



Short communication

Closing transdisciplinary collaboration gaps of food-energy-water nexus research



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ABSTRACT

The nexus of food, energy, and water (FEW) systems is key to ensuring global sustainability in the face of climate change, population growth, and urbanization. To address FEW resources inequity among different regions and countries, transdisciplinary research networking becomes increasingly important for tackling this intractable, complex grand challenge. In contrast to interdisciplinary or multidisciplinary research, transdisciplinary research emphasizes the interactions of scientific, cognitive, and social factors from a top-down view. Intellectual and strategic integrations entail weaving scientific, socioeconomic, and political perspectives together into a new convergence model and fostering a shared vision and comparable assessment, though these goals might not be realistically achievable in the short term. This article summarizes major barriers to transdisciplinary research on FEW nexus grand challenges and possible solutions to be implemented at multiple levels of distinct social systems. Implementation of the solutions relies on not only top-down incentives of governments but also bottom-up initiatives of academic communities and individual researchers. The relevance of shared interests and visions between the research communities and the public is emphasized.

1. Introduction

The food, energy, and water (FEW) nexus is globally embraced as a conceptual framework that seeks to understand the interrelationships and feedbacks among the three systems and their involved sectors in providing sustainable FEW resources for current and future generations. Multi-level collaborations (e.g., from individual to international levels) in addressing the impacts and challenges of the FEW nexus is critical for achieving the United Nation's Sustainable Development Goals (Bleischwitz et al., 2018). The effectiveness of such collaborations relies on the availability of robust transdisciplinary research coordination networks (Lawrence, 2015; Ghodsville et al., 2019). These networks often involve researchers and stakeholders (including decision makers) with different intellectual, economic, cultural, and sociopolitical backgrounds. Different from interdisciplinary or multidisciplinary research, transdisciplinary research emphasizes the interactions of scientific, cognitive, and social factors from a top-down view (Choi and Pak, 2006; Walter et al., 2007; Stock et al., 2011; Schmalz et al., 2019). However,

disparities of research communities among disciplines, societies, and countries complicate efficient communication and subsequent collaboration (Tschakert et al., 2016). It is relatively easy to bring together researchers and stakeholders for knowledge exchange and mutual learning of experiences but difficult to develop and implement actionable collaborations. Many studies have been performed to develop strategies and solutions to overcome the barriers of transdisciplinary collaboration (Pohl, 2005; Olawuyi, 2020). Unfortunately, such "solutions" are mostly effective only to a certain range of disciplines (such as psychology and ecology). Few studies have explored transdisciplinary collaboration strategies for a complex system, such as FEW nexus, which covers a spectrum of sectors, spanning from food and water supply to energy and policy, and scales, from local to international communities (Yu et al., 2020; Van Gevelt, 2020). Due to lack of motivations, communication is very difficult to implement among researchers, stakeholders, and policymakers, not to mention collaboration (Ansor, 2020). There is an imperative need for overcoming the barriers that prevent transdisciplinary collaboration in FEW nexus research. The

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objective of this perspective article is to identify and summarize those barriers and propose corresponding solutions at multiple levels of the social system. The presented perspectives are expected to benefit the development of transdisciplinary research communities at local, regional and global scales.

2. Barriers of transdisciplinary networking

In an effort to create an effective transdisciplinary research agenda at individual-to-international levels that would address fundamental FEW nexus questions, the following four barriers were identified through communications and outreach activities across disciplines, sectors, and nations. The communications were made among ~400 participants of three international workshops held during 2017–2019. The outreach activities included individual and panel meetings with policymakers, non-profit organizations, and leaders of various industries directly engaged in the FEW nexus.

The first barrier is unclear individual research stewardship. The transdisciplinary nature of FEW nexus research requires intense collaboration among multiple teams that cross disciplines, institutions, and nations. The perceived or actual inequity of credit sharing—often in terms of co-authorship on scientific publications and reports—can discourage individual researchers, especially junior contributors, from participating in large-scale research tasks. Further, the value systems that weigh and award credit for scholarly publications are very different for researchers in engineering, business, biology, and the social sciences. This disparity also exists among tenure-track faculty, research staff, and extension faculty. In some countries, well-established researchers are more likely to lead larger FEW research initiatives and claim disproportionately large credit, inclining junior researchers, who are an integral part of creative research, to feel less motivated to join such efforts. The underappreciation of the roles of younger researchers and students might impede transdisciplinary innovation of FEW nexus research activities.

