storage, with current and future climate change, including projected changes in rainfall, temperature and atmospheric CO2 concentration. Factors other than just the achievable yield will eventually influence any future development of this region for cropping, including the high sensitivity of the sandy soils to erosion and nutrient leaching, current relatively high land prices, restrictions on clearing for cropping, the distance to the nearest port and current unsuitable cultivars withstanding the high frost risk.

KEY: ARGENTINA; CROP MODEL; POSITIVE EFFECTS OF FUTURE CLIMATE CHANGE ON WHEAT PRODUCTION


The vulnerability of the agricultural sector in any region to future possible climate-change scenarios is determined to a great extent by the vulnerability of the sector to current climatic, economic and policy scenarios. Agricultural systems which are currently subject to extreme climatic interannual variability (drought, flood, storms, etc.) are likely to become even more vulnerable under the most commonly expected scenarios of climate change (i.e. increased temperatures, increased rainfall variability). Similarly, agricultural systems which are currently subject to drastic changes in economic and policy scenarios are also prone to become more vulnerable under expected climate-change conditions. The agricultural sector of Latin America has been subject to important variations in economical conditions and policies. These conditions have affected the structure of agricultural production, and resulted in a large reduction of the number of small farmers, who have migrated to poor metropolitan areas. Even for larger, commercial farmers, unstable and often inconsistent agricultural policies have increased the vulnerability of the sector. Additionally, large areas of Latin America are already affected by current interannual climatic variability related to the length of rainy seasons and the occurrence of extreme events (droughts, floods, etc.). The few studies conducted in the region to specifically assess the impact of climate change on agriculture have revealed expected reductions and increased variability in crop productivity. Similar results should be expected in the vast regions devoted to livestock production, since the systems are based on a fragile balance of nutrients, available water, stocking rates and pasture species. The characteristics of the current situation described in this article demonstrate the vulnerability of Latin American agriculture to climate change. Preparing the agricultural sector to mitigate the potential negative effects of climate change will require strong and consistent efforts in both the scientific
and policy sectors of the region.

**KEY: LATIN AMERICA; REVIEW; CLIMATE IMPACTS ON AGRICULTURE**


Climatic impact on agricultural production is a serious concern, as it is directly linked to food security and poverty. Whereas there are empirical studies that examine this issue with parametric approaches focusing on the "mean" level of variables, few studies have addressed climatic impacts in general settings. Given this paucity, we characterize the impacts on crop yield distributions with a non-parametric approach. We examine the case of rice yield in Andhra Pradesh, India, an important state producing rice as a main crop but reported to be vulnerable to climate change. Employing 34 years of data, we apply quantile regressions to untangle the climatic impacts across the quantiles of rice yield, finding three main results. First, substantial heterogeneity in the impacts of climatic variables can be found across the yield distribution. Second, the direction of the climatic impacts on rice yield highly depends on agro-climatic zones. Third, seasonal climatic impacts on rice yield are significant. More specifically, a monsoon-dependent crop is more sensitive to temperature and precipitation, whereas a winter crop remains largely resilient to changes in the levels of climate variables. These findings clarify the idiosyncratic climatic impacts on agriculture in India, and call for location- and season-specific adaptation policies. (c) 2012 Elsevier B.V. All rights reserved.

**KEY: INDIA; QUANTILE REGRESSION; RICE YIELD**


South Africa in general has been approximately 2% hotter and at least 6% drier over the ten years between 1997 and 2006 compared to the 1970s. The use of water has also increased greatly over this same period. By 2000, 98.6% of that year's surface water yield and 41% of the annual utilisable potential of groundwater was allocated to use. Irrigation agriculture, comprising 60% of total consumption, is by far the largest single consumer of water. Given these climatic and water use changes as a backdrop, we employed a panel data econometric model to estimate how sensitive the nation's agriculture may be to changes in rainfall. Net agricultural income in the provinces, contributing 10% or more to total production of both field crops and horticulture, is likely to be negatively affected by a decline in rainfall, especially rain-fed agriculture. For the country as a whole, each 1% decline in rainfall is likely to lead to a 1.1% decline in the production of maize (a summer grain) and a 0.5% decline in winter wheat. These results are discussed with respect to both established and emerging farmers, and the type of agriculture that should be favoured or phased out in different parts of the country, in view of current and projected trends in climate, increasing water use, and declining water availability.

**KEY: SOUTH AFRICA; PRECIPITATION IMPACTS; NATIONAL PANEL DATA; ECONOMETRIC MODEL**


This study examines how uncertainty associated with the spatial scale of climate change scenarios influences estimates of soybean and sorghum yield response in the southeastern United States. We investigated response using coarse (300-km, CSIRO) and fine (50-km, RCM) scale climate change scenarios and considering climate changes alone, climate changes with CO(2) fertilization, and climate changes with CO(2) fertilization and adaptation. Relative to yields
simulated under a current, control climate scenario, domain-wide soybean yield decreased by 49% with the coarse-scale climate change scenario alone, and by 26% with consideration for CO(2) fertilization. By contrast, the fine-scale climate change scenario generally exhibited higher temperatures and lower precipitation in the summer months resulting in greater yield decreases (69% for climate change alone and 54% with CO(2) fertilization). Changing planting date and shifting cultivars mitigated impacts, but yield still decreased by 8% and 18% respectively for the coarse and fine climate change scenarios. The results were similar for sorghum. Yield decreased by 51%, 42%, and 15% in response to fine-scale climate change alone, CO(2) fertilization, and adaptation cases, respectively - significantly worse than with the coarse-scale (CSIRO) scenarios. Adaptation strategies tempered the impacts of moisture and temperature stress during pod-fill and grain-fill periods and also differed with respect to the scale of the climate change scenario.

KEY: SOUTHEASTERN US; HOW SPATIAL SCALE IMPACTS YIELD PROJECTIONS


Climatic warming due to increased concentrations of greenhouse gases in the atmosphere is likely to lead to large-scale shifts in the pattern of agricultural potential. This article reports the results of a study to investigate the broad-scale sensitivity of crop potential to climatic change in Europe. A simple agroclimatic index, effective temperature sum (ETS), has been related to the minimum requirements for the successful cultivation of three crops: grain maize, sunflower and soya bean. With the aid of a computer mapping system, ETS has been mapped across Europe on the basis of present climate and of scenarios of future climate. In this way, the effects of changes in climate can be expressed as spatial shifts in the limits of crop potential, and the uncertainties in the estimates can be interpreted in terms of the likelihood of particular regions becoming climatically suitable for crop cultivation. The estimates point to a considerable dislocation of agricultural potential occurring over a matter of only several decades.

KEY: EUROPE; AGROCLIMATIC INDEX


A geographical analysis system is described for evaluating regional crop potential in Finland under possible future climatic change. The system comprises a data base and models of crop potential which are combined in a geographical information system. The data base includes information on administrative boundaries, physiographic features, climate, soils, land cover, agricultural land use and crop production. Agroclimatic indices and simple growth models are employed to compute the regional suitability for crop cultivation and potential productivity. These are depicted on a 10 km regular grid across Finland. As an example, the suitability of spring wheat (Triticum aestivum; cv. 'Kadett') is examined, both for present-day conditions and under a scenario of 0.3 degrees C warming per decade up to 2050. The results indicate that northward shifts in suitability ranging from 110 km per 1 degrees C warming in eastern Finland to 290 km degrees C-1 in western Finland could be anticipated. This represents a rate of extension of between 35 and 85 km per decade. At the same time, the duration of the heading to maturity phase shortens as the climate becomes warmer. Since this phase includes the grain filling period, a reduction in grain yields could be expected in warmer regions unless present-day cultivars were substituted by slower maturing and higher yielding cultivars.

