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Climate Change and Agriculture
Editorial

Climate change and variability impacts on agriculture

Impactos del cambio y la variabilidad climática en la agricultura
Impactos das mudanças e da variabilidade climática na agricultura

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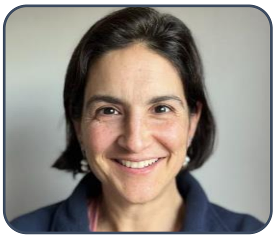

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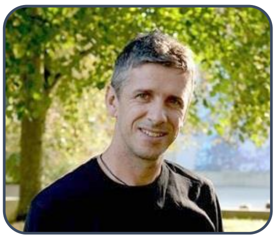

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While agriculture is crucial to feeding people, it is strongly impacted by climate change and variability, and also contributes to it. Agriculture and land use change are responsible for around ¼ of greenhouse gas emissions from human activities[(1)]. Climate change already impacts the quantity, quality and geographic distribution of food production from agriculture. Projected impact shows that 10% and more than 30% of current food production areas will be unsuitable by 2050 and then 2100 respectively, under the high-emissions scenario SSP-8.5 (compared with less than 8% by 2100 under the scenario SSP1-2.6)[(2)]. The negative effects of

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climate change are expected for all crops (perennial and annual crops) and latest 21st-century projections using ensembles of crop and climate models suggest a significant impact on yields for several major producing regions before 2040[3][4]. Impacts on the geographical distribution of food production will lead to an increase in the number of people threatened by hunger and will further increase pressure on the terrestrial ecosystem services (ES) that support global food systems[5][6]. These intertwined interactions create a vicious circle, with agriculture contributing to climate change, which in turn puts pressure on the sustainability and productivity of agricultural systems. Faced with these crucial challenges, sustainable and resilient agricultural practices that explore innovative solutions to mitigate the environmental footprint of agrosystems while strengthening the capacity of agricultural systems to adapt to climate change are urgently needed[1].

This broad ambition requires solving multiple challenges, one of which is the scale of design and implementation. Most research into climate change adaptation of agriculture is carried out at continental to global scale and considers abrupt adaptation, such as substituting a particular type of crop or shifting a crop to another region. However, landscape and land use can generate a high spatial variability of climate, which may increase or decrease the impact of climate change at local scales. And adaptation and mitigation strategies are generally applied at local scale by local authorities and farmers. The issue of mitigation is also crucial, as shifting to more productive areas under future climate conditions may be considered an effective strategy, but such adjustments will have a significant impact on mitigation efforts[7].

In this special issue, entitled "Climate change and variability impacts on agriculture", the selected articles address these different issues.

Firstly, there are three review articles that enclose and discuss climate change impacts on different agricultural systems. Specifically, **"Identification of sheep robust to climate change and variability"** aims to review the concepts of robustness, resilience and efficiency. It presents studies on these characteristics within breeds and/or breeds that could be considered in the sheep genetic improvement programs for a scenario of climate change and variability. The article "**Genetic selection and livestock sustainability: A review of research and development in Uruguay"** shows that Uruguay has had genetic evaluation systems for three decades and that new intensive phenotyping platforms are in place for measuring feed efficiency (FE) and enteric methane (CH_4) emissions in beef cattle and sheep. Given that FE and CH_4 are difficult-to-measure traits, the implementation of genomic selection is key to accelerate the potentially achievable genetic progress. Recording systems and protocols are described in this work, as well as the estimated genetic parameters and associations among feed intake, FE, CH_4 and productive traits. The last review article is **"Exploring the potential impact of global climate change on grapevine health with particular emphasis on grapevine trunk diseases".** In this review, the authors provide a summary of the impacts of climate change on plant diseases, with a specific focus on the potential implications for grapevine diseases. Among these, they highlight the complexity of grapevine trunk diseases, which currently pose a significant challenge to grape production worldwide. Additionally, they explore the potential effects of climate change on microbial communities at the root-soil interface associated with grapevines, their correlation with grape health, and key findings from a local study that examines the alterations induced by drought in the fungal composition of grapevine underground compartments.

