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3rd International Crop Modelling Symposium

Crop Modelling for Agriculture and Food Security under Global Change

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ABSTRACTS
KEYNOTE SPEAKERS

Crop models for a climate- and nutrition-resilient future

Jessica Fanzo, PhD, *Johns Hopkins University*

Cropping system models are increasingly critical for addressing the intersecting challenges of climate change, food security, and nutrition. As climate variability intensifies, these models must evolve to anticipate not only crop yields but also the nutritional quality of food produced under changing environmental conditions. Recent advances highlight the importance of integrating climate–crop nutrient modeling to project how climate impacts may alter the availability of essential micronutrients and macronutrients, with profound implications for global nutrition and health outcomes. The need for nutrient-dense, climate-resilient food baskets is underscored by the growing recognition that food security is not just about calories, but also about the diversity and quality of nutrients accessible to all populations. These models must go beyond yields, accurately forecasting disruptions to micronutrient availability and the resilience of nutrient-dense food baskets that underpin human health. However, current models face significant challenges, including data gaps and integration of climate, agronomic, and nutrition data, the complexity of nutrient–climate interactions, and the need for interdisciplinary collaboration across agronomy, nutrition, and climate science. Addressing these challenges requires innovative approaches that combine high-resolution climate projections, crop physiology, and nutritional science to inform policy and practice that support sustainable, equitable food systems capable of withstanding shocks and promoting dietary diversity for populations most vulnerable to food insecurity. This talk will explore the evolving demands on cropping system models, emphasizing their role in supporting sustainable, equitable, nutritious and resilient food systems in the face of global change.

Integrative adaptation strategies for stabilizing wheat productivity with climate warming in China

Prof. **Bing Liu**, Nanjing Agricultural University

Global wheat production faces growing threats from climate change, particularly climate warming, necessitating region-specific adaptive strategies. Climate warming impacts on crop production could arise from both rising mean growing season temperature and more frequently extreme heat stress events. Adapting to these two impacts could be substantially different, and the overall contribution of these two factors on the effects of climate warming and crop yield is not well known yet. With the improved process-based crop model, which can reproduce the extreme heat stress effects, the separate impacts of temperature increase and heat stress on wheat yield and production were quantified across the main wheat-producing region of China under both historical and future climate scenarios. Divergent responses of wheat yield to increasing temperature and heat stress were projected for the cooler northern sub-regions and the warmer southern sub-regions. Most negative impacts of climate warming are attributed to increasing mean growing-season temperature, while changes in heat stress are projected to reduce wheat yields by an additional 1.0% to 1.5% in northern sub-regions. This underscored the importance of considering the different regional and temperature impacts in climate change adaptation. Further, how adaptive strategies—adjusting sowing dates, anthesis dates, and enhancing heat tolerance—can mitigate the adverse impacts of warming on wheat yields across China's diverse wheat-producing subregions were evaluated through scenario analysis. Under warming scenarios, comprehensive adaptation strategies will significantly reduce potential yield losses in all four wheat producing subregions. A gene-based crop modelling with current wheat germplasms also reveal potential in stabling wheat growth duration under climate warming by breeding efforts. These findings offered actionable insights for sustaining wheat productivity amid climate change and enhancing food security in China.

Systems modelling for Agriculture and Food Security

Prof Daniel Rodriguez, The University of Queensland, Australia

The sustainable intensification of food and fiber production across the OECD divide presents distinct but equally complex challenges—each demanding fresh scientific approaches and innovative tools. In low-income countries, smallholder farmers face systemic barriers: scarce resources, weak market access, and inadequate infrastructure limit both opportunities and incentives to transform production systems. In high-income countries, meanwhile, farmers are approaching diminishing returns, where further gains are often uneconomical, environmentally unsustainable, or fraught with risk.

Despite modest progress since COVID-19, the world remains far from eradicating hunger and food insecurity by 2030 (SDG Target 2.1). At the same time, the global population is projected to surge by nearly 20% by 2050, reaching 9.6 billion, while climate change intensifies and reshapes agricultural realities.

Meeting rising demand for food and energy under these conditions requires more than incremental tweaks—it calls for bold innovation and the application of new scientific paradigms. Yet crop research has long been fragmented across disciplines. While breakthroughs have occurred, recent progress has been incremental, leaving the future outlook contested and uncertain.

Agriculture today is entangled in "wicked problems"—issues that cut across disciplines, knowledge systems, and values. Tackling them demands transdisciplinary, integrative, and forward-looking solutions.

Opportunities for such approaches emerge across interconnected scales: from genotype to phenotype, phenotype to crop, crop to farming system, and farm enterprise to agro-ecosystem. Crucially, farmers do not simply grow crops—they manage cropping systems, juggle scarce resources, and balance diverse objectives across multiple enterprises. Recognizing this complexity is the first step toward meaningful improvement.

In this presentation, I will focus on that step: shifting the lens from modelling crops to modelling farms and farmers. I will then return to highlight critical opportunities where crop modelling and physiology can sharpen our predictions and elevate the quality of our models.