KEY: FINLAND; AGROCLIMATIC INDEX; PROCESS-BASED CROP MODEL

Appropriate knowledge and understanding of the impact of climatic variability on agricultural production is essential for devising an adaptation strategy. Climate change impact studies have to cope with the cascade of uncertainties that enter at different levels of modelling (e.g., emission scenario, climate model structure, impact assessment models). Our study aims at addressing these uncertainties through an ensemble probabilistic approach, which accounts for uncertainties in climate model simulations as well as parametric uncertainties in a dynamic crop model, when simulating maize (Zea mays L.) growth and development. Simulations from eight regional climate models were used in combination with 10,000 different parameter sets from a dynamic crop model, reflecting biophysical uncertainties. Since regional climate model simulations can be subject to systematic biases, the use of such simulations to create impact assessment models can lead to unrealistic results. In the second phase of our study, we therefore determined the importance of bias correction of simulated meteorological variables prior to their use as input data in a dynamic crop model. The results revealed that using raw simulations from regional climate models to force a dynamic crop model produced unrealistic maize yield estimations, mainly because of underestimation of the intensity of daily precipitation. Corrected simulations from climate models significantly improved the quality of maize yield simulations, while a lower degree of improvement was observed in cases in which the frequency of wet days was underestimated in comparison to measured values. Using bias corrected climate model simulations in an ensemble probabilistic approach resulted in probability distributions of expected yield changes at three locations in Slovenia. Yield is expected to decrease on average between 10% and 16% in the 2050s and between 27% and 34% in the 2090s, while inter-annual variability is expected to increase compared to the control period between 1961 and 1990. Variance decomposition of the ensemble yield projections was performed in order to determine the RCM inter-model variability and crop model parameter uncertainty. The proportion of variance between RCMs increases during the 21st century, but never exceeds the inter-annual yield variability. Moreover, the parametric uncertainty of the WOFOST model can be regarded as negligible compared to RCM inter-model variability and yield inter-annual variability. A statistical emulator of the dynamic crop model was developed in order to analyze the impact on maize yield of weather variability within the growing season. It has been recognized that maize yield depends mostly on weather conditions during the period from 90 to 110 days after sowing, which coincides with the silking and tasseling period. High temperatures, low relative humidity and low rainfall during this period negatively affect maize growth, leading to a decrease in dry matter production. The analysis also revealed that precipitation during the growing season had a decisive impact on inter-annual yield variability at the selected locations. (C) 2011 Elsevier B.V. All rights reserved.


Significant progress has been made in the use of ensemble agricultural and climate modelling, and observed data, to project future productivity and to develop adaptation options. An increasing number of agricultural models are designed specifically for use with climate ensembles, and improved methods to quantify uncertainty in both climate and agriculture have been developed. Whilst crop-climate relationships are still the most common agricultural study of this sort, on-farm management, hydrology, pests, diseases and livestock are now also examined. This paper introduces all of these areas of progress, with more detail being found in
the subsequent papers in the special issue. Remaining scientific challenges are discussed, and a distinction is developed between projection- and utility-based approaches to agro-climate ensemble modelling. Recommendations are made regarding the manner in which uncertainty is analysed and reported, and the way in which models and data are used to make inferences regarding the future. A key underlying principle is the use of models as tools from which information is extracted, rather than as competing attempts to represent reality. (c) 2012 Elsevier B.V. All rights reserved.

KEY: GLOBAL; REVIEW; CROP MODELS

Chang, C. C., et al. (2012). "Evaluating the economic impacts of crop yield change and sea level rise induced by climate change on Taiwan’s agricultural sector." Agricultural Economics 43(2): 205-214. This article investigates the effects of sea level rise and climate change induced crop yield alterations on Taiwan as well as possible adaptation strategies. For sea level rise of up to 5 meters, as much as 4.9% of total acreage and 16% of rice acreage would be lost. The empirical findings show that the sea level damages range from NT$ 0.84 to 4.10 billion while crop yield losses range from NT$ 1.79 to 2.55 billion. We investigate alternative adaptation strategies finding crop yield technological progress and tariff reduction could significantly mitigate these effects.

KEY: TAIWAN; SEA LEVEL RISE

Chen, Y. F., et al. (2013). "The impacts of climate change on crops in China: A Ricardian analysis." Global and Planetary Change 104: 61-74. This paper assesses the impact of climate change on China’s agricultural production at a cross-provincial level using the Ricardian approach, incorporating a multilevel model with farm-level group data. The farm-level group data includes 13,379 farm households, across 316 villages, distributed in 31 provinces. The empirical results show that, firstly, the marginal effects and elasticities of net crop revenue per hectare with respect to climate factors indicated that the annual impact of temperature on net crop revenue per hectare was positive, and the effect of increased precipitation was negative when looking at the national totals: secondly, the total impact of simulated climate change scenarios on net crop revenues per hectare at a Chinese national total level, was an increase of between 79 USD per hectare and 207 USD per hectare for the 2050s, and an increase from 140 USD per hectare to 355 USD per hectare for the 2080s. As a result, climate change may create a potential advantage for the development of Chinese agriculture, rather than a risk, especially for agriculture in the provinces of the Northeast, Northwest and North regions. However, the increased precipitation can lead to a loss of net crop revenue per hectare, especially for the provinces of the Southwest, Northwest, North and Northeast regions. (C) 2013 Elsevier B.V. All rights reserved.

KEY: CHINA; RICARDIAN MODEL

Chipanshi, A. C., et al. (2003). "Vulnerability assessment of the maize and sorghum crops to climate change in Botswana." Climatic Change 61(3): 339-360. This study examines the sensitivity of maize and sorghum crops to global warming in Botswana, a country with arid climatic conditions and shortfalls in locally produced grain. The vulnerability of the maize and sorghum crops to climate change were studied using crop simulation models while climate change scenarios were generated from Global Circulation Models. Simulated yields indicated that rain-fed crop production under the observed climate was a small fraction of what could be produced under optimal conditions. The gap was attributed to both physical (especially lack of rain) and socio-economic constraints. Using the southern African core climate change scenario, simulated yields declined by 36% in the case of maize and 31% for sorghum in
the sand veldt region. Yield reductions from the hard veldt region were in the order of 10% for both maize and sorghum. The growing season became shorter, the average reduction in days in the sand veldt region being 5 and 8 days for maize and sorghum respectively, and correspondingly, 3 and 4 days over the hard veldt region. The food security option currently followed in Botswana was found to be a good adaptive strategy under a changed climate.

KEY: BOTSWANA; PROCESS-BASED CROP MODEL


During the past few years two new methods, each based on the analogous region concept, have been developed to account for farmer adaptation in response to global climatic change. The first, called 'Ricardian' by Mendelsohn, Nordhaus, and Shaw (1994), econometrically estimates the impact of climatic and other variables on the value of farm real estate. Under some conditions, estimates of climate-induced changes in farm real estate capture first-round adaptations by farmers and represent the economic value of climatic change on agriculture. The second method, promulgated by Darwin et al. (1994) in the Future Agricultural Resources Model (FARM), uses a geographic information system to empirically link climatically derived land classes with other inputs and agricultural outputs in an economic model of the world. FARM provides estimates of economic impacts that fully account for all responses by economic agents under global climate change as well as estimates of Ricardian rents. The primary objective of this analysis is to evaluate how well changes in Ricardian rents measure agricultural or other effects of climatic change after all economic agents around the world have responded. Results indicate that changes in Ricardian rents on agricultural land are poor quantitative, but good qualitative, measures of how global climatic change is likely to affect the welfare of agricultural landowners, if one recognizes that increases in Ricardian rents actually indicate losses in landowner welfare and vice versa. Results also indicate that regional changes in Ricardian rents on all land are good qualitative measures of changes in regional welfare. They are poor quantitative welfare measures because they systematically overestimate both benefits and losses and are on average upwardly biased because inflated benefits are larger than exaggerated losses. Results also indicate that, when based on existing land-use patterns, changes in Ricardian rents on all the world's land are poor quantitative and qualitative measures of changes in world welfare. Despite these shortcomings, changes in Ricardian rents can provide useful information when other measures are not available. In this analysis, for example, estimated changes in Ricardian rents on all land indicate that climatic change would likely have detrimental effects in Latin America and Africa, beneficial effects in the former Soviet Union, and either detrimental or beneficial impacts in eastern and northern Europe and western and southern Asia. This is consistent with previous studies showing that climatic change would likely have detrimental, beneficial, and mixed effects on economic welfare in, respectively, equatorial, high latitude, and temperate areas. Estimated changes in Ricardian rents also indicate that aggregating Africa, Latin America, the former Soviet Union, eastern and northern Europe, and western and southern Asia into one region causes FARM's economic model to generate upwardly biased changes in world welfare. Modified results from scenarios with moderately flexible land-use change and which account for current land-use patterns indicate that world welfare may increase if the average surface land temperature does not increase by more than 1.0 or 2.0 degrees C. If the average surface land temperature increases by 3.0 degrees C or more, however, then world welfare may decline.