The second barrier are widespread siloed and/or localized subsystems without substantive FEW interactions across disciplines and/or beyond local scale. Most research explicitly focused on the FEW nexus is rooted in a narrow range of disciplines or in the context of local FEW network. FEW investigators often package their ongoing research programs, which actually address only one or two pillars of the FEW system, as integrated and comprehensive. The majority of them always look at the FEW system from their own disciplines and justify their research relevance to the FEW nexus without truly identifying and addressing the systematic issues arising from the feedback interactions among individual FEW nexus components that are connected externally to regional system. This approach may satisfy FEW funding agencies, provide publication opportunities, and motivate people who have worked in one system for long time to think about the connection of their systems to other systems in the framework of FEW nexus. However, this side view from one discipline to another is a cross-disciplinary approach (i.e., tackling a research question of a discipline in terms of knowledge of another discipline), and it may fail to create and sustain true systematic FEW nexus research with the potential to benefit broader audiences of the global community.

The third barrier is limited societal impacts at regional level due to the lack of the social science and public policy components. Most FEW research projects start within a specific discipline (e.g., agriculture, natural science, and engineering) without overarching design and effective outreach plan, and the resulting models and solutions often achieve high intellectual merit within the academic community through peer-reviewed publications and presentations. However, the regional impacts of such research efforts on society are usually limited due to the lacks of connection between the results of scientific analysis and investigation, on the one hand, and stakeholders' direct interests on the other. Failures to incorporate human behaviors (e.g., consumption habits and climatic migration) and to consider social and cultural

differences among various interest groups or nations create a disparity between the FEW research and the public communities, including individuals (such as farmers and consumers), corporations, and policy-makers. The inadequate involvement of potentially FEW-impacted groups could demoralize the implementation of a comprehensive FEW research agenda.

The fourth barrier is a lack of recognition of social and political differences in FEW systems in a global context. In terms of both natural and social perspectives, FEW systems are inherently heterogeneous, both spatially and temporally. For example, many countries differ in water right and land ownership, and also have vastly different patterns in the consumption of FEW resources (WSC, 2016; Zhuang et al., 2021). These differences must be fully acknowledged in FEW nexus research or academic "solutions" will have no practical impact. Incorporating these differences in a FEW nexus research agenda may unveil new opportunities to enhance worldwide sustainability by allocating the unevenly distributed FEW resources for synergistic consumption demands (e.g., energy-food trade between water-scarce and water-abundant countries). Furthermore, international politics (e.g., trade wars) might play a crucial role in the reallocation of FEW resources among countries, and global sustainability models should fully incorporate potential political influences on FEW supply chains. Economic deglobalization, as it is currently occurring, presents a new challenge for international transdisciplinary collaborations. The consequences of (de)globalization will be complex and hard to predict. Ideally, coordinated collaborative research develops a robust transdisciplinary network that can compensate any negative geopolitical impacts of (de)globalization on global FEW sustainability.

3. Solutions toward transdisciplinary networking

Multi-level solutions to the above four barriers are proposed in Fig. 1. At the level of the individual, the solution is to identify and define the specific roles that individual investigators can perform when an integrated FEW research agenda is being pursued. The aim of the role clarification is to ensure an acceptable, if not considerable, career payback for all those contributing to a large transdisciplinary research effort. Success in the academic arena is commonly measured in terms of publications, project funds, mentored students, and so forth. While these activities remain important, the target beneficiary of FEW nexus solutions is the diverse public community at large. Therefore, a set of shared indicators must be developed to demonstrate the progress of collaborations between individual researchers and the public (Fig. 2). The indicators, which emphasize knowledge transfer, should be able to inform policy in response to changes in the amount of nutritious food the public can access, the volumes of clean water the public can consume, the breaths of clean air the public can inhale, and the number of kilowatt hours the public can afford to use. For instance, a policy idea proposed by researchers, once adopted by government, is credited as a key research contribution in China. The credit is equivalent to or higher than that of a publication in a high-impact journal. Such a reward system has greatly motivated Chinese scientists and engineers for rooting research into the soil of societal needs. However, in some countries, policy time frames of government may differ substantially from promotion time frames of researchers, and policy adoption may be laden with factors (e.g. political infighting or resource allocation) beyond the control of researchers. Therefore, academic institutions must develop assessment rubrics that encourage contributions of transdisciplinary efforts to disciplinary knowledge and its transfer to society.

