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Climate Change and Projected Impacts in Agriculture: an Example on Mediterranean Crops

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Recently, the availability of multi-model ensemble prediction methods has permitted the assignment of likelihoods to future climate projections. This allowed moving from the scenario-based approach to the risk-based approach in assessing the effects of climate change, thus providing more useful information for decision-makers that, as reported by Schneider (2001), need probability estimates to assess the seriousness of the projected impacts.
The probabilistic approach to evaluate crop response to climate change mainly consists in applying an impact model (such as crop growth model) to a very large number of climate projections so to provide a probabilistic distribution of the variable selected to evaluate the impact. By comparing the outputs of the multi-simulation with a critical threshold (such as minimum yield below which it is not admissible to fall), it is possible to evaluate the risk related to future climate conditions.
Unfortunately, such an approach is a time-consuming process due to the large number of model runs needed for such a procedure. An alternative method relies on the set up of impact response surfaces (RS) with respect to key climatic variables on which a probabilistic representation of projected changes in the same climatic variables may be overlaid (Fronzek et al. 2008).
This approach was exploited within the ENSEMBLES EU Project aiming at assessing climate change impact on typical Mediterranean crops. This work presents the results of the project with a particular concerning about the assessment of risk, of durum wheat (T. turgidum L. subsp. durum (Desf.) Husn) and grapevine (Vitis vinifera L.) yield falling below fixed thresholds, using probabilistic information about future climate.

Methodology
The simple mechanistic crop growth models, SIRIUS Quality (Jamieson et al., 1998) and VITE-model (Bindi et al., 1997a,b), were selected to respectively simulate durum wheat and grapevine yields in present and future scenarios. SIRIUS Quality is a wheat simulation model that calculates biomass production from photosynthetically active radiation and grain growth from simple partition rules. VITE-model is a model that uses a simplified mechanistic approach based on the accumulated degree days, the radiation use efficiency and the fruit biomass index to simulate the main processes regulating grapevine development, growth and yield.
The selected crop growth models were adopted to create yield RSs of both crops over the suitable cultivated area in the Mediterranean Basin. Yield RSs were calculated performing a scenario sensitivity analysis by altering the baseline climate with respect to temperature and precipitation changes. The baseline climate consisted of 30 years (1975-2005) of daily minimum and maximum temperatures, rainfall and global radiation. Meteorological data were extracted from the MARS JRC Archive and are referred to a grid with a spatial resolution of 50 Km x 50 Km covering the whole European area.
The sensitivity analysis was performed for precipitation changes (from -40% to 20%) and temperature changes (from 0°C to +8°C), uniformly applied across all the year. To take in account for the effect of rising CO_2, the yield RSs for future periods, were produced considering CO_2 air concentration level according to the A1B SRES emission scenario. For each rainfall and temperature combination the average yield over the 30-years period was calculated.
The probabilistic distribution of future yields was estimated by applying a bilinear interpolative method to overlap, onto the RSs, the data from perturbed physics experiment of Hadley Centre for future scenarios (joint distribution of annual temperature and rainfall changes).
Critical thresholds of impact were determined by calculating, for each grid cell, the distribution of the 30-years

average yield according to the joint distribution data for present period (1990-2010) and selecting the values that correspond to the 20th percentile of the cumulative distribution.
Finally, future yields were compared with yield threshold to assess the risk of yield shortfall that, in each time period, was defined as the percentage of projected yields that not overcome the selected threshold.

Results

Maps of durum wheat and grapevine low productivity risk were generated for the next century over the Mediterranean Basin.
For durum wheat, with the exception of Portugal and Southern Spain, in the next 30 years risk of low crop productivity shows an overall reduction, due to the fertilizing effect of CO_2 increase that counterbalances for the negative impact of rising temperature and reducing rainfall. Thereafter, these latter negative effects become greater and the risk progressively increases starting from lower latitudes. Maximum risk was estimated in 2060 when strong reductions in yield were accounted all over the study area. The smaller reductions in risk, estimated for the end of the next century, may be explained by the greater uncertainty in climate projections. South Portugal, South Spain and Peloponnesus resulted the most vulnerable areas showing increase in risk probability up to 50%, while risk in Galicia, Slovenia, Croatia and central-southern France always resulted lower then present time.
As regard grapevine, in the great part of the case study area, the yield seems to have beneficial effect from future climate change. In Central-Western Europe and at lower latitudes the projected yields never fall below the risk threshold, indicating a prevailing effect of CO_2 fertilisation. By the other hand, Central-Northern Italy and North of Greece result the most vulnerable areas. In these regions the likelihood of reduced yields quickly rises and remains very high (>50%) until the end of the century, denoting a greater negative effect of temperature and rainfall.

Conclusions

From these results it may be argued that the impact of future climate change on crop yields is the resultant of the contrasting effects of changes in temperature and precipitation, CO_2 increase and uncertainty in climate projections. The intensity of these effects is very site and crop dependent and may vary with time, differently affecting the assessment of risk. As a consequence, the patterns of risk of low crop productivity will change depending on which of these effects will prevail.

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