KEY: GLOBAL; COMPARISON OF RICARDIAN AND FARM MODELS

Because of many uncertainties, quantitative estimates of agriculturally related economic impacts of greenhouse gas emissions are often given low confidence. A major source of uncertainty is our inability to accurately project future changes in economic activity, emissions, and climate. This paper focuses on two issues. First, to what extent do variable projections of climate generate uncertainty in agriculturally related economic impacts? Second, to what extent do agriculturally related economic impacts of greenhouse gas emissions depend on economic conditions at the time of impacts? Results indicate that uncertainty due to variable projections of climate is fairly large for most of the economic effects evaluated in this analysis. Results also indicate that economic conditions at the time of impact influence the direction and size of as well as the confidence in the economic effects of identical projections of greenhouse gas impacts. The economic variable that behaves most consistently in this analysis is world crop production. Increases in mean global temperature, for example, cause world crop production to decrease on average under both 1990 and improved economic conditions and in both instances the confidence with respect to variable projections of climate is medium (e.g., 67%) or greater. In addition, and as expected, CO2 fertilization causes world crop production to increase on average under 1990 and improved economic conditions. These results suggest that crop production may be a fairly robust indicator of the potential impacts of greenhouse gas emissions. A somewhat unexpected finding is that improved economic conditions are not necessarily a panacea to potential greenhouse-gas-induced damages, particularly at the regional level. In fact, in some regions, impacts of climate change or CO2 fertilization that are beneficial under current economic conditions may be detrimental under improved economic conditions (relative to the new economic base). Australia plus New Zealand suffer from this effect in this analysis because under improved economic conditions they are assumed to obtain a relatively large share of income from agricultural exports. When the climate-change and CO2-fertilization scenarios in this analysis are also included, agricultural exports from Australia plus New Zealand decline on average. The resultant declines in agricultural income in Australia plus New Zealand are too large to be completely offset by rising incomes in other sectors. This indicates that regions that rely on agricultural exports for relatively large shares of their income may be vulnerable not only to direct climate-induced agricultural damages, but also to positive impacts induced by greenhouse gas emissions elsewhere.

KEY: GLOBAL; REVIEW


This study used the Ricardian approach that captures farmer adaptations to varying environmental factors to analyze the impact of climate change on crop farming in Ethiopia. By collecting data from farm households in different agro-ecological zones of the county, net crop revenue per hectare was regressed on climate, household and soil variables. The results show that these variables have a significant impact on the net crop revenue per hectare of farmers under Ethiopian conditions. The seasonal marginal impact analysis indicates that marginally increasing temperature during summer and winter would significantly reduce crop net revenue per hectare whereas marginally increasing precipitation during spring would significantly increase net crop revenue per hectare. Moreover, the net crop revenue impact of predicted climate scenarios from three models (CGM2, HaDCM3 and PCM) for the years 2050 and 2100 indicated that there would be a reduction in crop net revenue per hectare by the years 2050 and 2100. Moreover, the reduction in net revenue per hectare by the year 2100 would be more
than the reduction by the year 2050 indicating the damage that climate change would pose increases with time unless this negative impact is abated through adaptation. Additionally, results indicate that the net revenue impact of climate change is not uniformly distributed across the different agro-ecological zones of Ethiopia.

**KEY: ETHIOPIA; RICARDIAN ANALYSIS**


This paper measures the economic impact of climate change on US agricultural land by estimating the effect of random year-to-year variation in temperature and precipitation on agricultural profits. The preferred estimates indicate that climate change will increase annual profits by $1.3 billion in 2002 dollars (2002$) or 4 percent. This estimate is robust to numerous specification checks and relatively precise, so large negative or positive effects are unlikely. We also find the hedonic approach—which is the standard in the previous literature—to be unreliable because it produces estimates that are extremely sensitive to seemingly minor choices about control variables, sample, and weighting.

**KEY: US; ECONOMETRIC MODEL**


Using county-level data from the United States Department of Agriculture’s Census of Agriculture, this study evaluates the effect of weather and climate on agricultural profits in the State of California. The approach is to estimate revenue less variable production cost per acre as a function of land characteristics, weather realizations, and climate. This model is then used to evaluate the effect of two scenarios of climate change for the state of California over the coming century. The preferred estimates indicate that climate change is associated with a negative effect on aggregate agricultural profits by the end of the century. There are significant caveats to this result, including the lack of statistical precision, and keeping water supply and farm prices constant.

**KEY: CALIFORNIA; ECONOMETRIC MODEL**


Anthropogenic climate change does not only affect water resources but also water demand. Future water and food security will depend, among other factors, on the impact of climate change on water demand for irrigation. Using a recently developed global irrigation model, with a spatial resolution of 0.5degrees by 0.5degrees, we present the first global analysis of the impact of climate change and climate variability on irrigation water requirements. We compute how long-term average irrigation requirements might change under the climatic conditions of the 2020s and the 2070s, as provided by two climate models, and relate these changes to the variations in irrigation requirements caused by long-term and interannual climate variability in the 20th century. Two-thirds of the global area equipped for irrigation in 1995 will possibly suffer from increased water requirements, and on up to half of the total area (depending on the measure of variability), the negative impact of climate change is more significant than that of climate variability.

**KEY: GLOBAL; IRRIGATION CROP MODEL**

Water use assessments are a necessary prerequisite for sustainable water resources management and planning in river basins, federal states, or countries. For reasons of transparency, flexibility, ease of update, and the possibility to generate scenarios of future water use, such assessments are best carried out by applying a water use model. To support water resources planning in two federal states of semi-arid Northeastern Brazil, Ceara and Piaui, the regional-scale water use model NoWUM was developed. It computes withdrawal and consumptive water use for each of 332 municipalities, distinguishing five water use sectors: irrigation, livestock, households, industry, and tourism. The model is suited to simulate the impact of global change and of management measures on water demand. Using NoWUM, the present-day water use situation in Ceara and Piaui is assessed. In addition, the impact of inter-annual climate variability and long-term climate change on irrigation requirements is considered. Scarce and uncertain input data lead to a high level of uncertainty in the model results. It is likely that water use in the most important sector irrigation, is underestimated, while industrial water use is possibly overestimated. With some modifications, NoWUM has the potential to be applied for water use assessments in other data-poor regions of the globe.

KEY: BRAZIL; WATER USE MODEL


Short-term perspectives appear to be relevant in formulating adaptation measures to changed climate variability (CCV) as a part of the European Rural Development Policy (RDP). Indeed, short-run CCV is the variation that farmers would perceive to such an extent that a political demand would be generated for adapting support measures. This study evaluates some relevant agronomic and economic impacts of CCV as modelled in a near future time period at the catchment scale in a rural district in Sardinia (Italy). The effects of CCV are assessed in relation to the availability of irrigation water and the irrigation needs of maize. The Environmental Policy Integrated Climate (EPIC) model was used to simulate the impact of key climatic variables on the irrigation water requirements and yields of maize. A three-stage discrete stochastic programming model was then applied to simulate management and economic responses to those changes. The overall economic impact of a simulated CCV was found to be primarily caused by reduced stability in the future supply of irrigation water. Adaptations to this instability will most likely lead to a higher level of groundwater extraction and a reduction in the demand for labour. Changed climate variability will most likely reduce the income potential of small-scale farming. The most CCV-vulnerable farm typologies were identified, and the implications were discussed in relation to the development of adaptation measures within the context of the Common Agricultural Policy of European Union. (C) 2013 Elsevier Ltd. All rights reserved.

KEY: ITALY; PROCESS-BASED CROP MODEL


Climate change is anticipated to affect European agriculture, including the risk of emerging or re-emerging feed and food hazards. Indirectly, climate change may influence such hazards (e.g. the occurrence of mycotoxins) due to geographic shifts in the distribution of major cereal cropping systems and the consequences this may have for crop rotations. This paper analyses the impact of climate on cropping shares of maize, oat and wheat on a 50-km square grid across Europe (45-65 degrees N) and provides model-based estimates of the changes in cropping shares in response to changes in temperature and precipitation as projected for the time period...
around 2040 by two regional climate models (RCM) with a moderate and a strong climate change signal, respectively. The projected cropping shares are based on the output from the two RCMs and on algorithms derived for the relation between meteorological data and observed cropping shares of maize, oat and wheat. The observed cropping shares show a south-to-north gradient, where maize had its maximum at 45-55 degrees N, oat had its maximum at 55-65 degrees N, and wheat was more evenly distributed along the latitudes in Europe. Under the projected climate changes, there was a general increase in maize cropping shares, whereas for oat no areas showed distinct increases. For wheat, the projected changes indicated a tendency towards higher cropping shares in the northern parts and lower cropping shares in the southern parts of the study area. The present modelling approach represents a simplification of factors determining the distribution of cereal crops, and also some uncertainties in the data basis were apparent. A promising way of future model improvement could be through a systematic analysis and inclusion of other variables, such as key soil properties and socio-economic conditions, influencing the comparative advantages of specific crops.

KEY: EUROPE; RCM; CROPPING SHARE


There are many incentives for applying a crop model on a regional scale, i.e. over an area larger than that for which it has been developed. This is what we call "spatialising" a crop model. These large areas can have very heterogeneous soil, climate and management practices. Consequently, spatialising a crop model can raise serious problems. One set arises from the fact that the basic concepts, hypotheses and validity domains of crop models are derived on the plot scale and may not apply on a larger scale. Another set arises from the lack of adequate and sufficient data to run the model on a regional scale. The workshop held in Toulouse (France) on 14-15 January 2002 dealt with the topic of spatialising crop models. The present paper is a comprehensive summary of the thoughts we had before, during and after the workshop.

