PRUDENCE: a project seeking to minimise uncertainties in the evaluation of climate change impacts on agriculture in Mediterranean areas

M. In?s M?nguez, M. Ruiz-Ramos, Carlos G.H. D?az-Ambrona, M. Quemada and F. Sau[1]

Depto de Producci?n Vegetal: Fitotecnia, E.T.S.Ing. Agr?nomos, Universidad Polit?cnica de Madrid. Ciudad Universitaria
28040, Madrid, Spain, Email iminguez@pvf.etsia.upm.es.
[1]Depto de Producci?n Vegetal, E.P.S., Campus Universitario de Lugo, Universidad de Santiago de Compostela, 27002,
Lugo, Spain.

Abstract

The EU project PRUDENCE was established to evaluate deficiencies in climate projections and focuses on reducing uncertainties in impact predictions. The work applies the outputs of several high resolution Atmosphere General Circulation Models and Regional Climate Models to crop models to evaluate uncertainties in the impacts of climate projections and to identify major adaptation strategies for the Iberian Peninsula. Differences among climate models that exist under current and future scenarios are transferred to impact models. Uncertainties may be enhanced or attenuated by the impact models.

Media summary

PRUDENCE is an EU project that evaluates uncertainties in predictions of climate change and its impacts. This work focuses on agriculture of the Iberian Peninsula.

Key words

Climate change, impact, uncertainty, crop models, yield.

Introduction

PRUDENCE is an EU project using four Atmosphere General Circulation Models (AGCM) and eight Regional Climate Models (RCM) to quantify the uncertainties associated with climate predictions and impacts of future climate changes on Europe. Such quantification is required before realistic adaptation and mitigation strategies can be formulated and implemented (Arnell, 1996). Currently available projections of future climate change are deficient in regional detail and in the characterisation of uncertainty. To date, the assessment of potential impacts of climate change has generally relied on data from coarse resolution Atmosphere-Ocean General Circulation Models (AOGCMs) that include only a limited physical representation of the atmosphere-ocean-biosphere system and are incapable of resolving spatial scales of less than ~300 km (Mearns et al., 2001). In particular, AOGCM information is insufficient for simulating the spatial structure of temperature and precipitation in areas of complex topography and land use distribution (e.g. the Alps, the Iberian Peninsula, Scandinavia).

The objectives of PRUDENCE are: first to identify and reduce these deficiencies on a European scale; and second, to provide a methodology for the use of the resulting climate change scenarios in models of impacts. Together, these will enable quantitative assessment of the risks arising from changes in regional weather and climate over the whole of Europe, and the effects of adaptation and mitigation strategies. PRUDENCE is providing improved model representation of climate change scenarios by utilising high-resolution models (at spatial scales of ~50 km) for current (1961-1990) and future (2071-2100) climate, characterising the level of confidence in these scenarios, and assessing the uncertainty resulting from model formulation.

Our work within PRUDENCE focuses on the Iberian Peninsula where it evaluates impacts on agriculture. The objective is to assess, within the range of predictions from RCMs and higher resolution (~150 km)

AGCMs , the impact of climate change on crop yield, water use, and sustainability of both rain-fed and irrigated systems. It is accepted that climate uncertainties may have an attenuated or enhanced impact on production, water use, and sustainability.

Material and methods

Climate data from the following RCMs and AGCMs for current and future scenarios were prepared for impact models. The RCMs are: HIRHAM (Danish Meteorological Institute), PROMES (Universidad Complutense de Madrid, Spain), ICTP RegCM (CINECA, Italy), ARPEGE (M?teo-France/CNRM), CHRM (Climate Research ETH, Switzerland), LM (GKSS Research Center, Germany), RCA (SMHI, Swedish Meteorology and Hidrology Institute), and CRCM-2 (University of Fribourg, Germany). The AGCMs are: NCAR CCM3 (CINECA, Italy), HadAM3H AGCM (Hadley Centre, United Kingdom), ECHAM AGCM (Max Planck Institute, Germany). Future scenarios correspond to the IPCC A2 and B2 CO_2 emissions (IPCC, 2001). The files of individual variables from the climate models (per grid, per year) were reformed into yearly file layers for 34 different soil groups with all climate variables for each grid position. Most climate model runs are made for a 360-day year (30 days for each month) so for use with crop models these data were extended to actual years (365 or 366 days) by adding an extra day to February (only leap years), May, July, August, October, and December. For the additional days, the climate variables (temperature, radiation, wind speed etc.) were estimated as means of the previous and following days and precipitation was set to 0 mm, so there was no increase in monthly precipitation. Because the climate models provide predictions to different grids, it was necessary to include grids in the GIS system for all model combinations of GIS-climate-soil-crop . An example is provided in Fig. 1 for the HIRHAM model.

