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SPECIAL SECTION: TRANSDISCIPLINARY CONTRIBUTIONS AND OPPORTUNITIES IN SOIL PHYSICAL HYDROLOGY

Transdisciplinary soil hydrology

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Abstract

In this paper, I present an evolutional pathway from disciplinary towards transdisciplinary science and research and offer contemporary examples of interdisciplinary research in soil hydrology. I further explore exciting opportunities that can lead to transdisciplinary research (TDres), as society demands for our science expertise to be increasingly involved in developing solutions in global issues of sustainability, food and water security, as well as in the decision-making process. By way of TDres involvement in public policy, the scientist is going to be working in the trans-science domains for which (s)he is likely not very prepared. Recommendations are presented to better train students and early-career scientists so that they can be effective in participating in TDres and communicating their scientific knowledge to relevant stakeholders, the public, and decision makers as part of the policy-making process.

1 | AN INTRODUCTION TO TRANSDISCIPLINARITY

In the past decade, we increasingly hear about the need for transdisciplinary research (TDres); however, many of us have an unclear understanding of what that really means, and how it differs from other collaborative research efforts such as multidisciplinary and interdisciplinary research. Much of the need to work collectively with expertise from different backgrounds is coming from the fact that societal issues most often cannot be addressed successfully by a single discipline because of their complexity. Such complex matters are sometimes also called "wicked" problems (https://en.wikipedia.org/wiki/Wicked_problem) and require a breadth of expertise across knowledge fields. Furthermore, we realize that our own discipline is becoming increasingly complicated and requires excellent disciplinary knowledge to be effective in our research contributions. Hence, solutions of scientific "wicked" problems demand both specialists and collaborative efforts across disciplines. This notion is not new, but it remains an issue especially in the academic world, where scholarship and merit are still mostly rewarded based on individual achievements. In this treatise, I will attempt to explain the meaning of TDres and provide examples of both interdisciplinary and transdisciplinary research collaborations. I conclude with suggestions for higher education to prepare students and early-career scientists, as well as the need to establish working environment conditions that facilitate TDres among academics and nonacademic participants, in part using my personal experiences.

The challenge is to collaborate in ways that are productive and effective, although we have different cultures of conducting science across the natural sciences, social sciences, and the humanities. Thus, let me start by clarifying the many different forms of collaborative research as explained in the following blog: https://medium.com/we-learn-we-grow/what-is-transdisciplinary-13c16eacf57d. It is best to first describe disciplinary science, which can be loosely defined

Abbreviations: AAAS, American Association for the Advancement of Science; CZ, critical zone; ILRP, Irrigated Lands Regulatory Program; ISMC, International Soil Modeling Consortium; NGO, nongovernmental organization; NSF, National Science Foundation; RWB, Regional Water Board; SDG, Sustainable Development Goal; SSSA, Soil Science Society of America; TDres, transdisciplinary research; VZJ, *Vadose Zone Journal*.

(adapted from Petrie, 1992) as "a specialization of knowledge within some sort of overriding unity, such as an organization or unity of a group of people who study the discipline, train others, and arbitrate about the 'truth' of the claims within the discipline." As one conducts disciplinary science, the progression in Figure 1 demonstrates the increasing level of integration of knowledge sharing between disciplines, resulting in what could be claimed as a new discipline when achieving transdisciplinarity.

The first step of progression must be research within the framework of the established discipline, through *intradisciplinary* collaborations. Most of us have a record of doing so and jointly publish our research results in disciplinary journals, predominantly (e.g., *Soil Science Society of America Journal*). As the scientist moves to *multidisciplinary* research, the project would involve other disciplines for problem solving by working together through knowledge sharing from multiple viewpoints, but each would draw on their own disciplinary knowledge. However, as Petrie (1992) points out, the end effect is additive, not integrative. It will also lead to joint research publications but is typically limited to the specific project. As the project becomes increasingly collaborative, *cross-disciplinary* teams intersect and transfer knowledge between disciplines, likely leading to *interdisciplinary* research, further integrating the shared knowledge and methodologies using a synthesis approach. Typically, this leads to new applications and may result in new research fields (soil biophysics, hydropedology, and critical zone research). In the final step of this progression, by transcending the boundaries of disciplinary perspectives, new intellectual frameworks and disciplines may emerge from interdisciplinary research groupings involving nonacademics. This then leads to *transdisciplinary* participatory approaches towards TDres, to solve meaningful and often complex societal problems that address issues of public concern (real-world problems). This requires inclusion of nonacademics, such as stakeholders, public agencies, and policymakers, at the relevant problem scale. Often, transdisciplinary projects address environmental issues of concern to the public or are being applied to emerging questions around sustainability.