KEY: GLOBAL; REVIEW; REGIONAL CROP MODELS


This paper explores the relation between coffee production and climatic and economic variables in Veracruz in order to estimate the potential impacts of climate change. For this purpose, an econometric model is developed in terms of those variables. The model is validated by means of statistical analysis, and then used to project coffee production under different climatic conditions. Climate change scenarios are produced considering that the observed trends of climate variables will continue to prevail until the year 2020. An approach for constructing simple probability scenarios for future climate variability is presented and used to assess possible impacts of climate change beyond what is expected from changes in mean values. The model shows that temperature is the most relevant climatic factor for coffee production, since production responds significantly to seasonal temperature patterns. The results for the projected climate change conditions for year 2020 indicate that coffee production might not be economically viable for producers, since the model indicates a reduction of 34% of the current production. Although different economic variables (the state and international coffee prices, a producer price index for raw materials for coffee benefit, the national and the USA coffee stocks) were considered as potentially relevant, our model suggests that the state real minimum wage could be regarded as the most important economic variable. Real minimum wage is interpreted here as a proxy for the price of labor employed for coffee production. This activity in Mexico is very labor intensive representing up to 80% of coffee production costs. As expected,
increments in the price of such an important production factor increase production costs and have strong negative effects on production. Different assumptions on how real minimum wage could evolve for the year 2020 are considered for developing future production scenarios.


A methodology is described for estimating robustness of recommended farm plans under climate change while maintaining a meaningful representation of the underlying farm system. Monte Carlo Simulation (MCS) of crop yield data is used in conjunction with a fully specified farm-level model and output from a field worktime model. Estimates of farm net margin, enterprise mix (choice and area of enterprises), labour, machinery, storage and animal housing under mean crop yields and field worktimes for current (2000s) and 2050s conditions are generated. MCS is used to estimate the effect of crop yield variation on farm profitability and enterprise mix for the same periods by running the farm-level model with no constraints and running it constrained to the mean data plan. Estimates of robustness, measured as the percentage difference and the probability of exceeding the mean farm net-margin, were calculated from the outputs from these runs. For three representative farm types, mean farm net margin increased; however changes in robustness as shown by percentage difference in farm net margin depended on farm type while the probability of exceeding the mean plan net-margin decreased by 2050 indicating an increase in robustness. The most robust farm type had a diversified mix of enterprises and required no additional fixed resources by the 2050s. The least robust farm type was in a marginal location and mean plan recommendations for the 2050s required additional investment in fixed resources, particularly irrigation. It is concluded that the information provided by the methodology would be particularly useful to farmers: where mean data plans are not robust, MCS results could be used with financial planning techniques to minimise the impact of variability, rather than using high cost inputs to reduce variability per se.


When compared to the agronomic aspects of agriculture the contribution of climate is poorly integrated into the body of scientific knowledge in Ireland. It is known that specific crops grow well in specific regions and that success of a crop can be related to climate factors. The aim of this paper was to derive agroclimatic regions of Ireland using hydro-thermal climate (as expressed by climographs using mean monthly rainfall and temperature) in conjunction with a statistical clustering technique (k-means clustering) to relate crop yield, estimated using mathematical simulation models for grass, barley, maize, potato and soybean to hydro-thermal climate data. A dataset, on a <10 km×10 km grid, consisting of monthly radiation, rainfall, maximum temperature and minimum temperature was used to drive crop simulation models to predict average yields, for each grid square. Results showed that the crops simulated were sensitive to either available water or length of growing season. As there are few objective measures of the ideal number of clusters to use in order to create agroclimatic regions, clusterings to 3, 4 and 7 regions were evaluated against known properties of the Irish climate and crop responses. A seven cluster agroclimate region map was thought to be a good basis for describing Ireland’s agroclimates and was compared with climate data for the national synoptic station network. Results suggested a reasonably good correspondence between clusters and
their associated synoptic observation stations. Some anomalies were observed. The resulting agroclimatic map could be used for extrapolation of empirical research findings, for agri-environmental experimental design and as a framework for assessment of the impact of climate change on Irish agriculture. [Copyright &y& Elsevier]

KEY: IRELAND; PRODUCTION FUNCTION CROP MODEL


This paper describes calibration methods for models of agricultural production and water use in which economic variables can directly interact with hydrologic network models or other biophysical system models. We also describe and demonstrate the use of systematic calibration checks at different stages for efficient debugging of models. The central model is the California Statewide Agricultural Production Model (SWAP), a Positive Mathematical Programming (PMP) model of California irrigated agriculture. We outline the six step calibration procedure and demonstrate the model with an empirical policy analysis. Two new techniques are included compared with most previous PMP-based models: exponential PMP cost functions and Constant Elasticity of Substitution (CES) regional production functions. We then demonstrate the use of this type of disaggregated production model for policy analysis by evaluating potential water transfers under drought conditions. The analysis links regional production functions with a water supply network. The results show that a more flexible water market allocation can reduce revenue losses from drought up to 30%. These results highlight the potential of self-calibrated models in policy analysis. While the empirical application is for a California agricultural and environmental water system, the approach is general and applicable to many other situations and locations. (C) 2012 Elsevier Ltd. All rights reserved.

KEY: CALIFORNIA; PRODUCTION FUNCTION MODEL; CALIBRATION METHODS


Climate change inevitably leads to large regional variations in risks and opportunities and is likely to affect most farmers in the Mediterranean in the next decades. The interpretation of climate projections to determine appropriate policy responses is not without difficulties, such as understanding local uncertainty and responses of specific crops to sets of conditions. Here we analyse the potential impacts of climate on agriculture in the Mediterranean—a region that exemplifies other regions of the world that are prone to drought and are likely to experience increased frequency and intensity of droughts in the future. Our analysis relies on understanding the sources of uncertainty derived from climate scenarios, agricultural systems, impact responses and risk levels to support informed decisions for planned agricultural adaptation. We generated multiple projections of impacts based on different models of climate change and crop response in order to capture uncertainties. We used statistical models of yield response and projections of climate change generated from 16 climate scenarios to address the likelihood of projected impacts on traditional Mediterranean farming systems, represented in this study by cereals, grapes, olives and citrus. Results show that uncertainty varies widely by crop and location, and adaptation priorities will therefore depend on the risk focus of adaptation plans.

KEY: SPAIN; PROCESS-BASED CROP MODEL


This paper develops an econometric model of stochastic production functions to quantify the
impacts of climatic variables on the mean, variance, and covariance of crop yields. The estimates of the production function parameters and their elasticities are utilized to analyse the impacts of the projected climate change on agriculture. The results show that the climate change will have modest effects on the mean crop yields, but will significantly reduce the variance and covariance for most of the crops considered. The results have implications for allocations of agricultural land among crops and for crop production mix.

KEY: PRODUCTION FUNCTION CROP MODEL


This paper measures the economic impact of climate on crops in Kenya. The analysis is based on cross-sectional climate, hydrological, soil, and household level data for a sample of 816 households, and uses a seasonal Ricardian model. Estimated marginal impacts of climate variables suggest that global warming is harmful for agricultural productivity and that changes in temperature are much more important than changes in precipitation. This result is confirmed by the predicted impact of various climate change scenarios on agriculture. The results further confirm that the temperature component of global warming is much more important than precipitation. The authors analyze farmers' perceptions of climate variations and their adaptation to these, and also constraints on adaptation mechanisms. The results suggest that farmers in Kenya are aware of short-term climate change, that most of them have noticed an increase in temperatures, and that some have taken adaptive measures.

KEY: KENYA; RICARDIAN MODEL


Measurement of the likely magnitude of the economic impact of climate change on African agriculture has been a challenge. Using data from a survey of more than 9,000 farmers across 11 African countries, a cross-sectional approach estimates how farm net revenues are affected by climate change compared with current mean temperature. Revenues fall with warming for dryland crops (temperature elasticity of -1.9) and livestock (-5.4), whereas revenues rise for irrigated crops (elasticity of 0.5), which are located in relatively cool parts of Africa and are buffered by irrigation from the effects of warming. At first, warming has little net aggregate effect as the gains for irrigated crops offset the losses for dryland crops and livestock. Warming, however, will likely reduce dryland farm income immediately. The final effects will also depend on changes in precipitation, because revenues from all farm types increase with precipitation. Because irrigated farms are less sensitive to climate, where water is available, irrigation is a practical adaptation to climate change in Africa.

