Agriculture in Spain and the climate change issue

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The Iberian Peninsula is almost an island that lies between temperate and subtropical zones and has complex orography. In Spain, where average altitude is 600 m above sea level (asl) cropping and pasture areas receive annual rainfall between 300 to 1200 mm/year against a reference evapotranspiration (ETo) from 500 to 1200 mm/year.

Climate is mostly Mediterranean and varies from the humid, Atlantic climate of the North-North West that is much affected by the Northern Atlantic Oscillation to the arid areas of the South East on the Mediterranean coast and adjacent inland territory. Maximum temperatures in summer are above 30°C in most cropped areas but may exceed 35°C in the south and centre during periodic heat waves that mostly penetrate north from the African Sahel. This implies that climate change will affect the agricultural regions differently and that given the large evaporative demand that water supply is and will remain the main issue to add to current high and extreme temperature events.

Climate change projections and crops

Several international initiatives are trying to establish trends in future climate in the Mediterranean region where complex interactions and feedbacks within ocean-atmosphere-land-biogeochemical processes play a prominent modulating role over a range of spatial and temporal scales. As reported in the CORDEX project[1], the Mediterranean region is expected to be one of the most prominent and vulnerable climate change "hot spots" of the 21st century, but the physical mechanisms underlying this remain unclear.

The climate variability phenomena such as the Atlantic and Pacific Niños connection, the El Niño's impact on the Sahelian and Euro-Mediterranean rainfall, and the basic properties of explosive cyclones, are currently affecting the Iberian Peninsula and behave differently depending on the time period analyzed. This non-stationary behavior seems to be caused by natural oscillations as the Pacific Decadal (PDO) and the Atlantic Multidecadal (AMO) oscillations, as well as by the anthropogenic Global Warming (GW) signal in the ocean. Current droughts are mainly related to climate variability and it is expected that the trends in climate change will affect this variability.

Climate projections are commonly based on simulations from Global Climate Models (GCM) run under various emission scenarios to describe the future driving forces, see for example the SRES scenarios (Special Report on Emission Scenarios). Higher resolutions of climate variables can be obtained by other methodologies, including ensembles of regional climate models (RCM) nested in those GCMs. For the Iberian Peninsula, these RCMs still predict a bias for temperature (higher than observed) and rainfall (lower than observed) under current climate (e.g. with ENS-EOBS or ENS-Spain02). Although a correction can be made to reduce the uncertainty linked to the use of RCMs it cannot be checked for future climate (Ruiz-Ramos et al. 2015).

Projected precipitation has great uncertainties although an average decrease is expected, especially for the South-East of the Peninsula. For crop and pasture production more important issues will be changes to intensity and seasonal distribution, especially to delays in the onset of autumn rainfall. Temperature increases focus on the evolution of daily Tmax (maximum temperature), in particular Extreme Tmax events, but also on Tmin, and on diurnal range (Tmax-Tmin).

[1] http://journals.ametsoc.org/doi/10.1175/BAMS-D-14-00176.1

Frost incidence on vines and olive orchards has diminished, consistent with records of weather stations and the experience of insurance companies. Chilling hours of fruit crops and vernalization requirements in annual crops are currently being studied for near-future (2015-2024) and future (>2024) climate projections.

In Spain as a consequence of climate change awareness, as well as competition for water, two approaches are receiving important National and European funds for research. On the one hand those related to improvement of seasonal forecasts (e.g. TROPA-FIS-UCM[2]) to manage current cropping systems, and on the other hand those addressing climate change projections for use in vulnerability/impact/adaptation assessment studies considering the Mediterranean as a fully coupled environmental system (AgSystems Research Group at CEIGRAM).

Crop production is directly and non-linearly related to climatic variables. In the Mediterranean basin, agriculture has always been affected by large natural climate variability (e.g. del Río et al., 2007 for the Iberian Peninsula), and will continue to be affected in future. Studies on climate change, considering forced changes due to the buildup of atmospheric carbon dioxide (CO_2) and other greenhouse gases, suggest escalating temperatures, and different or increased climate variability, and other new extremes in the Mediterranean area (Sánchez et al., 2004 and CLIVAR project[3]). Agriculture faces a scenario of increasing total variability (natural and forced).