At the local level, the solution is to establish shared scientific models and technical language to ensure that the same transdisciplinary targets, goals, objectives, and outcomes are collectively understood, agreed upon, and communicated. A huge endeavor is needed to understand what different models can accomplish and to integrate various models for system-level simulation and prediction. Transdisciplinary researchers must be aware that individual perspectives and positionality

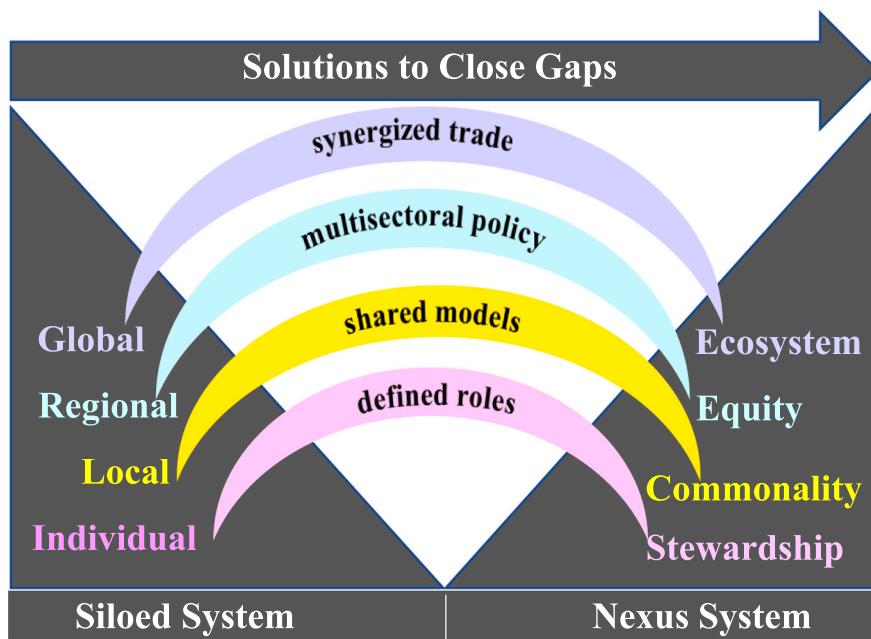


Fig. 1. Multi-level solutions to close the gaps that prevent transdisciplinary research collaboration in the nexus of food, energy, and water systems.