KEY: AFRICA; RICARDIAN MODEL


This study analyzes the impacts of climate change on maize yields using an econometric model that incorporates climate, economic, and technology variables. The major finding is climate change will not universally cause negative impacts of maize yields in the United States and China. The results of a simulation of climate change on maize yields over the period 2008-2030 show that a combination of changes in temperature and precipitation can either bring positive or negative effects on maize yields. Furthermore, variation in regional climatic and economic conditions makes the impacts of climatic change on maize yields substantially different in
different regions. In this research, the impacts of climate change on maize yields are not simply
examined by climate factors. Economic and technology adaptation effects on maize yields are
also incorporated. Thus, even with significant changes in climate conditions that alter the maize
crop’s growing environment and affect crop yields, a decrease in maize supply due to a decrease
in maize yields would lead to an increase in the maize price, which in turn would induce farmers
to add more investments in production inputs to raise yields. Thus, the decrease in actual yields
may not be as dramatic as predicted in only climate factor considered cases. In this research,
findings gained from the study can be used for early-staged policymaking decisions and
advanced problem prevention programs. To ensure the continuous increase in maize yields in
the future, further studies and research, as well as efficient environmental policies and actions
are required. (C) 2010 Elsevier Ltd. All rights reserved.

KEY: CHINA; ECONOMETRIC MODEL

Lippert, C., et al. (2009). "A Ricardian analysis of the impact of climate change on agriculture in
Germany." Climatic Change 97(3-4): 593-610.

Based on a Ricardian analysis accounting for spatial autocorrelation and relying on recent
climate change forecasts at a low spatial scale, this study assesses the impact of climate change
on German agriculture. Given the limited availability of data (e.g., the unknown average soil
quality at the district level), a spatial error model is used in order to obtain unbiased marginal
effects. The Ricardian analysis is performed using data from the 1999 agricultural census along
with data from the network of German weather observation stations. The cross-sectional
analysis yields an increase of land rent along with both a rising mean temperature and a
decreasing spring precipitation, except for in the Eastern part of the country. The subsequent
simulation of local land rent changes under three different IPCC scenarios is done by entering
into the estimated regression equations spatially processed data averages for the period
between 2011 and 2040 from the regional climate model REMO. The resulting expected benefits
arising from climate change are represented in maps containing the 439 German districts; the
calculated overall rent increase corresponds to approximately 5-6% of net German agricultural
income. However, in the long run, when temperature and precipitation changes will be more
severe than those simulated for 2011-2040, income losses for German agriculture cannot be
excluded.

KEY: GERMANY; RICARDIAN MODEL


Changes in the global production of major crops are important drivers of food prices, food
security and land use decisions. Average global yields for these commodities are determined by
the performance of crops in millions of fields distributed across a range of management, soil and
climate regimes. Despite the complexity of global food supply, here we show that simple
measures of growing season temperatures and precipitation - spatial averages based on the
locations of each crop - explain similar to 30% or more of year-to-year variations in global
average yields for the world's six most widely grown crops. For wheat, maize and barley, there is
a clearly negative response of global yields to increased temperatures. Based on these
sensitivities and observed climate trends, we estimate that warming since 1981 has resulted in
annual combined losses of these three crops representing roughly 40 Mt or $5 billion per year,
as of 2002. While these impacts are small relative to the technological yield gains over the same
period, the results demonstrate already occurring negative impacts of climate trends on crop
yields at the global scale.

We measure the economic impact of climate on land prices. Using cross-sectional data on climate, farmland prices, and other economic and geophysical data for almost 3,000 counties in the United States, we find that higher temperatures in all seasons except autumn reduce average farm values, while more precipitation outside of autumn increases farm values. Applying the model to a global-warming scenario shows a significantly lower estimated impact of global warming on U.S. agriculture than the traditional production-function approach and, in one case, suggests that, even without CO2 fertilization, global warming may have economic benefits for agriculture.


In this analysis, we undertake a comparative Ricardian analysis of agriculture between Canada and the United States. We find that the climate responses of the two countries are similar but statistically different despite the fact that the two countries are neighbors. Comparing the marginal impacts of climate change, we find that Canadian agriculture is unaffected by warmer temperatures but would benefit from more precipitation. US farms are much more sensitive to higher temperatures and benefit relatively less from increased precipitation. These marginal results were anticipated given that Canadian farms are generally cooler and drier than American farms.


The agriculture of some areas considered marginal in the EU agricultural context is being questioned due to its low productivity and growing dependence on economic aid programs Common Agricultural Policy (CAP). This study shows that climate change increases these areas marginalisation of since worsens crop growth conditions. The influence of climate change on the agricultural sector is analyzed using the Multicriteria Decision Paradigm with information provided by the Erosion-Productivity Impact Calculator (EPIC) and a General Circulation Model (GCM) as inputs for multicriteria mathematical programming models. The results obtained show climate change effects on the crop portfolio. Further results suggest that climate change effects are not only economics and environmental, reducing the suitable area for crops, but also social as it causes loss of jobs in the agricultural sector. (C) 2008 Elsevier B.V. All rights reserved.


This paper reviews the knowledge on effects of climate change on agricultural productivity in Europe and the consequences for policy and research. Warming is expected to lead to a northward expansion of suitable cropping areas and a reduction of the growing period of determinate crops (e.g. cereals), but an increase for indeterminate crops (e.g. root crops). Increasing atmospheric CO2 concentrations will directly enhance plant productivity and also increase resource use efficiencies. In northern areas climate change may produce positive
effects on agriculture through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation. Disadvantages may be an increase in the need for plant protection, the risk of nutrient leaching and the turnover of soil organic matter. In southern areas the disadvantages will predominate. The possible increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops. These effects may reinforce the current trends of intensification of agriculture in northern and western Europe and extensification in the Mediterranean and southeastern parts of Europe. Policy will have to support the adaptation of European agriculture to climate change by encouraging the flexibility of land use, crop production, farming systems etc. In doing so, it is necessary to consider the multifunctional role of agriculture, and to strike a variable balance between economic, environmental and social functions in different European regions. Policy will also need to be concerned with agricultural strategies to mitigate climate change through a reduction in emissions of methane and nitrous oxide, an increase in carbon sequestration in agricultural soils and the growing of energy crops to substitute fossil energy use. The policies to support adaptation and mitigation to climate change will need to be linked closely to the development of agri-environmental schemes in the European Union Common Agricultural Policy. Research will have further to deal with the effect on secondary factors of agricultural production, on the quality of crop and animal production, of changes in frequency of isolated and extreme weather events on agricultural production, and the interaction with the surrounding natural ecosystems. There is also a need to study combined effects of adaptation and mitigation strategies, and include assessments of the consequences on current efforts in agricultural policy to develop a sustainable agriculture that also preserves environmental and social values in the rural society.

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KEY: EUROPE; REVIEW


A simulation model of the direct effects of climate on winter wheat production and grain yield is presented. The model was calibrated using data from field experiments in Denmark. The model was validated using data from near optimally managed experimental plots with winter wheat from The Netherlands and Denmark. The model was further evaluated using data from 1971 to 1997 for 7 sites in Denmark. The model explained from 0 to 20% of the variation in detrended observed yields, depending on soil type. A regression analysis of observed yields against monthly climate data showed a positive effect of temperature in October, November and January on grain yield, a positive effect of radiation in April and a strongly negative effect of precipitation in July. Only the positive effect of radiation in April was predicted by the simulation model, probably because the indirect effects of climate are not taken into account by the model (e.g. effects of rainfall on lodging or Septoria disease). The sensitivity of simulated grain yield to changes in mean temperature, temperature variability, precipitation, length of dry spells and CO2 concentration was analysed for 4 soil types using generated climate data from 1 site in Denmark. Yield decreased with increasing temperature. This decrease was strongly non-linear with temperature: change when using a fixed sowing date, but almost linear for the optimal sowing date. There was only a very small response to changes in temperature variability. Increasing precipitation increased yields with the largest response on the sandy soils. Large changes in grain yield were also seen on sandy soils with changes in the length of dry spells. A comparison of the simulated responses to the direct effects of temperature and rainfall with those to the indirect effects of these variables as estimated from the regression analysis showed
that the indirect and the direct effects had opposite effects and that they may almost cancel each other out. The simulated increase in grain yield due to increasing CO2 concentration in most cases exceeded the simulated responses to changes in climate variables.