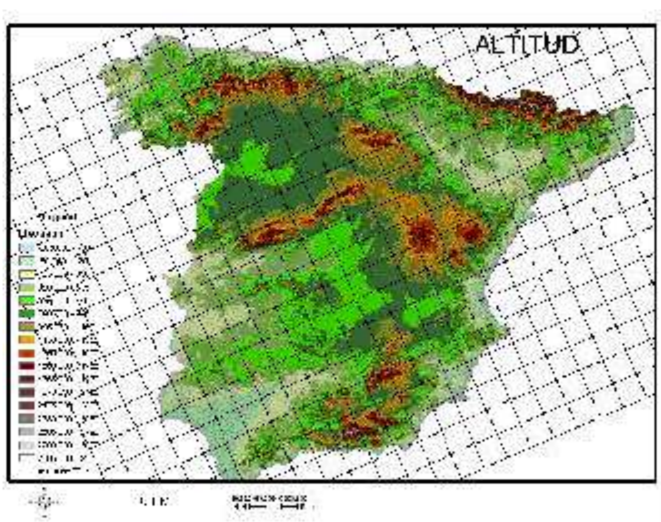

Fig. 1. Grids 50 km x 50 km, for the RCM HIRHAM over an altitude map of Spain.

A soil database was constructed comprising the mean and standard deviation of soil properties by profile layers for 34 different soil groups. Soil information was obtained mainly from the literature and from CIEMAT (Trueba et al., 2000). Soil organic matter was set to 1.2 % for Xeric and Aridic soils and to 1.5% for the rest.

Soil data from experimental stations, where field trials have been carried out, were also included for reference simulations under both current and future scenarios. The outputs of these simulations are not presented in maps.

The impact models, CropSyst v3-03-12 (St?ckle and Nelson, 1994) and DSSAT v.3.5 and 4 (Tsuji et al., 1994) were linked to the Geographical Information System ArcView™ (ESRI, 1994) for the spatial analysis across the region. Uncertainty is evaluated by comparison among the outputs from the combinations of climate and crop models included. Various methods of applying AOGCM/RCM outputs to impact models will be tested. Among them is the direct use of the climate-model outputs as inputs for two crop models (Guere?a et al., 2000).

Results and discussion

Maps are being generated for biomass, grain yield, evapotranspiration and irrigation requirement for reference crops under current and future climate scenarios. Results are shown here for simulation of a rain-fed barley with the CropSyst model using predictions from the climate models HIRHAM and PROMES under current climate (Fig. 2) and future climate (Fig. 3).

Differences arise as a consequence of downscaling of HIRHAM and PROMES and the different numerical methods used for integration of the equations of energy, mass and momentum transfer. These climate models are centred in northern and southern Europe respectively, and generate differences between their climate outputs that are transferred onto the impact results, especially at the periphery of the simulation areas.

