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Climate variability and change impacts on crop productivity

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In light of current trends in global population levels, the main challenge for agriculture is to increase production by 40% by the middle of the century to meet the demand for food, fibre and biomass. However, projected climate patterns will make this target hard to achieve because of increased climate variability and the frequency of extreme weather events (Intergovernmental Panel on Climate Change, 2021).

Climate change impacts on crop productivity and quality can be studied using various approaches, ranging from statistical models to process-based crop models (Lobell and Asseng, 2017). Most studies on these climate change impacts focus on the application of models to simulate crop growth at different spatial scales to aid climate change impact assessments and quantify adaptation and mitigation strategies.

This special issue Climate Variability and Change impacts on crop productivity addresses the agronomic implications of climate variability and change through analysis of modelling attempts to characterise and quantify the likely effects on yield and sociological analysis of the attitudes and policies that will determine the likely success or failure of mitigation/adaptation strategies in the agronomic context.

This special issue is opened by a perspective paper by Basso (2022) that discusses Techno-diversity for carbon farming to build climate resilience. The perspective paper offers an interesting prospective on the context of thinking about feedbacks between agriculture and climate. In this view, carbon farming aims to reduce greenhouse gas emissions to the atmosphere and increase the sequestration of carbon within the soil. However, while those concepts are well established, the perspective paper defines *Techno-diversity* as a novel approach to agricultural activities based on equity, diversity, inclusion, and justice.

The manuscript of Ferrise *et al.* (2022) used an ensemble of crop simulation models to quantify the accuracy of simulating soil organic carbon changes in long-term experiments. They analysed any uncertainty originating from the simulation in soil organic carbon and how this is related to model routines and management factors. The evaluation of such modelling uncertainty has mostly focused on aboveground processes, and therefore the results presented in the manuscript have important implications for future studies involving soil carbon sequestration in agricultural fields for climate change mitigation. The authors found close agreement between the ensemble of multiple crop model's and the dynamics of soil organic carbon.

To increase our understanding of how climate variability has affected crops, and how this trend might evolve in the near future, long-term weather data are often used. In Cammarano *et al.* (2022) a weather series from 1764 to 2017 was used to evaluate the impact of climate on the phenology (a proxy of impacts of long-term climate) of a summer and a winter cereal and four different vines (perennials) in two locations in Italy. They found that there has been a shortening of the growing seasons and a shift of developmental stages in line with the findings of Asseng *et al.* (2013, 2015) and Wang *et al.* (2017). In addition, any further increase in air temperature will cause disruption in vernalization requirements for winter wheat which will impact grain yield.

The understanding of how climate patterns contribute to phenology and yield has also been analysed in a different agro-environmental condition by Li *et al.* (2022). Having access to long-term crop management data in several locations, these authors were able to include the effects of crop management on rapeseed yield. They found that the planting date has been delayed by an average of 6 days per decade, which advanced the mean maturity dates by about 7 days per decade and causing an average yield increase. These results were dependent on the region considered. But the authors also pointed out that amongst all the regions the most important climatic factor limiting yield was cumulative sunshine hours, especially in the upper reaches of the Yangtze River.

Another important aspect of climate change that is complementary to the physical environmental effects of climate change is the perception of such changes by farmers. Acibuca *et al.* (2022) explored farmer awareness of climate change impacts. They evaluated farmers' adaptation capacity in different regions of Turkey. Farmers associated climate change with changes in precipitation and their implications for crop productivity. An interesting aspect of these findings is that there is a spatial pattern, because farmers in the continental region were more concerned about excess rain while those in the Mediterranean basin were more concerned about drought and heat. Overall, there was agreement among farmers that climate change is human-induced, and they are keen to collaborate with researchers and policymakers to make farming more climate resilient.

The integration of past weather patterns and impacts, along

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with farmers' perception about climate change, give an important indication of the perceived risks posed by changing climate in agricultural districts. Ehsan *et al.* (2022) addressed the impacts of climate change on wheat production, adaptation strategies and the limitations of the adaptation to Climate Smart Agriculture. Evidence of production trends showed that, in the area under study, wheat yield has increased over the past thirty years, but that this trend was inconsistent. In addition, the perception of climate among farmers indicated that the level of literacy, rather than age, was the main factor influencing their view on such projected changes and impacts. The adoption of Climate Smart practices lagged behind in all farmers surveyed because of the lack of knowledge, skills, technologies, finances and political support.

In Africa, the evaluation of climate impacts in agriculture are important because of the implications for sufficient agricultural production to feed its population. Among the many crops grown in Africa, cowpea (that can grow well under drought conditions) which is popular in Central and West Africa, contributes significantly to food security. In nations like Ghana, cowpea represents one of the most important cultivated crops. Adusei *et al.* (2022) evaluated the projected impacts of climate change on cowpea productivity under different phosphorous-deficient soils using different socio-shared scenarios. They found that cowpea biomass production and grain yield will remain high under projected future conditions despite a slight shortening of the growing cycle, a projected trend that was also noted in Sudan and Guinea Savanna.

An increase in extreme events like hail and strong winds can become common in some geographical areas because of global warming. This will have practical implications for local communities that will need to plan adequate policies to mitigate and adapt to these new climatic trends. However, once the damage caused by an extreme climate event has happened it is important to spatially quantify it. Schillaci *et al.* (2022) used satellite data from Sentinel 2 to evaluate hail damage in several areas. They also evaluated which vegetation index would have the highest accuracy in evaluating the damage. The accuracy increased with the extent of the damage (*e.g.* when a field had more than 50% of damage). In low intensity events, one of the vegetation indices analysed, the modified soil-adjusted vegetation index (MSAVI), showed good accuracy in determining the degree of damage.

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