Future impacts and adaptations of crop production can only evaluated by using crop simulation models driven by the outputs from climate models run under chosen emission scenarios. Large International and European consortia such as AgMIP[4] and MACSUR[5] demonstrate the effort invested.

Spanish agricultural systems under climate change

Agricultural land (crops, pastures, agro-forestry systems) cover 40% of the 50.5 Mha area of Spain. The driving forces that shape these agricultural systems are markets and the Common Agricultural Policies (CAP), as well as climate. For example, more diversified rotations are now used in response to specific subsidies in the form of direct payments to farms > 30 ha that grow at least 3 crops in each cropping season.

A description of the important agricultural systems is presented here according to the land area occupied with some comments on impacts and adaptations. Horticulture - vegetables and fruits-, olives, and vines represent over 50% of agriculture production value[6].

Changes in cereal grain quality, pest and disease evolution, weed control would need a specific chapter and are not dealt with here, and similarly for extensive and intensive animal production. Mitigation measures linked to specific crop practices mostly relate to good agricultural practices that should have been long been applied; e.g. minimum or no till, soil cover on tree crops, residue management are recommended for semiarid areas.

Cereal-based systems

The area sown annually to cereals in Spain is around 6 Mha and production usually exceeds 25 Mt (2015). Pre-crop fallow can occupy an additional 2.8 Mha. In 2012, however, drought reduced cereal production to 17.5 t. The two large plateaux in the Centre-North and in Central Spain are the main production areas where barley and wheat are mostly grown under rainfed conditions. Barley occupies more area than wheat because it is more resistant to terminal drought. Strategic irrigation may be applied on farms that also grow vines, sugar beet, alfalfa, or other high value crops. Highest cereal prices are obtained in the Guadalquivir valley for malting-quality barley and for durum wheat for pasta. The quantity of total nitrogen (N) varies depending on grain and fertilizer prices so that wheat grain can be produced for either bread (more N added) or animal fodder.

[2] http://tropa.fis.ucm.es/research
[3] http://www.clivar.es/
[4] www.agmip.org
[5] www.macsur.eu
[6] http://www.magrama.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/esyrce/

Farms that also manage sheep use flocks to graze stubble, and also unharvested crops following severe drought conditions. The numbers of animals in 2015 were 16.5 M sheep and 3.0 M goats. Ten years previously there were more than 22 M sheep but goat numbers the same.

Maize and rice are summer crops grown under irrigated or flooded conditions and are managed with high inputs with yields close to potential. The extent of their cultivation depends on grain prices and competition for water from the horticultural and urban sectors. Where flooded rice can be cultivated in the future is still a matter of study because it will have to contend with the impacts of raising sea levels. Phenology and heat stress resistance or avoidance are main topics for research. Other adaptations are non-flooded rice, earlier sowing dates and longer crop cycles to compensate faster development rates.

Many studies have been undertaken using crop simulation models to evaluate adaptations to climate change; direct effects of CO2 on crops are taken into account in the crop simulation models following the Free Air Carbon Experiments (FACE) results. Studies focus on phenological development - including changes in vernalization requirements - as well as responses to sowing dates. These processes are relatively well understood.

Crops develop faster under higher temperature so the crop cycle is shortened and timing of key vulnerable stages, e.g. the extreme sensitivity of flowering to high temperature, are changed. Adaptation involves choosing cultivars or changing crop species to achieve a better synchrony of development with weather conditions (rainfall and frost occurrence). Other proposed changes relate to selection for root systems to improve soil exploration and extend activity during grain filling, or to characteristics such as cultivar vigor, or increased radiation-use efficiency and larger specific leaf area are being explored with the simulation models. Collaborative work with breeders is required so that changes proposed are achievable with available genetic material.

Olive and viticulture

Approximately 2.6 Mha of olives and 1.0 Mha of vines are grown under rainfed and irrigated conditions. Drip irrigation has boosted productivity of both olive oil and wine.

