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Editorial overview: Water–energy–food nexus

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This review comes from a themed issue on **Environmental Monitoring Assessment**
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With the increasing demand of food, serious concerns rise about the environmental impact of agricultural and agrofood processes in both developing and developed countries. A sustainable food production relies on the effective use of natural resources and, primarily, of water and energy resources. To this purpose, researchers, policymakers and decision-makers need consistent and widely accepted methodologies and tools to evaluate the relations among water and energy consumptions, food productivity and environmental impact. With regard to this latter aspect, the environmental consequences related to food production should rely as much as possible on primary data, in particular regarding the emissions due to crop cultivation [1,17,18], the pollutants released by agricultural machineries [11] and the impact due to the waste generated by livestock and food industries [3,4,14].

In this special issue on water–energy–food nexus (WEFN), there are 13 mini review articles that deal with various aspects of the environmental issues related to the nexus among water use and availability, energy consumption and production in agriculture and food industry and environmental impact of the food production processes. Besides this, additional contributions deal with the development of methodologies and tools for the evaluation of the WEFN. This special issue aims to highlight the relations among the aforementioned aspects and also the ecosystem services related to agricultural activities.

The contributions to this special issue can be grouped as follows:

- Three focus on methodology, methods and tools developed in the last few years for the assessment of the WEFN. Endo et al. [7] conducted a review to understand the current status of the WEFN, focussing on its methodology, and the process through which the nexus approach has expanded across. As there are no standalone methods and tools for practicing and implementing the nexus approach, a nexus methodology should be developed by combining multiple methods and tools, including qualitative and quantitative, and natural and social science mixed methods. Del Borghi et al. [6] discuss the circular economy approaches devoted to understanding the interdependencies among water, energy and food sectors. The authors highlighted that despite the concepts of WFEN and circular economy are clear, there is an ongoing discussion on how to best transfer the concept from a theoretical framework into an integrated approach and policy. In addition, van Gevelt [19] pointed out that although our technical understanding of WEFN dynamics continues to improve, this knowledge has not yet been translated into effective and implementable policy. According to the author, the key to bridging the science–policy divide is introducing a political dimension into our understanding of the WEFN;

