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Editorial: Water-Energy-Food-Health Solutions and innovations for low-carbon, climate-resilient drylands

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Editorial on the Research Topic
Water-Energy-Food-Health Solutions and innovations for low-carbon, climate-resilient drylands

We live in a world of complex and tightly interconnected grand challenges that threaten the sustainability of our societies. Examples of such challenges are summed up in the United Nations Sustainable Development Goals (UN-SDGs), which include specific goals to address water, energy, and food insecurities. Our ability to address these challenges depends on our readiness to collaborate across disciplines and sectors to reimagine thriving, healthy, resilient societies that respect the boundaries and health of our planet. As nations work toward implementing the UN- SDGs, we need to support decision makers, create synergies, and avoid unintended competition between societal goals. Thus, the urgent need for innovative simulation and assessment tools and governance models to represent these complex systems in an accessible manner.

Drylands face important resource gaps including access to water, food, energy, nutrition, and healthcare. These gaps are expected to increase with demographic conflicts and climate change. The highly interlinked primary resources carry high risks and vulnerabilities. Understanding these interlinkages and associated risks and vulnerabilities to better comprehend the complex system of systems they represent is crucial and requires multi-disciplinary work that encompasses technologies, science, policies, health, communication, and socioeconomics at both local process and system-level scales.

In 2018, the American University of Beirut (AUB) launched WEFRAH: the Water-Energy-Food- Health Nexus of Renewable Resources initiative. WEFRAH comprises one of the largest research communities in the Middle Eastern North Africa (MENA) region. It is a university-wide initiative led by the Faculty of Agricultural and Food Sciences. WEFRAH includes a critical mass of faculty from disciplines across the University whose focus is collaboration to achieve security of primary resources. Its core conviction is achieving water,

energy, and food security, improving health, harmonizing humans with nature, and implementing integrated solutions that require holistic, system-level thinking.

This Research Topic presents some of the collaborative research outcomes from the WEFRAH community. It also honors Professor Rabi H. Mohtar, Department of Biological and Agricultural Engineering, Texas A&M University. Mohtar's leadership of multiple initiatives during his interdisciplinary career has resulted in seminal contributions to the development of Water-Energy- Food nexus research, education, and engagement globally.

The 2021 annual symposium of the American Chemical Society (ACS), Toward Creating a Water- Energy-Food Nexus Community of Practice - A Symposium in Honor of Professor Rabi H. Mohtar, included invited and contributed oral and poster sessions, with multi-stakeholders from academia, private, civil society, and public sectors. The symposium focused on the various thematic areas related to operationalizing WEF nexus research and development, and highlighted lessons learned from cross-disciplinary collaborations using national and global case studies in this research space. The symposium focused on the opportunities that lie in creating a cross-cutting and inclusive WEF nexus Community of Practice and the role of existing disciplinary societies in that Community.

Research Topic of the WEFRAH Initiative and of the ACS symposium included.

- *Water-Energy-Food-Health nexus and the Sustainable Development Goals*
- *Sustainable food production systems*
- *Renewable energy and sustainable agri-food systems*
- *Building systems thinking and leadership capacity*
- *Behavioral changes towards sustainability in the Water–Energy–Food Nexus*
- *Governance of the Water–Energy–Food Nexus*
- Introductory perspective to the Nexus in drylands
- *Approaches to integrate the WEFH nexus in drylands*
- Health as a resource and its contribution to the Nexus
- *Circular and Sustainable food production systems*
- *Antibiotics and other contaminants fate in the environment (soils, water, and plants) and technologies for their removal*
- *Food or water waste management*
- *Building climate resilience in drylands*
- *Climate smart agriculture in drylands*

This Research Topic represents these contributions, and a synthesis is offered below.

Nuwayhid and Mohtar highlight the ways in which health is included in the nexus literature and argue for its inclusion in the WEF nexus conceptualization and definition. They note that, despite the relatively short history of the WEF Nexus as a discipline, it has been adopted by many international agencies. Including health as part of the resource nexus is timely.

Ramos et al. present the SIM4NEXUS approach to address a gap in the Nexus research and introduce comprehensive, transferable, accessible methodologies with operational potential. SIM4NEXUS, a project funded by the European Commission under the Horizon 2020 programme, investigated the Water-Energy-Food-Land and Climate (WEFLC) Nexus. SIM4Nexus was operationalized in twelve Case Studies of differing spatial scope, socioeconomic, and biophysical contexts, and thus, differing Nexus challenges. They found that trans-disciplinarity and integration of qualitative and quantitative methodologies are vital elements for policy support in Nexus assessments. They propose steps to advance Nexus assessments that include integration of the policy cycle in research, multidisciplinary collaboration, and inclusion of ecosystems.