KEY: DENMARK; PROCESS-BASED CROP MODEL


This paper analyses the global consequences to crop yields, production, and risk of hunger of linked socio-economic and climate scenarios. Potential impacts of climate change are estimated for climate change scenarios developed from the HadCM3 global climate model under the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) A1FI, A2, B1, and B2. Projected changes in yield are calculated using transfer functions derived from crop model simulations with observed climate data and projected climate change scenarios. The basic linked system (BLS) is used to evaluate consequent changes in global cereal production, cereal prices and the number of people at risk from hunger. The crop yield results elucidate the complex regional patterns of projected climate variables, CO2 effects, and agricultural systems that contribute to aggregations of global crop production. The A1FI scenario, as expected with its large increase in global temperatures, exhibits the greatest decreases both regionally and globally in yields, especially by the 2080s. The contrast between the yield change in developed and developing countries is largest under the A2a-c scenarios. Under the 131 and B2 scenarios, developed and developing countries exhibit less contrast in crop yield changes, with the B2 future crop yield changes being slightly more favourable than those of the B1 scenario. When crop yield results are introduced to the BLS world food trade system model, the combined model and scenario experiments demonstrate that the world, for the most part, appears to be able to continue to feed itself under the SRES scenarios during the rest of this century. However, this outcome is achieved through production in the developed countries (which mostly benefit from climate change) compensating for declines projected, for the most part, for developing nations. While global production appears stable, regional differences in crop production are likely to grow stronger through time, leading to a significant polarisation of effects, with substantial increases in prices and risk of hunger amongst the poorer nations, especially under scenarios of greater inequality (A1FI and A2). The use of the SRES scenarios highlights several non-linearities in the world food supply system, both in the biophysical sense, where the levels of atmospheric CO2 tested reach new levels, and the socio-economic sense, where changes in population dynamics and economic and political structures complicate the translation of biophysical climate change impacts into social indices, such as the number of people at risk of hunger. (C) 2003 Elsevier Ltd. All rights reserved.

KEY: GLOBAL; PRODUCTION FUNCTION CROP MODEL


This research estimates the impact of climate on European agriculture using a continental scale Ricardian analysis. Data on climate, soil, geography and regional socio-economic characteristics were matched for 37612 individual farms across the EU-15. Farmland values across Europe are sensitive to climate. Even with the adaptation captured by the Ricardian technique, farms in Southern Europe are predicted to suffer sizeable losses (8%-13% per degree Celsius) from warming. In contrast, agriculture in the rest of Europe is likely to see only mixed impacts. Increases (decreases) in rain will increase (decrease) average farm values by 3% per centiliter of
precipitation. Aggregate impacts by 2100 vary depending on the climate model scenario from a loss of 8% in a mild scenario to a loss of 44% in a harsh scenario. The present report has been prepared as part of the activities of WP 7.1.3 "Cooperazione Italia-USA sugli aspetti socio-economici delle attività di adattamento (Yale University)" of the GEMINA project. The authors would kindly want to express their gratitude towards DG AGRI for access to the Farm Accountancy Data Network (FADN). Steven Van Passel thanks FWO for funding his research stay at Yale university. Steven Van Passel is also obliged to the OECD for awarding a fellowship of the co-operative research program "Biological Resource Management for Sustainable Agricultural Systems". Emanuele Massetti kindly acknowledges financial support from the International Outgoing Marie Curie Fellowship "Cli-EMA" sponsored by the FP7 of the European Union and the GEMINA project.

KEY: EUROPE; RICARDIAN MODEL


The "Ricardian" technique for projecting climate change impacts on agriculture has generated an unusual amount of critical attention. Ricardian climate sensitivities are typically viewed as the necessary and static result of exclusively local economic and biophysical conditions. In this paper, six spatial econometric models are estimated to explore how human-environment relationships associated with climate sensitivities have varied over space and time in the Great Plains, 1969-1992. Results indicate that spatial effects, such as extra-local communication processes and proximity to and regulation of Ogallala irrigation water, are important influences on climate sensitivities. Projected climate change impacts also vary significantly with the scale, location, and time of analysis. Under a hypothetical climate change, at the county scale, land values would decline (by up to one-third) in the western counties, but increase (by up to one-half) in the eastern counties. In some cases, the projected impacts for a given county change algebraic sign or order of magnitude during the study period. At the regional scale, impacts are significantly higher in the early years (a projected increase of about 5 percent of regional land values, similar to $7 billion [1992$]) than in the later years (an increase of about one-half of one percent, similar to $0.7 billion). These results suggest that, suitably modified, the Ricardian framework can be used constructively to explore subtle yet important social dimensions of dynamic climate risk, and that on balance the Great Plains system of agricultural production, despite a heterogeneous picture of projected impacts, appears to be increasingly vulnerable to the effects of climate change.

KEY: US GREAT PLAINS; RICARDIAN ANALYSIS


Increasing competition for water across sectors increases the importance of the river basin as the appropriate unit of analysis to address the challenges facing water resources management; and modeling at this scale can provide essential information for policymakers in their resource allocation decisions. This paper introduces an integrated economic-hydrologic modeling framework that accounts for the interactions between water allocation, farmer input choice, agricultural productivity, non-agricultural water demand, and resource degradation in order to estimate the social and economic gains from improvement in the allocation and efficiency of water use. The model is applied to the Maipo river basin in Chile. Economic benefits to water use are evaluated for different demand management instruments, including markets in tradable water rights, based on production and brnt fit functions with respect to water fur the

This integrated study examines the implications of changes in crop water demand and water availability for the reliability of irrigation, taking into account changes in competing municipal and industrial demands, and explore the effectiveness of adaptation options in maintaining reliability. It reports on methods of linking climate change scenarios with hydrologic, agricultural and planning models to study later availability for agriculture under changing climate conditions, to estimate changes in ecosystem services, and to evaluate adaptation strategies for the water resources and agriculture sectors. The models are applied to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US, using projections of climate change, agricultural production, population, technology, and GDP growth. For most of the relatively water-rich areas studied, there appears to be sufficient water for agriculture given the climate change scenarios tested. Northeastern China suffers from the greatest lack of water availability for agriculture and ecosystem services both in the present and in the climate change projections. Projected runoff in the Danube Basin does not change substantially, although climate change causes shifts in environmental stresses within the region. Northern Argentina's occasional problems in water-supply for agriculture under the current climate may be exacerbated and may require investments to relieve future tributary stress. In Southeastern Brazil, future water supply for agriculture appears to be plentiful. Water supply in most of the US Cornbelt is projected to increase in most climate change scenarios, but there is concern for tractability in the spring and water-logging in the summer. Adaptation tests imply that only file Brazil case study area can readily accommodate an expansion of irrigated land under climate change. while the other three areas would suffer decreases in system reliability if irrigation areas were to be expanded. Cultivars are available for agricultural adaptation to file projected changes, but their demand for water may be higher than currently adapted varieties. Thus, even in these relatively water-rich areas, changes in water demand due to climate change effects on agriculture and increased demand from urban growth will require timely improvements in crop cultivars, irrigation and drainage technology, and water management. Published by Elsevier Ltd.


In West Africa, agriculture, mainly rainfed, is a major economic sector and the one most vulnerable to climate change. A meta-database of future crop yields, built up from 16 recent studies, is used to provide an overall assessment of the potential impact of climate change on yields, and to analyze sources of uncertainty. Despite a large dispersion of yield changes ranging from -50% to +90%, the median is a yield loss near -11%. This negative impact is assessed by both empirical and process-based crop models whereas the Ricardian approach gives very contrasted results, even within a single study. The predicted impact is larger in northern West Africa (Sudano-Saharan countries, -18% median response) than in southern West Africa (Guinean countries, -13%) which is likely due to drier and warmer projections in the northern part of West Africa. Moreover, negative impacts on crop productivity increase in severity as warming intensifies, with a median yield loss near -15% with most intense warming, highlighting the importance of global warming mitigation. The consistently negative impact of climate
change results mainly from the temperature whose increase projected by climate models is much larger relative to precipitation change. However, rainfall changes, still uncertain in climate projections, have the potential to exacerbate or mitigate this impact depending on whether rainfall decreases or increases. Finally, results highlight the pivotal role that the carbon fertilization effect may have on the sign and amplitude of change in crop yields. This effect is particularly strong for a high carbon dioxide concentration scenario and for C3 crops (e.g. soybean, cassava). As staple crops are mainly C4 (e.g. maize, millet, sorghum) in WA, this positive effect is less significant for the region. (C) 2011 Elsevier Ltd. All rights reserved.

KEY: WEST AFRICA; REVIEW


We link farmland values to climatic, soil, and socioeconomic variables for U. S. counties east of the 100th meridian, the historical boundary of agriculture not primarily dependent on irrigation. Degree days, a nonlinear transformation of the climatic variables suggested by agronomic experiments as more relevant to crop yield, gives an improved fit and increased robustness. Estimated coefficients are consistent with the experimental results. The model is employed to estimate the potential impacts on farmland values for a range of recent warming scenarios. The predictions are very robust, and more than 75% of the counties in our sample show a statistically significant effect, ranging from moderate gains to large losses, with losses in the aggregate that can become quite large under scenarios involving sustained heavy use of fossil fuels.