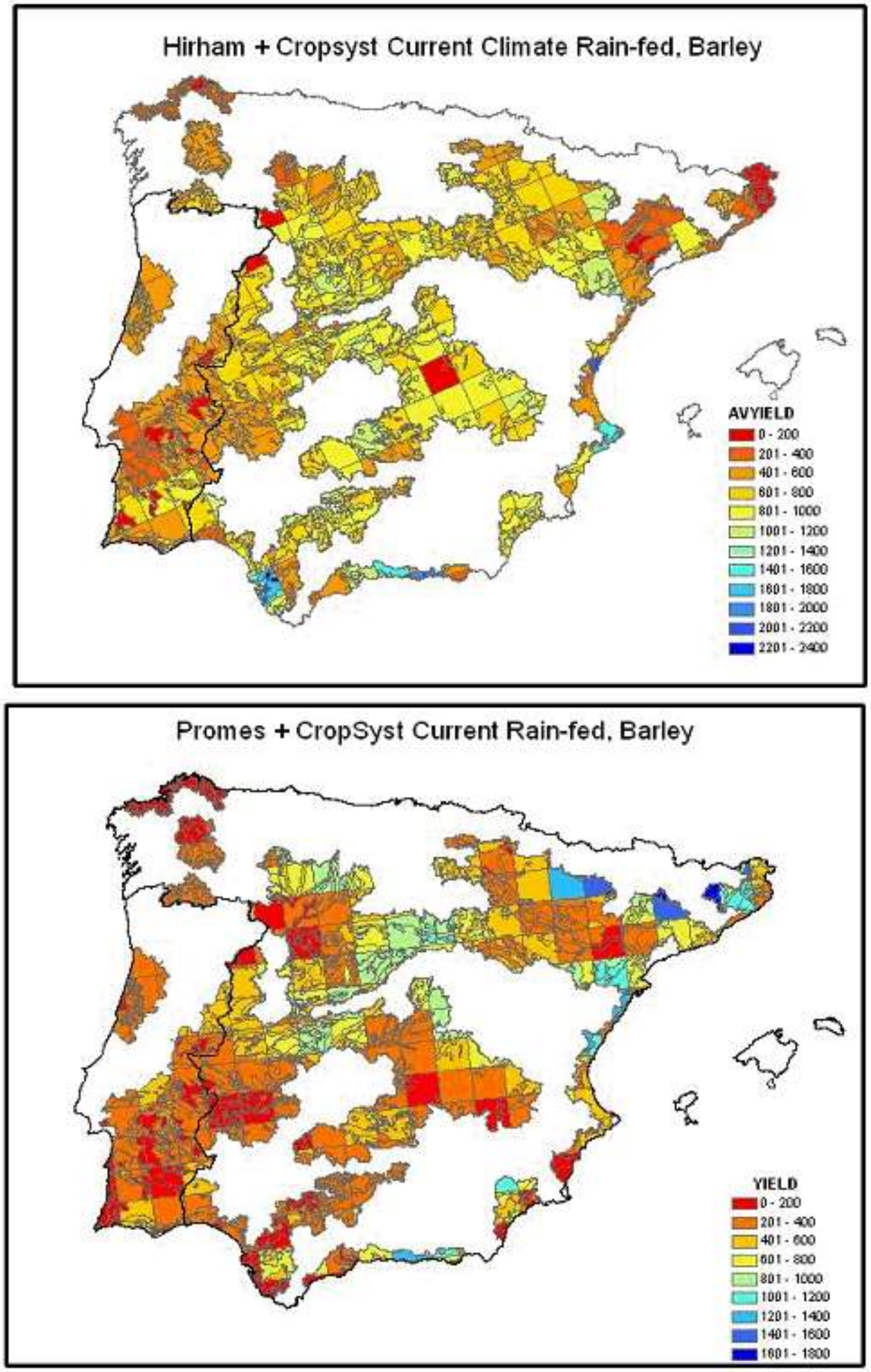

Fig. 2. Barley grain yields under current climate from HIRHAM (top) and PROMES (bottom) simulations.

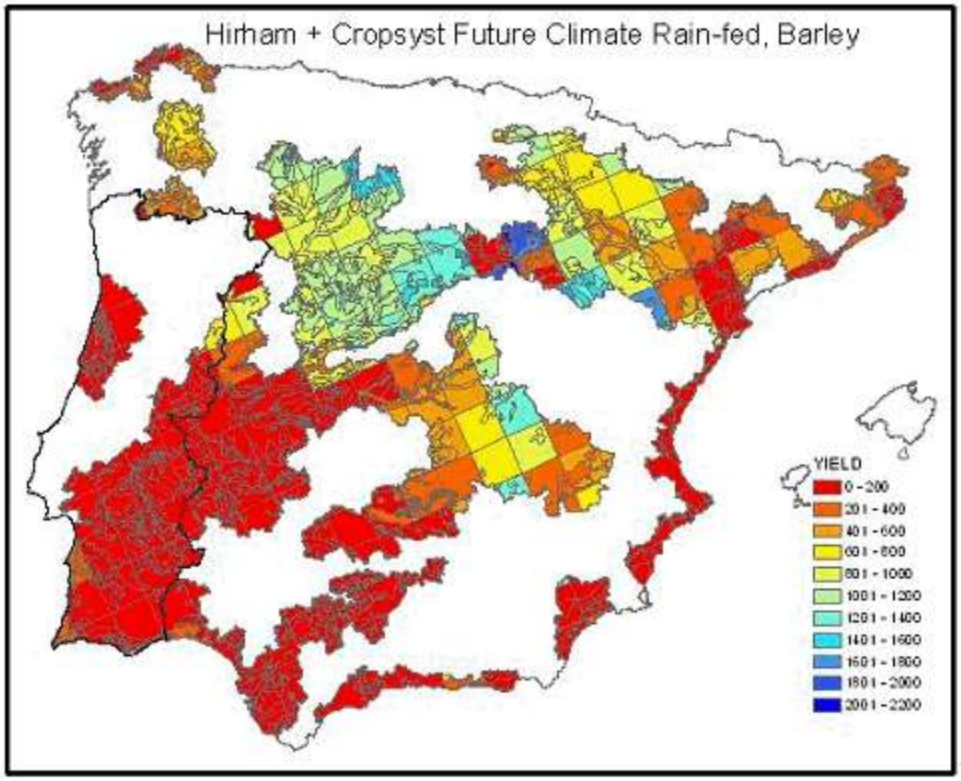

Fig. 3. Barley grain yields under future climate generated by HIRHAM.