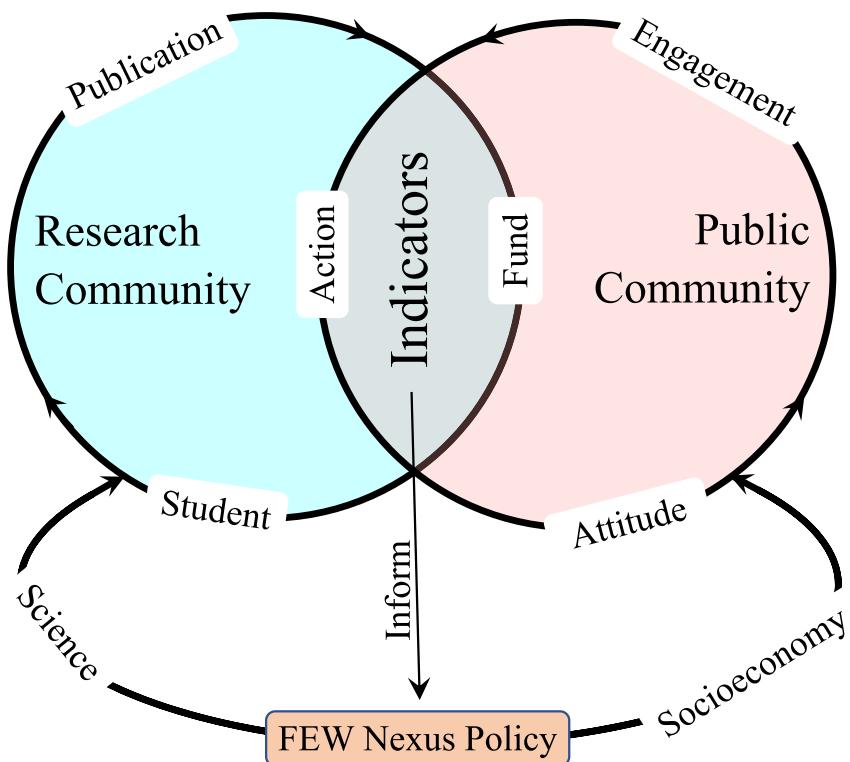


Fig. 2. Scope and roles of progress indicators shared between research and public communities in transdisciplinary collaboration of food-energy-water (FEW) nexus research.

in the local community can bias the information and values that are, or are not, considered into FEW models. The integration of different models or perspectives is possible at the local level since local community represents a relatively small-scale network of researchers and/or stakeholders who may have affective relations, correlative values/ perceptions, and a coherent identity under similar FEW challenges and environmental impacts. To date, models that satisfy all needs of FEW researchers and/or stakeholders do not exist. A prerequisite for filling

this technical gap is to develop shared interests and overcome technical language barriers hampering communication between academic and non-academic groups. It is also imperative that the FEW researchers ensure that the developed shared interests are truly representative of the community, not just those that align with their research objectives.

At the regional level, the solution is to strengthen the interactions or mutual learning opportunities between researchers and stakeholders (including policymakers). The interactions and learning should be

dynamic and gradually escalate to cultivate common and effective approaches to advancing the agenda of FEW research and technology application across sectors. Such efforts, which very likely alter traditional practices, must incorporate equity into the FEW research agenda for receiving broad public support. For instance, operationalizing equity in FEW nexus requires inclusive prior study of the economic, cultural, and societal norms and behaviors of involved population groups. Public-engagement events and outreach should be evaluated based on the results of how well the FEW research agenda is aligned with the interests of people it is meant to serve and how many improvements are made to the agenda due to incorporation of equity and public perspectives.

At the global level, the solution is to acknowledge the transition to globalized ecosystems as a model for sustained human existence. Such consciousness might not be temporarily acceptable by the global society. Nevertheless, the FEW researchers must inform the world that globalized ecosystem restoration is an overarching framework that could minimize the impacts of climate change, resource degradation, and social inequity (Fischer et al., 2021) or may perpetuate social inequities if local restoration projects ignore biocultural relationships and environmental justice (Hall et al., 2021). To convince socio-politically diverse groups, the FEW researchers must define the transition point, at which managed ecosystems (e.g., autonomous agriculture and urban green infrastructure) supersede natural ecosystems as a result of adaptation to altered climatic conditions and accelerating demographic change worldwide. In other words, the FEW researchers need to develop an understanding for minimum ecosystem functions and services that can accommodate economic, societal, and political requirements of society at local, regional, and global levels. Such minimum levels must be measurable with a set of indicators, which are flexible enough to embody the differences of socio-economic systems, community perspectives, and individual and societal consumption behaviors of FEW resources. The availability of such indicators will allow transdisciplinary teams to quantify and compare achievements while identifying remaining issues and shortcomings and facilitating mutual learning experiences.

4. Summary

Identification of dominant barriers to transdisciplinary FEW research and development of effective solutions are critical for multi-level, multi-sectoral collaborations among fundamental science and technology researchers, system modelers, sociologists, and information technologists. Existing barriers include weak attraction to young researchers, disciplinarily siloed research, disconnection to society and policy, and ignorance of sociopolitical disparities. Corresponding solutions to these barriers include changes of career payback to junior researchers, establishment of shared transdisciplinary research interests and models, stronger support from stakeholders and government agencies, and optimization of global FEW network. Effective implementation of these solutions should, on one hand, take a top-down strategy (e.g., starting from government and funding agencies) for stimulating systematic thinking and transdisciplinary synthesis across scales and, on the other hand, adopt a bottom-up strategy for converging research ideas and developing broadly transdisciplinary academic communities. These efforts could be greatly leveraged by peer-reviewed journals, international meetings, and institutional evaluation systems.

Author Statement

JZ wrote the manuscript. FL provided financial support and organized three workshops, which generated the main perspectives presented in this article. GS developed an outline of the article and wrote a large portion of the initial draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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