KEY: US; NON-IRRIGATED AGRICULTURE; ECONOMETRIC MODEL


The United States produces 41% of the world's corn and 38% of the world's soybeans. These crops comprise two of the four largest sources of caloric energy produced and are thus critical for world food supply. We pair a panel of county-level yields for these two crops, plus cotton (a warmer-weather crop), with a new fine-scale weather dataset that incorporates the whole distribution of temperatures within each day and across all days in the growing season. We find that yields increase with temperature up to 29 degrees C for corn, 30 degrees C for soybeans, and 32 degrees C for cotton but that temperatures above these thresholds are very harmful. The slope of the decline above the optimum is significantly steeper than the incline below it. The same nonlinear and asymmetric relationship is found when we isolate either time-series or cross-sectional variations in temperatures and yields. This suggests limited historical adaptation of seed varieties or management practices to warmer temperatures because the cross-section includes farmers' adaptations to warmer climates and the time-series does not. Holding current growing regions fixed, area-weighted average yields are predicted to decrease by 30-46% before the end of the century under the slowest (B1) warming scenario and decrease by 63-82% under the most rapid warming scenario (A1FI) under the Hadley III model.

KEY: US; ECONOMETRIC MODEL


Crop simulation models are used widely to predict crop growth and development in studies of the impact of climatic change. An important problem is the uncertainty inherent in the
construction of the future weather scenarios used as inputs to models. In seeking to couple meteorological information to crop-climate models it must be remembered that many interactions between crops and weather are non-linear. Non-linearity of response means it is necessary to preserve the variability of weather sequences to estimate the effect of climate on agricultural production and to assess agricultural risk. To date, only changes in average weather parameters derived from general circulation models (GCMs) and then applied to historical data have been used to construct climatic change scenarios and in only a few studies were changes in climatic variability incorporated. Accordingly, a computer system, AFRCWHEAT 3S, was designed to couple the simulation crop model for wheat, AFRCWHEAT2, with a stochastic weather generator based on the series approach. AFRCWHEAT 3S provides flexible construction of climatic scenarios and allows changes not only in mean values but also in the variance or type of distribution for a wide variety of weather parameters. Analyses of sensitivity to changes in the variability of temperature and precipitation, as compared with changes in their mean values, were made for locations in the UK and France for winter wheat. Results indicated that changes in climatic variability can have a more profound effect on yield and its associated risk than changes in mean climate.

KEY: UK; FRANCE; PROCESS-BASED CROP MODEL


A comparison of the performance of 5 wheat models (AFRCWHEAT2, CERES, NWHEAT, SIRIUS and SOILN) was carried out for 2 sites in Europe: Rothamsted, UK, and Seville, Spain. The aims of this study were (1) to compare predictions of wheat models for climate change scenarios, and (2) to investigate the effects of changes in climatic variability in climate change scenarios on model predictions. Simulations were run for climate change scenarios derived from a number of 2 x CO2 equilibrium and transient GCM (global circulation model) experiments. For most climate change scenarios the model results were broadly similar. Where results differed, much of the difference could be explained by model sensitivity to climate and differences in initial conditions. Transient scenarios without changes in climatic variability usually resulted in large yield increases for Rothamsted and in nil to large yield increases for Seville. Incorporation of changed climatic variability in the transient scenario had a more profound effect on grain yield and resulted in a substantial decrease in mean yield with a strong increase in yield variation at Seville. This was associated with the changes in the duration of dry spells and a redistribution of precipitation over the vegetation period. The results show that future studies of the effect of climate change on crop yields must consider changes in climatic variability as well as changes in mean climate.

KEY: UK; SPAIN; COMPARISON OF PROCESS-BASED CROP MODELS


This study estimates the vulnerability of Latin American agriculture to climate change using a Ricardian analysis of both land values and net revenues. Examining a sample of over 2200 farms, the results indicate both land value and net revenue are sensitive to climate. Both small farms and large farms have a hill-shaped relationship with temperature. Estimating separate regressions for rainfed and irrigated farms reveals that rainfed farms are more sensitive to temperature but irrigated farms are more sensitive to precipitation. Examining the impacts from future climate change scenarios reveals that severe scenarios could reduce farm earnings by as much as 62% by 2100 whereas more moderate scenarios could reduce earnings by about 15%.
Small and large farms are equally sensitive to global warming. Land value and net revenue analyses produce quite similar results.

KEY: LATIN AMERICA; RICARDIAN ANALYSIS


The arid and semi-arid regions account for approximately 30% of the world total area and are inhabited by approximately 20% of the total world population. Issues of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics of the world were examined and discussion under each of these issues had been presented separately for Asia, Africa and Latin America. Several countries in tropical Asia have reported increasing surface temperature trends in recent decades. Although, there is no definite trend discernible in the long-term mean for precipitation for the tropical Asian region, many countries have shown a decreasing trend in rainfall in the past three decades. African rainfall has changed substantially over the last 60 yr and a number of theoretical, modelling and empirical analyses have suggested that noticeable changes in the frequency and intensity of extreme events, including floods may occur when there are only small changes in climate. Climate in Latin America is affected by the El Niño southern oscillation (ENSO) phases and there is a close relationship between the increase and decrease of rainfall depending upon the warm or cold phases of the phenomenon. Over land regions of Asia, the projected area-averaged annual mean warming is likely to be 1.6 +/- 0.2 degrees C in the 2020s, 3.1 +/- 0.3 degrees C in the 2050s, and 4.6 +/- 0.4 degrees C in the 2080s and the models show high uncertainty in projections of future winter and summer precipitation. Future annual warming across Africa is projected to range from 0.2 degrees C per decade to more than 0.5 degrees C per decade, while future changes in mean seasonal rainfall in Africa are less well defined. In Latin America, projections indicate a slight increase in temperature and changes in precipitation. Impacts of climate variability and changes are discussed with suitable examples. Agricultural productivity in tropical Asia is sensitive not only to temperature increases, but also to changes in the nature and characteristics of monsoon. Simulations of the impacts of climate change using crop simulation models show that crop yield decreases due to climate change could have serious impacts on food security in tropical Asia. Climate change is likely to cause environmental and social stress in many of Asia's rangelands and drylands. In the arid and 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. Impacts were described as those related to projected temperature increases, the possible consequences to water balance of the combination of enhanced temperatures and changes in precipitation and sensitivity of different crops/cropping systems to projected changes. In Latin America, agriculture and water resources are most affected through the impact of extreme temperatures (excessive heat, frost) and the changes in rainfall (droughts, flooding). Adaptation potential in the arid and semi-arid tropics of Asia, Africa and Latin America was described using suitable examples. It is emphasized that approaches need to be prescriptive and dynamic, rather than descriptive and static.

KEY: GLOBAL; REVIEW


Any change in climate will have implications for climate-sensitive systems such as agriculture, forestry, and some other natural resources. With respect to agriculture, changes in solar
radiation, temperature, and precipitation will produce changes in crop yields, crop mix, cropping systems, scheduling of field operations, grain moisture content at harvest, and hence, on the economics of agriculture including changes in farm profitability. Such issues are addressed for 10 representative agricultural areas across the midwestern Great Lakes region, a five-state area including Indiana, Illinois, Ohio, Michigan, and Wisconsin. This region is one of the most productive and important agricultural regions in the world, with over 61% of the land use devoted to agriculture. Individual crop growth processes are affected differently by climate change. A seasonal rise in temperature will increase the developmental rate of the crop, resulting in an earlier harvest. Heat stress may result in negative effects on crop production. Conversely, increased rainfall in drier areas may allow the photosynthetic rate of the crop to increase, resulting in higher yields. Properly validated crop simulation models can be used to combine the environmental effects on crop physiological processes and to evaluate the consequences of such influences. With existing hybrids, an overall pattern of decreasing crop production under scenarios of climate change was found, due primarily to intense heat during the main growth period. However, the results changed with the hybrid of maize (Zen Inngs L.) being grown and the specific location in the study region. In general, crops grown in sites in northern states had increased yields under climate change, with those grown in sites in the southern states of the region having decreased yields under climate change. Yields from long-season maize increased significantly in the northern part of the study region under future climate change. Across the study region, long-season maize performed most successfully under future climate scenarios compared to current yields, followed by medium-season and then short-season varieties. This analysis highlights the spatial variability of crop responses to changed environmental conditions. In addition, scenarios of increased climate variability produced diverse yields on a year-to-year basis and had increased risk of a low yield. Results indicate that potential future adaptations to climate change for maize yields would require either increased tolerance of maximum summer temperatures in existing maize varieties or a change in the maize varieties grown. (C) 2000 Elsevier Science B.V. All rights reserved.