- Four mini reviews deal with the aspect of energy consumption and production in agricultural processes. Nikkhah and Van Haute [13] reviewed the mathematical (multiple linear regressions and data envelopment analysis) and computational intelligent–based (artificial neural networks, adaptive neuro fuzzy inference systems and genetic algorithm) approaches for modelling and optimization of the energy flow in food supply chain and showed that these methods can be generally applicable for optimizing energy flows of food systems. Sarkodie and Owusu [16] focused the attention on the application of WEFN on renewable energies and highlighted that although they have been described as environmentally sustainable, while fossil fuel energy technologies compete with water withdrawal and consumption, some renewables compete with food for land use, which is a situation that requires cost and benefits policy estimation. Nazir et al. [12] paid the attention specifically on wind energy discussing current developments of this renewable energy, its increasing trend and the adverse ecological impacts, that is, noise, visual, deforestation and land erosion. Finally, Scardigno [17] also considered water besides energy and, in particular, reviewed the new solutions to reduce water and energy consumption in crop production;
- Five contributions explore different aspects related to the environmental impact of agriculture and food. Bilal et al. [3] reviewed the aspect related to antibiotics traces in the aquatic environment and highlight that antibiotic residues–based contaminants can influence microbial populations by bacteriostatic and bactericidal effects, leading to disappearing key microbial groups associated with ecological activities or affecting their physiological functions. The livestock contribution to water contamination with antibiotic metabolite or residues has not been largely studied, whereas antibiotics administration to animals by contaminated water source has been reported. These facts resulted in the conveyance of antibiotics/antibiotics resistance to all the food chains. About the waste produced in livestock, food processes and industrial activities, Parra-Saldivar et al. [14], discussed the recent advances in life cycle assessment (LCA) in wastewater treatment technology and their effective deployment to know the fate of hazardous pollutants. A proper LCA providing comprehensive information to producers, consumers and policymakers or legislative authorities can help minimize the environmental insecurity and reduce the human health risks related to waste treatment. Concerning overexploitation or full exploitation of fishing stocks, Vazquez-Rowe [21] reviewed the relation between fishing industry and environmental impacts, highlighting how not only will fisheries have to expand their approach from single-species stock assessment to ecosystem-based approaches but also other metrics will have to be brought forward to maintain competitiveness and minimize food security concerns. Even Ruiz-Salmon et al. [15] focused on seafood sector at a European scale, addressing challenges and opportunities under a circular economy perspective. According to the authors, the sustainable development of the seafood sector in the European area requires a consistent methodology for products ecolabelling and defining ecoinnovation strategies for production and consumption under a circular economy approach. Even if not included in this special issue, the review performed by Conti et al. [4] explores an often-overlooked impact related to the food production systems, the odour, and highlights how the introduction of odour in the LCA framework is necessary. The contribution of Ingrao et al. [9] investigates the field of research of constructed wetlands to contribute to enhancing the state of the art and the knowledge on these systems that cause less green house gas (GHG) emissions and less environmental impacts than conventional WWTPs. Constructed wetlands can contribute to sustainable enhancement of the ecological carrying capacity of the global ecosystem through wastewater treatment as part of global waste disposal.
- Finally, Falcone et al. [8] and Batlle-Baye et al. [2] discuss the environmental impact of different dietary patterns. The contribution proposed by Falcone et al. [8] deals with the topics of sustainability assessment of different food consumption patterns. Authors performed a brief systematic literature review by analyzing recent scientific works based on LCA. The findings of this study revealed that a lower consumption of meat, processed meat and dairy products in favour of diets with high vegetable content contributes positively in reducing the GHG effects, as well as in terms of land use and water depletion. However, more attention should be paid to all the secondary services related to food products (e.g. packaging, storage, cooking) that can have a significant influence on the environmental performance of a diet, in relation to real food consumption patterns (e.g. consumption of frozen, precooked, fourth range foods, single serving etc). In addition, the promotion of diets with a high vegetable content must consider the consequences that a change in dietary habits can cause on a large-scale perspective (e.g. availability of food, land use transformation, etc.). Batlle-Baye et al. [2] reviewed the state of the art of the combined LCA

and WEFN approach in assessing the effects of diet transitions and pointed out that (i) a limited number of nexus methods have been developed at the food and diet levels, and no commonly recognizable methodology has been achieved for the nexus assessment and (ii) an integrated LCA and WEFN approach can be a decisive tool to improve the understanding of the interconnections in the nexus, as it enables the consideration of entire supply chains. Similar conclusions were drawn by two studies not included in this Special Issue. Gonzalez-Garcia et al. [9] reviewed the carbon footprint and nutritional quality of different human dietary choices to determine the differences in carbon footprint and nutritional quality identifying the main hotspots trying to give advice towards the identification of sustainable diets. According to Gonzalez-Garcia et al. [9] dietary choices rich in vegetables (e.g. vegan, vegetarian as well as Indian and Peruvian) have a better environmental profile than those rich in meat (mainly ruminant meat); moreover, the Mediterranean and Atlantic diets present higher nutritional scores and lower carbon footprints respect to dietary choices identified in Northern and Western Europe, as well as in the United States. Finally, Cooreman-Algoed et al. [5] propose a methodology for the classification of meals based on environmental policy targets and nutritional recommendations and pointed out that future research may focus on a further optimization of the combined environmental and nutritional assessment, especially for the classification of reference values.

However, results and policy effects among all the studies focused on methodology are heterogeneous because of the lack of a common conceptual framework of WEFN, making this conceptual tool more challenging. For a comprehensive evaluation of the WFEN, a holistic assessment should be carried out. In this regard, the combination of LCA with indicators specifically developed to assess the water and energy consumption and their relation, as well as other impacts (loss of biodiversity, odour, etc.), would be an added value.

Uncited References

10; 20.

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