Why We Model: Scientific Advances, “What If” Questions, and Aids for Decision Making

Dr. Cynthia Rosenzweig - NASA Goddard Institute for Space Studies (GISS), Columbia Climate School, USA

Modeling advances understanding and knowledge, for example, how CO2 affects are masking the negative effects of climate change. Scenario analyses, such as “with or without adaptation,” help to nail down the critical role of climate change resilience strategies. Finally, our models provide an unbiased evidence base for decision making. Examples from the current state of AgMIP and iCROPM Sessions provide the rationale for “why we model.”

Pathways towards trustworthy, transparent and transferable machine learning for agricultural modelling

***Lily-belle Sweet**, Helmholtz Centre for Environmental Research*

Recent advances in artificial intelligence have demonstrated excellent performance across scientific tasks such as numerical weather prediction and protein-structure prediction. Agricultural science is also adopting these tools: machine learning techniques are increasingly used to build data-driven crop models, calibrate existing process-based models and generate, process or gap-fill environmental input datasets. Interpretable machine learning approaches are also being used to analyse the biophysical relationships influencing crop yields.

However, the use of machine learning for agricultural research applications has exposed several methodological limitations. Models have a tendency to overfit to their training data in ways that are difficult to detect, often performing well on familiar conditions but failing when applied to new regions or years. Commonly-used model interpretation methods have been found to return ambiguous or contradictory results. Additionally, the inductive bias of some model architectures makes them potentially inappropriate for some use-cases; for example, random forests are fundamentally unable to extrapolate beyond the training data distribution, limiting their suitability for tasks such as projecting agricultural outcomes under future climate scenarios.

For robust, trustworthy and impactful use of machine learning in agricultural research, we need to understand the extent to which the limitations of current methods impact domain-specific modelling tasks, and how this is influenced by data quality or availability, the use of different methodologies, model architectures, or other factors. This requires community effort to share knowledge, to create and maintain benchmark datasets, evaluation strategies and metrics that meaningfully reflect the complexities of agricultural modelling tasks and stakeholder needs. By testing and comparing the performance of different approaches on these benchmarks, researchers can develop improved methods for specific applications, and can build trust, where warranted, in the utility of these tools.

This talk will share insights from the AgMIP Machine Learning community (AgML) since its launch in 2023, highlighting lessons emerging from a recent benchmark challenge focused on predicting climate change impacts on agricultural yields, and outline pathways for more robust and trustworthy use of machine learning for agricultural modelling.

Functional Biodiversity Modelling for Agricultural Systems: Lessons from Environmental Risk Assessment

Prof. Christopher John Topping - Aarhus University, DK

Functional biodiversity modelling aims to understand how species traits and ecological processes sustain agricultural productivity through pollination, pest control, and ecosystem resilience. Yet translating these models into management decisions reveals a fundamental challenge exemplified by environmental risk assessment (ERA): the reductionist trap. Current ERA illustrates this problem starkly. We have developed sophisticated assessments for individual chemicals with great precision, yet real agricultural systems face multiple interacting stressors that do not conform to these isolated evaluations. The current ERA takes over 10 years and can cost €100,000 in administrative costs per product, yet still produces ecological surprises such as delayed neonicotinoid bans and ongoing pollinator declines. We assess chemicals individually with detailed precision but miss landscape-scale cumulative effects because we optimise for single-chemical safety rather than ecosystem stress capacity. Precise isolated assessments created false confidence while missing the emergent properties and system-level thresholds that drive real-world biodiversity outcomes.

This talk advocates reversing traditional workflows: instead of building isolated models and connecting them later, we must define agricultural systems first, establish ecosystem-level thresholds for functional biodiversity analogous to carbon budgets, then assess interventions within this integrated context. We can demonstrate this is feasible, enabling questions impossible with siloed approaches such as “Can we establish chemical stress budgets maintaining biodiversity services while enabling sustainable agriculture?”. The path forward requires functional biodiversity modellers to embrace interoperability from the start, building tools interoperable across ecological, agronomic, and chemical domains. Agricultural systems do not respect disciplinary boundaries, and our models should not either.

Food Systems Transformation Needs – Challenges for Policy and Opportunities for Modelling Systems, Crops, and Food Security

Joachim von Braun, Bonn University, DE

Professor (em.) for Economic and Technological Change, Center for Development Research, Bonn University, and Member of the Advisory Board of the UN Food Systems Summits This presentation describes how the world is confronted with an aggravated food systems crisis. Climate change, environmental deterioration such as related to soils and biodiversity, markets, political disruptions and wars are generating short and long-term effects that cause human suffering. The elements of crises differ by regions and countries, as well as ecosystems. Political responses to food crises at national and global level have been initiated such as by the UN Food Systems Summit of 2021 and its follow up stocktaking events in 2023 and 2025. Driving forces of the food crisis, and needed policy actions are discussed in this presentation, that also touches upon opportunities for modelling food systems, crops, and ending hunger. Science-driven priorities of innovations in support of the food systems transformation will be outlined.