KEY: MIDWESTERN US; REVIEW

In this paper, a new methodology for global estimation of crop productivity is proposed. This methodology integrates Erosion Productivity Impact Calculator (EPIC) model with Geographic Information System (GIS) and Inference Engine (IE) technique. EPIC was developed by USDA to analyze the relationship between soil erosion and agricultural productivity just at field level. With the integration of GIS, EPIC can be extended to the application of global or regional level. In this integration, IE is developed to determine possible crop combinations, the optimum starting and ending dates of growth cycle for each crop type and grid cell, in order to ensure best possible crop yields for both rain-fed and irrigated conditions. A case of global crop productivity estimation is tested with GIS-based EPIC in 2000. National averages are computed to be comparable to yields in FAO statistics. The comparison indicates that the GIS-based EPIC is able to simulate crop productivity at global level. In addition, with the global climate change data provided by the Intergovernment Panel on Climate Change (IPCC) from the first version of the Canadian Global Coupled Model (CGCM1), GIS-based EPIC is run for scenarios of future climate in the year of 2010, 2020, 2030, 2040, and 2050 to predict the effects of global warming on main crop yields. Results show the global warming will be harmful for most of the countries, and an efficient adaptation to alternative climates tends to reduce the damages. (C) 2003 Elsevier Science B.V. All rights reserved.

KEY: GLOBAL; PROCESS-BASED MODEL

The potential effects of future climate change were investigated, corresponding to a doubling of atmospheric CO2 from 350 to 700 ppm, on agricultural production of four different cropping systems at two Italian locations, Modena and Foggia. Climate change scenarios, derived from two general circulation models (GCMs), were used as weather input to a soil-plant growth simulator, CropSyst. This model was recently modified to include the effects of elevated CO2 on crop photosynthesis and transpiration. Six different crops in total were simulated at the two Italian sites. At Modena, a 3-year maize-maize-wheat rotation and a 2-year soybean-barley-summer sorghum rotation were studied. At Foggia, a 2-year sunflower-wheat-fallow rotation, and a 2-year wheat-fallow-sorghum rotation were simulated. Results suggested that the combined effects of elevated atmospheric CO2 and climate change at both sites would depress crop yields if current management practices were not modified. Specifically, predicted warmer air temperatures accelerated plant phenology, reducing dry matter accumulation and crop yields by 10-40%. By investigating adaptation strategies, it was found that a combination of early planting for spring-summer crops and the use of slower-maturing winter cereal cultivars succeeds in maintaining crop yields at current levels at both sites. For irrigated maize and soybean production at Modena, 60-90% more irrigation water was required under climate change to keep grain yields at current levels. This implies that adaptation to climate change may be limited for irrigated crops, depending on site-specific water availability. (C) 2000 Elsevier Science B.V. All rights reserved.

KEY: ITALY; SOIL-PLANT GROWTH SIMULATOR


Several studies addressing the supply and demand for food in China suggest that the nation can largely meet its needs in the coming decades. However, these studies do not consider the effects of climate change. This paper examines whether near future expected changes in climate are likely to alter this picture. The authors analyze the effect of temperature and precipitation on net crop revenues using a cross section consisting of both rainfed and irrigated farms. Based on survey data from 8,405 households across 28 provinces, the results of the Ricardian analysis demonstrate that global warming is likely to be harmful to China but the impacts are likely to be very different in each region. The mid latitude region of China may benefit from warming but the southern and northern regions are likely to be damaged by warming. More precipitation is beneficial to Chinese farmers except in the wet southeast. Irrigated and rain red farmers have similar responses to precipitation but not to temperature. Warmer temperatures may benefit irrigated farms but they are likely to harm rainfed farms. Finally, seasonal effects vary and are offsetting. Although we were able to measure the direct effect of precipitation and temperature, we could not capture the effects of change in water How which will be very important in China. Can China continue feeding itself if climate changes? Based on the empirical results, the likely gains realized by some farmers will nearly offset the losses that will occur to other farmers in China. If future climate scenarios lead to significant reductions in water, there may be large damages not addressed in this study.

KEY: CHINA; RICARDIAN MODEL


Ecophysiological models are widely used to forecast potential impacts of climate change on
We reviewed 221 peer-reviewed papers that used crop simulation models to examine diverse aspects of how climate change might affect agricultural systems. Six subject areas were examined: target crops and regions; the crop model(s) used and their characteristics; sources and application of data on [CO(2)] and climate; impact parameters evaluated; assessment of variability or risk; and adaptation strategies. Wheat, maize, soybean and rice were considered in approximately 170 papers. The USA (55 papers) and Europe (64 papers) were the dominant regions studied. The most frequent approach used to simulate response to CO(2) involved adjusting daily radiation use efficiency (RUE) and transpiration, precluding consideration of the interacting effects of CO(2), stomatal conductance and canopy temperature, which are expected to exacerbate effects of global warming. The assumed baseline [CO(2)] typically corresponded to conditions 10-30 years earlier than the date the paper was accepted, exaggerating the relative impacts of increased [CO(2)]. Due in part to the diverse scenarios for increases in greenhouse gas emissions, assumed future [CO(2)] also varied greatly, further complicating comparisons among studies. Papers considering adaptation predominantly examined changes in planting dates and cultivars; only 20 papers tested different tillage practices or crop rotations. Risk was quantified in over half the papers, mainly in relation to variability in yield or effects of water deficits, but the limited consideration of other factors affecting risk beside climate change per se suggests that impacts of climate change were overestimated relative to background variability. A coordinated crop, climate and soil data resource would allow researchers to focus on underlying science. More extensive model intercomparison, facilitated by modular software, should strengthen the biological realism of predictions and clarify the limits of our ability to forecast agricultural impacts of climate change on crop production and associated food security as well as to evaluate potential for adaptation. Published by Elsevier B.V.

KEY: GLOBAL; REVIEW


The effects of climate change (for the year 2050 compared to ambient climate) and change in climatic variability on potato growth and production at 6 sites in Europe were calculated. These calculations were done with both a simple growth model, POTATOS, and a comprehensive model, NPOTATO. Comparison of the results from both models indicated the sort of climate change conditions in which model results differed and may become less reliable. The effectiveness of possible management responses to climate change and the uncertainty in the model results were also evaluated with both models. With both models, climate change in northern Europe resulted in moderate to strong tuber yield increases in Jokioinen, Finland, and Tylstrup, Denmark, and in almost no yield change in Oxford, UK, both with and without irrigation. NPOTATO calculated for climate change in central and southern Europe nil to slight decreases in irrigated yield for the HCGG climate change scenario and nil to moderate yield increases for the HCGS scenario, and variable changes in water-limited yield for the HCGG scenario and slight to moderate yield increases for the HCGS scenario. POTATOS calculated less positive or more negative changes in both irrigated and water-limited yield by climate change in central and southern Europe than NPOTATO. With both models, changes in climatic variability did not result in changes in both irrigated and water-limited yields in Europe. The management response analyses showed that both cultivation of an earlier crop variety and an advanced planting date resulted in higher yields and in more positive or less negative yield change due to
climate change, in particular in southern Europe, and that only in the case of an earlier planting date did irrigation requirements always decrease with climate change. This pointed to the need for advancing the planting date with climate change. The uncertainty analyses showed that the yield change due to climate change was practically not affected by the soil type, but that this yield change may become different when a different growth model is applied, a different planting date is chosen, or a different crop variety is used.

KEY: EUROPE; CROP MODELS


The effects of climate change (for 2050 compared to ambient climate) and change in climatic variability on soya bean growth and production at 3 sites in the EU have been calculated. These calculations have been done with both a simple growth model, SOYBEANW, and a comprehensive model, CROPGRO. Comparison of the results from the 2 models indicated the sort of climate change conditions in which model results differed and may become less reliable. The effectiveness of possible management responses to climate change and the uncertainty in the model results were also evaluated with both models. Both models calculated for the climate change scenarios at Oxford a strong increase in irrigated seed yield. For Montpellier and Seville, however, CROPGRO calculated a considerable increase in irrigated yield for these scenarios, whereas SOYBEANW calculated only a slight increase. Without irrigation, the seed yield increase for the climate change scenarios was almost identical for the 2 models, i.e. considerable, slight and nil for Oxford, Montpellier and Seville, respectively. Changes in climatic variability did not result in a yield change at any site, both with and without irrigation and both for CROPGRO and SOYBEANW. With irrigation, the change in the coefficient of variation (CV) of seed yields by climate change was nil (except for decrease at Oxford) for both models and without irrigation, this change in CV was variable depending on site, climate change scenario and model. The management response analyses showed that the crop variety did not need to be changed in response to climate change, that the yield increase due to climate change was stronger for an advanced sowing date (but only without irrigation), and that irrigation requirements decreased with climate change only in the case of an early sowing date. This pointed to the need for advancing the sowing date with climate change. The uncertainty analyses showed that the yield change due to climate change was practically not affected by the used crop variety and soil type, but that this yield change may become different when a different growth model was applied or a different sowing date was chosen.

KEY: EUROPE; CROP MODELS