Then, three articles address results on mitigation strategies to face climate change and variability. The work **"Greenhouse gasses potential offset by forest species and CO_2 balance in integrated forestry-livestock systems in Uruguay"** aimed to estimate GHG emissions from livestock, crops and forestry, CO_2 captured by Eucalyptus and Pine plantations, as well as soil organic carbon for all land uses in Uruguay. Results showed that cattle enteric fermentation accounted for 54 $kg.ha^{-1}.yr^{-1}$ of methane (CH_4), and total emissions accounted for 1746 $kg.ha^{-1}.yr^{-1}$ of CO_2 equivalent. Based on GWP100, *Eucalyptus grandis*, *Eucalyptus dunnii*, and *Pinus* spp. captured 31, 38, and 17 $T.ha^{-1}.yr^{-1}$ tons of CO_2 equivalent, respectively, mitigating emissions from 18, 22, and 10 hectares of cattle production. GTP100 and GWP* metrics indicated significantly lower CO_2eq emission values. The work titled **"Assessing the contribution of enteric methane emissions from Uruguayan livestock to global warming using an alternative metric"** assesses the differential warming contribution of Uruguayan livestock enteric methane emissions using GWP (Global Warming Potential, GWP) and GWP* (Alternative metrics of GWP) metrics from 1900 to 2023 and its potential usefulness in negotiating future emissions reduction commitments. The relative long-term stability shown by the cattle stock resulted in a 3.6% (±7.7%) average change in methane emissions every 12 years. The total accumulated emissions using GWP* represented 56% of the CO_2-equivalent estimated value (1,139 vs 2,027 Mt CO_2 equivalent). Moreover, the reduction trend in annual CO_2 warming-equivalent emissions in the past three decades (-60.6%) has been along with an important improvement in emissions intensity (-13.0%). Lastly, the article **"A graduated methodology for mitigating GHG emissions and nutrient losses in Integrated Crop-Livestock Production Systems"** presents a methodology for guiding producers in developing strategies to reduce environmental impacts while enhancing system resilience through circularity and ecosystem-based practices. The methodology assists in identifying high-impact actions based on the farm's organization and development level. Some practices can be immediately implemented, while others need longer-term structural changes.

The final section of this special issue presents four articles which address adaptation strategies to reduce the impacts of climate change and variability. The work **"Use of bioclimatic indices for characterization and sustainable agricultural management in Sancti Spíritus, Cuba"** has the objective of defining characteristics for sustainable agricultural management in the province of Sancti Spíritus through bioclimatic indices, focused on the main agricultural and livestock productions. The main results show that the Rivas-Martínez thermic index (ITRM) records warm conditions for most of the province, while the Thornthwaite humidity (IH) presents variations, fundamentally, in the subhumid categories. Rainfall on the land is a potential cause of soil erosion and degradation, and the degree of seasonality increases this risk. The article titled **"Multicriteria viticultural climate zoning of the Sierras Pampeanas Cordobesas (2002-2022) using satellite data"** shows the wine climate potential of the Sierras Pampeanas Cordobesas through bioclimatic indices. The results identify twenty viticultural climates, classifying them into three groups: a) with thermal limitations, b) with high night temperatures, and c) 7% of the study area without thermal limitations. Groups b and c record precipitations and late frost dates, which imply risks for the normal development of the vine. Then, the article **"Development of a predictive model of phenology in grapevines cv. Cabernet Sauvignon under conditions of high spatial variability in Maule Valley"** explores a prediction model of phenology in Cabernet Sauvignon in a high spatial variability field located in the Maule Valley in Chile. The results show that the proposed model had a high degree of fit between both estimated and observed phenological stages ($R^2 > 0.98$ and standard deviation between 1.0 and 1.84 phenological units), suggesting that it can be used to predict phenology stages in Cabernet Sauvignon vineyards established under high and low spatial variability and different management systems in the Maule Valley. The last scientific article is titled **"Malbec viticultural zoning studies in Argentina based on the UCI bioclimatic index and bias-corrected CORDEX-CORE simulations".** The objective of this work is to use the regional climate models (RCMs) of the CORDEX-CORE simulations to represent the current zoning of Malbec grape production regions in Argentina. The results allow the authors to conclude that the set of corrected CORDEX-CORE simulations satisfactorily reproduces the main characteristics of the observed zoning of the Malbec grape in terms of UCI and its four components.

This special issue of *Agrociencia Uruguay* on "Climate change and variability impacts on agriculture" aims to highlight the contribution of science to the development of adaptation and mitigation in the agricultural sector in a variable and changing climate. The articles published show the impacts of climate change and the adaptation strategies proposed or already applied in different sectors of agriculture (e.g. perennial crops, livestock, etc.) and in different regions of the world. The different approaches developed and the diversity of case studies confirm that it is essential to strengthen the resilience of agro-ecosystems to climate change, enabling them to respond, reorganise and maintain their basic functions, while increasing their capacity to adapt.

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