Jalloul et al. present a review of the contamination of irrigation water with tetracycline (TC), its impact on edible crops, and associated health risks. They propose a solar-mediated photocatalytic degradation using a Titania-based photocatalyst to remove the antibiotic from irrigation water and highlight the methods as efficient, cost effective, and ecofriendly photocatalysts for degrading TC in irrigation water.

Ioannou and Laspidou study the impact of climate change on water–energy–food security. They present a resilience policy analysis framework for a water–energy–food nexus system under climate change in Greece. They performed parametric sensitivity analysis for socioecological systems in a case study based on the structure of a system dynamics model. The model maps sector-specific data from major national and international databases using engineering and ecological resilience metrics, then quantifies system resilience and identifies policies that increase system resilience.

Mohtar presents an historical background of the Nexus journey, beginning in a Purdue University classroom, continuing to the World Economic Forum and promoting the concept among decision makers and industry leaders. He describes how the Nexus emerged into the discipline that it is today, offers definitions, success stories from around the world, and reflections on the future of the Nexus.

Jalloul et al. investigate photocatalytic degradation as a potential treatment of tetracycline (TC) antibiotic-contaminated water using a TiO_2 semiconductor sensitized with Fe ions and immobilized beta (BEA) zeolite support. They showed improved TC adsorption resulting from the expanded surface area due to the immobilization of the TiO_2 on the BEA zeolite. They also showed that the presence of Fe3+ ions reduces the band gap energy of the TiO_2, leading to a red shift in its absorption spectrum to the visible light region, minimizing the extent of recombination of the charge carriers.

Mohtar et al. present key messages and conclusions from the ACS Environmental Chemistry Symposium honoring his contribution to the field. It includes anticipated challenges and opportunities as we move toward establishing a resource-nexus community of science and practice and outlines the roles of chemistry and chemical processes in understanding the interlinkages of nexus systems. The paper proposes including the resource of health, highlighting major challenges and opportunities in the Water-Energy-Food-Health-Ecosystems (WEFH) Nexus, and highlights future steps for fostering dialogue among this broad, multidisciplinary, multi-stakeholder community as it moves toward establishing an inclusive community of science and practice.

Mohtar and Fares present a new, more sustainable approach to water-for-food reduction and identify inter-dependencies between food and fresh water by exploring new and alternative sources of water, including improved efficiencies of green and recycled water.

Karam et al. create a novel image generation tool, made publicly available, to detect pests on plant leaves. Early and accurate detection of plant pests will allow both small and large-scale farmers to treat the plants in a timely manner, thus improving crop yield. In addition, the work proposes the use of a novel Generative Adversarial Networks (GANs)-based pseudo-automated pipeline for data augmentation, thereby leveraging synthetic data generation to increase dataset sizes, decrease data Research Topic, and improve performance of lightweight Convolutional Neural Networks (CNNs) for detecting and counting large numbers of small pests on plant leaves.

Muell et al. develop and evaluate a Water-Energy-Food-Waste nexus-based analysis and resource allocation tool to evaluate the economic, environmental, and social feasibility of the Closed-loop dairy system. The study shows that the closed-loop dairy system can be profitable for dairy farms of 200 cows or more.

Daher et al examine the resilience of resource systems in Lebanon and show how the Water-Energy-Food (WEF) Nexus can help us understand the dynamics of the interactions of this system. The paper explores some of the underlying political and economic challenges and the impact of climate and socioeconomic shocks and triggering events on the interconnected resource systems. The paper identifies emergent themes, including decentralization and systems thinking and their roles as catalysts toward more resilient resource systems. It also highlights the opportunities that lie in creating platforms for integrative resource planning and decision making, as well as empowering decentralized initiatives at the local level to build resilient, bottom-up solutions to WEF challenges.

Antukh et al (2022) present a review of currently available biogas upgrading technologies for anaerobic digestion (AD) of waste biomass. They highlight biological technologies, especially a hydrogenotrophs-based one, that would be more cost-effective and sustainable in upgrading biogas produced by an AD system.

Author contributions

RHM, MA, BD, CL, HK, and VS all made substantial contributions to the conception and design of the work and to drafting and revising it for important intellectual content.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Antukh, T., Lee, I., Joo, S., and Kim, H. (2022). Hydrogenotrophs-based biological biogas upgrading technologies. *Front. Bioeng. Biotechnol.* 10, 2022. doi:10.3389/fbioe.2022.833482