Olive management has changed dramatically in Spain in the last decades: irrigation, mechanization, and changes in tree architecture have increased yield and quality. Traditional olive orchards provide much temporal employment in the South. The introduction of super-intensive hedge-rows orchards using low vegetative vigor cultivars seems a success, and has lowered demand for hand labor diminishing production costs.

The studies around this intensification are taking into account more sustainable soil and an improved pest management, thus expanding these practices to more traditional olive orchards. Tilled soils on hilly slopes cause very high erosion rates (soil loss > 40 t/ha.year) and these are issues of great importance under current climate that should not be forgotten.

The phenological development of the many cultivars that differ in chilling requirements and/or heat resistance is currently simulated under climate change projections to map their best locations. Soil and irrigation management can also lower temperatures in olive canopies to better withstand heat events.

Wine quality has improved significantly due to choice of trellis systems, cultivars, monitored irrigation, in parallel with disease and pest control, and oenological improvements. The objective of avoiding frosts and keeping adequate (Tmax-Tmin) amplitude for wine quality has made this sector very much aware of climate impact on their products. The use of cover crops between rows is improving soil quality and rainfall infiltration rates in various important commercial companies.

Two strategies initially considered for future warmer conditions are being put in place now with positive effects under current climate: 1) trellis systems that lift grape bunches from the soil to avoid infrared radiation in particular during the night (lower Tmin for the grapes) and sprawled shoots that protect these bunches during the daytime (to lower Tmax for the grapes); and 2) new vineyards in cooler areas or at a greater altitude, evaluating frost probabilities.

Horticulture and greenhouses

Fruit and vegetables are the corner stone of the agricultural sector in Spain. They represent 40% of production and provide 50% of employment in agriculture. They are grown over 1.5 Mha including 90 thousand ha of greenhouses, with ca. 17 billion € of value for more than 24 Mt of fresh products. Exports of 13Mt are worth 13 billion €. Water, temperature (mild winter temperatures), pest and disease management, and nutrient supply as well as a high number of sun daily hours, are at the basis of these production systems. Water for agriculture in the eastern and southeastern regions competes mainly with the urban (and tourist) sectors, as is common around the entire Mediterranean coast.

Fruit tree production, including nuts, is a dynamic sector that is addressing the prospect of temperatures increase with the evaluation of the chill requirements of cultivated species and cultivars, as well as the need for heat avoidance and water access for irrigation. Research on improved irrigation systems, including the utility of deficit and precision irrigation will have a continuing positive effect for future climate.

Greater productivity within greenhouses, plastic or recently established glasshouses, could be attained in cooler areas than where they are currently used. Greenhouses of southern and southeastern regions rely more and more on desalination and groundwater so their sustainability should be studied with care under current climate; water for agriculture in those regions is competing with urban (including tourist sector). Migration of these cropping systems to cooler areas is a possibility. Nevertheless technology, production costs, and markets may be a shorter term issue to deal with.

Dehesa systems and pastures

The dehesa is a rainfed agro-forestry system of evergreen oaks and pastures where cattle, sheep, and high value Iberian pigs are raised. It is a sub-climax agricultural system that extends to ca. 4 Mha. Together with native pastures it covers ca. 8 Mha. Acorn production diminishes markedly in years of low rainfall (Iglesias et al., 2016)- and may increase sudden death syndrome in ever green oak - which in turn reduces an essential component of fodder supply for finishing Iberian pigs.

Pastures are mainly based on C3 annual species in the Mediterranean regions and perennial in the Atlantic zones. Pastures in the former are adapted to the summer dry months. Overgrazing has to be addressed under current climate to protect soil from erosion on mostly undulating areas. This problem will be exacerbated in future if rainfall is more intense. Effect of higher temperatures on evergreen oaks and on the introduction of C4 plants with less protein content should considered.

Conclusions

Climate change awareness is pushing research and innovation in agriculture. Studies are booming on phenology and heat stress physiology - in parallel with improvement of their simulation in crop models- water use, irrigation requirements and improvement - be it deficit, strategic or precision irrigation-, cereal grain quality, and pest and disease evolution; large international and European research projects are working on these and mapping new areas for cultivation or species/cultivar changes.

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