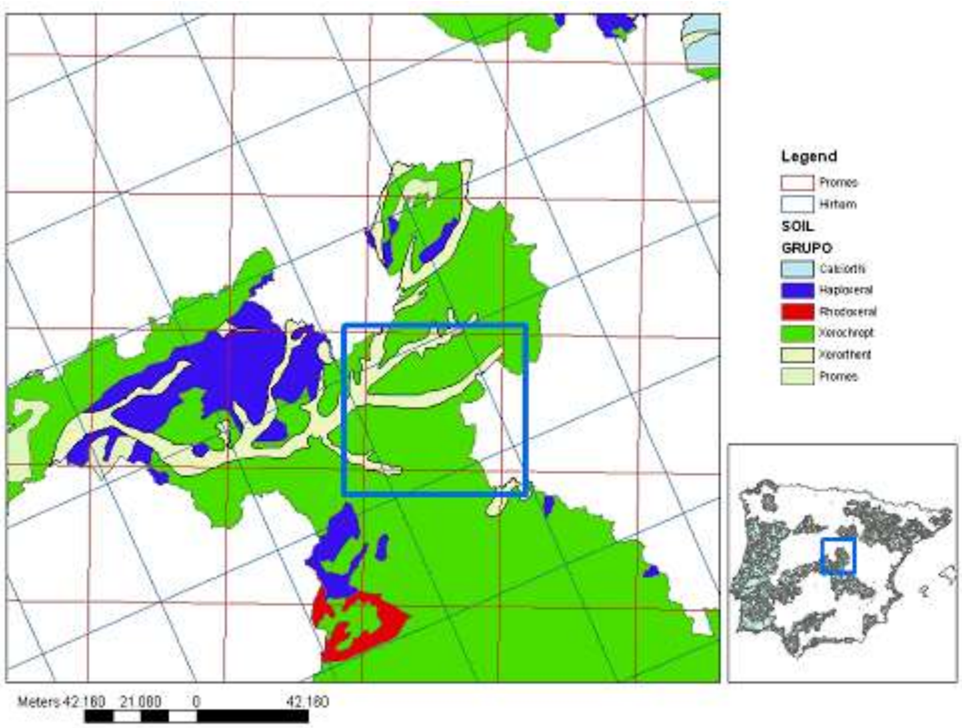

Fig. 4. HIRHAM and PROMES grids in central Spain simulation in Table 1. The soil belongs to the Xerochrept group.

Yields of barley under rain-fed and irrigated conditions in central Spain (Fig. 4), and maize under irrigation in the north-east, show the discrepancies that arise (Table 1). Variability is represented by the coefficient of variation (CV). For irrigated barley, variability is much less for future climate compared with current climate using the HIRHAM output, but comparable under both climate scenarios using PROMES. Further work will compare all combinations of climate and impact models.

Other ways to apply AOGCM/RCM outputs, e.g. the observed baseline climate data adjusted for the mean monthly differences or ratios between simulated GCM/RCM outputs for the future and baseline climates, will be compared to using the climate outputs directly. Rotations with winter reference crops, centred on agronomic issues such as productivity, water use efficiency and soil organic matter content will be simulated for evaluations of environmental sustainability and will enable the analysis of cropping systems, with or without simple adaptations to climate change.

Table 1. Comparison of grain yields for different crops and scenarios using output from two regional climate models.

Scenario		Regional Climate Model	Grain yield (kg/ha)			
			Barley (grid in central Spain) 600 m elev.		Maize (grid in n-e Spain) 200 m elev.	
			Mean	CV	Mean	CV
Current	Rain-fed	HIRHAM	3609	0.33	no crop	
		PROMES	1970	0.29	no crop	
	Irrigation	HIRHAM	3599	0.33	5101	0.56
		PROMES	2448	0.36	9496	0.33
Future A2	Rain-fed	HIRHAM	4181	0.36	no crop	
		PROMES	2409	0.33	no crop	
	Irrigation	HIRHAM	7375	0.05	3273	0.42
		PROMES	3073	0.39	4369	0.81
Change, % relative to current	Rain-fed	HIRHAM	+16		no crop	
		PROMES	+22		no crop	

Irrigation	HIRHAM	+105	-36
	PROMES	+25	-54

Yields were simulated with Cropsyst v3-03-12.

Conclusions

The use of several high resolution climate models linked to impact/crop models will enable us to quantify the uncertainties of predictions and analyse how these uncertainties are transferred from the climate models into the crop models. Regional detail is necessary for the Iberian Peninsula because its orography, latitude and being almost an island, increase the uncertainties not only of current climate simulations but also of future projections.

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