Executive summary

This report presents the final results of the study named AVEMAC (Assessing Agriculture Vulnerabilities for the design of Effective Measures for Adaptation to Climate Change). This study has been realized in collaboration of the Actions AGRI4CAST, GeoCAP, AGRI-ENV, and AGRITRADE of the Institute for Environment and Sustainability (IES) and the Institute for Prospective Technological Studies (IPTS) within the European Commission's Joint Research Centre.

The motivation of this study has been the lack of information on vulnerabilities, risks, and needs for the adaptation of European agriculture under a changing climate in the next decades. Directorate-General for Agriculture and Rural Development (DG AGRI) therefore asked the scientific support of the Joint Research Centre to conduct this study in order to present the existing knowledge through mapping and characterizing the vulnerabilities of EU agricultural systems to climate change, to come up with a methodological framework and to propose follow-up actions. Eventually the results of this study shall help the formulation of appropriate policy options and the development of adequate policy instruments to support the adaptation to climate change of the EU agricultural sector.

An impact assessment of climate change scenarios on agriculture was run covering EU27, being centred on time horizons centred on the years 2020 and 2030, in comparison to the baseline centred on the year 2000. Two realizations of the Intergovernmental Panel on Climate Change (IPCC) were used as the input of the analysis, based upon emission scenario A1B (i.e. scenario of a more integrated world with a balanced emphasis on all energy sources) from the runs of the global circulation models HadCM3 and ECHAM5, both bias-corrected and downscaled from the original ENSEMBLES data set by the same regional climate model to a 25 km grid resolution. The two chosen realizations represent a "warm" and a "cold" realization within the A1B scenario with regard to the air temperature development, averaged over Europe and the envisaged time horizons. The analysis was run on priority crops, identified as maize, wheat, rapeseed, sunflower, and rice. An exploratory analysis on grapevine phenology was also run for the horizons 2020 and 2050.

Two types of analysis were performed as the basis of the assessment. The first one focused on specific crop responses as derived from crop growth simulations forced with climate data of the two realizations of the A1B emission scenario. The simulations for both realizations were performed for the time horizons 2020 and 2030 in comparison to the baseline of 2000, and included the abstractions of the production systems potential production, water-limited production, and production limited by diseases. The second one computed static indicators as proxies of potential vulnerabilities of agricultural systems, expressed as changes in the classification of agricultural areas under climate constraints in Europe. Four agro-climatic indicators of potential vulnerability of agricultural areas were computed – length of growing period, thermal-time sum, heat stress and aridity index – and aggregated at NUTS2 level. The analysis was run for both the "warm" (HadCM3) and "cold" (ECHAM5) realization of the emission scenario A1B. The results present changes in the areas under climate constraints for 2020 and 2030 as compared to baseline.

Assessing the importance of climate change vulnerability requires not only the localisation of relative yield changes, but also the analysis of the impact of the change on the acreage affected. Consequently, the simulation results of the impact assessment on crops were further processed to estimate the potential changes in production at NUTS2 level. This was achieved by relating the simulation results to farm typologies from the ASEMARS and SEAMLESS projects and then comparing the aggregated simulation results to reference statistics of the year 2005.

In this study adaptation measures have not been considered in the model simulations. Results refer to the simulation of abstractions of current agricultural systems under scenarios of climate change.

The impact assessment of climate change on crops at 25 km grid scale has shown contrasting results in response to the different realizations of the emission scenarios. One key aspect has been the changing rainfall pattern in Southern Europe, which can lead to either an improvement or a deterioration of the performance of crops, especially for winter sown crops, but also for sunflower that uses the first part of the year to complete its cycle.

Under potential production the simulations for wheat showed a negative response at northern latitudes, and a mainly unchanged yield response at southern latitudes. For rapeseed a negative potential impact was simulated at southern latitudes. Sunflower yield was simulated to potentially improve at northern latitudes, but with negative effects on yield at southern latitudes. The simulation results for maize were potentially positively at northern latitudes, but negative at southern latitudes. The potential production level simulated for rice was positive. Finally, simulations for grapevine phenology showed predominantly an advance in the development stages, indicating a large potential vulnerability of *terroir*-bound production.

Under water-limited production the different precipitation patterns estimated by the two GCMs led to a different response of rain-fed crops (wheat, rapeseed, sunflower). With the "warm" realization of the HadCM3-derived weather data, potential yields were simulated to improve in Southern Europe. Simulations forced with ECHAM5-derived weather data showed a smaller impact on yields of the rain-fed crops in Southern Europe.

The analysis of vulnerability, which integrates results from both the bio-physical simulations and the agro-climatic indicators, provides an indication of which regions may expect potentially significant production changes by the time horizons of 2020 and 2030. In the warm scenario little to no potential changes are expected for grain maize, sunflower and rapeseed by 2020; however, by 2030 the analysis indicates potential decreases in production in various areas, if adaptation to climate change is not taken into account. The cold scenario foresees a potential increase of grain maize production in several southern regions by 2020, which is confirmed in the simulations for 2030. For the warm scenario wheat production is estimated to increase potentially in some regions of Southern Europe by 2020, but these potential increases are not expected to be maintained by 2030; furthermore, Northern Europe is estimated to experience reductions in wheat production by 2030. The cold scenario does not foresee significant potential increase for wheat and the regions affected by a significant potential decrease are mainly different from the ones that are indicated with a potential decrease by the warm scenario. An indication of the farm types that could be more vulnerable than others is further obtained crossing this analysis with a dominant farm typology layer.

It must be pointed out that simulation results of a climate scenario with a positive impact on crop performance could be considered a realistic realization of a possible future, i.e. this outcome might become reality. On the other hand, simulation results with negative impacts on crop performance do represent a pessimistic outcome, because no adaptation measures have been included in this analysis that in reality would be effective and could limit the realization of the simulated outcome. Therefore the outcome of simulations with negative impacts can be considered as potential vulnerabilities only that do not allow deriving any conclusions on the actual vulnerabilities. Having potential vulnerabilities turning into actual vulnerabilities can be overcome, if corrective means are technically available at that time and if they are affordable by farmers.

The analyses of this study must be considered as a first step only, since they have neither included adaptation nor a bio-economic evaluation of estimated vulnerabilities. Therefore main aspects of and requirements for a possible future integrated analysis at EU27 level to address climate change and agriculture with the target of providing policy support, including relevant workflows, are presented.

This report will be made available on DG AGRI studies web page which can be found at http://ec.europa.eu/agriculture/analysis/index_en.htm, DG AGRI climate change web page at http://ec.europa.eu/agriculture/climate-change/index_en.htm and the Joint Research Centre MARS web pages at http://mars.jrc.ec.europa.eu/mars/Projects/AVEMAC. There will be also available a link to this study in the web portal of the European Climate Adaptation Platform (CLIMATE-ADAPT) http://climate-adapt.eea.europa.eu/.