Core Ideas

- A review of transdisciplinary science is presented.
- Opportunities in soil science and hydrology for transdisciplinary research are plentiful.
- There remain challenges for researchers to contribute to the science–policy interface.

A recent historical overview and analysis of TDres was written by Klein (2014), who attributes its origin to the discourse of problem solving, and the development of a new synthetic framework of problem solving that transcends the narrowness of disciplinary worldviews and combinations of cross-disciplinary combinational approaches. The analysis suggests that TDres originates from sociopolitical movements and governments, demanding democratic participation among relevant stakeholders in solving problems of society. Klein (2014) points to the essential merging of academic and professional contexts of transdisciplinary science, from the interactions between science and society. This, in turn, may lead to trans-science (Weinberg, 1972), as referenced by Philip (1980, 1991), suggesting that potential conflicts of interest through policy-driven science may lead to a surrogate scientific field that is largely driven by politics rather than societal needs and may even ignore scientific facts. Weinberg (1972) defines trans-scientific questions as a category of questions that can be stated scientifically but are unanswerable by science. As stated by Weinberg (1972), "scientists accept the responsibility to bring their disciplinary expertise to bear on the trans-scientific questions raised by society, but they are mostly working outside the realm of their expert knowledge. The scientist and science provide the means; the politician and politics decide the ends."

In his 1991 opinion paper, Philip comments on the future discipline of soil science and offers either a warning (glass is

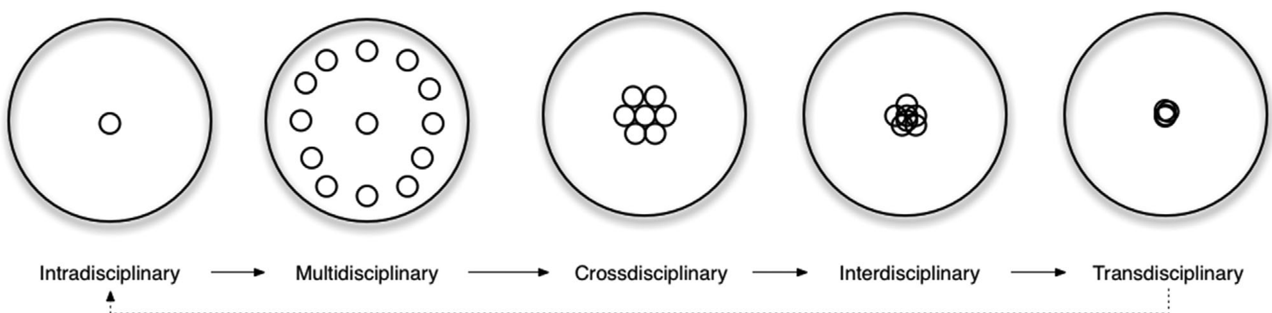

FIGURE 1 Collaborative research through progression from intradisciplinary to transdisciplinary.
Source: Jensenius (2012)

half full) or a bleak outlook (glass is half empty) on changing attitudes and accountability of the soil science community, especially as related to computer modeling. It is relevant to the topic of TDres, as soil science is both a natural science and a professional practice. He elaborates on the ideal science and its community ethical norms, such as the norm that scientific knowledge should be in the public domain with fully open communication lines, and the norm that scientific outcomes and truth should not be "contaminated" by personal rewards or towards social interests. He argues that since science is largely paid for by governments or industries, conflicts of interest may arise, and scientists may be swayed to "obey" society or political demands. It is certainly worth reading his commentaries, despite that he wrote them 30 years ago.

Philip (1991) argues that we cannot know the scientific truth when solving societal problems, and that the scientific community (including soils) is applying computer simulation models that give answers that are not necessarily true and based on poorly understood processes, and are thus far away from the real-world truth. He concludes that decision makers (professionals and politicians) seek answers to satisfy their stakeholders and can do so using uncertain model outcomes that provide the answers they want! In one of his earlier publications, Philip (1980) acknowledges the possible lack of relevance for solving scientific issues related to characterizing field-scale heterogeneities in soil and hydrologic sciences using stochastic processes, and whether the resources used justify societal benefits at all when transcending into the realm of trans-science. Whether this is true or not, he concludes on a positive note that irrespective of the amount of scientific knowledge gained, it will likely be beneficial to be well informed when making predictions in the trans-science domain.

2 | APPLICATIONS OF TDRES IN SOIL SCIENCE AND HYDROLOGY

Despite that TDres has been mostly applied in the social and human sciences, the groundwork for advocating and defining transdisciplinarity comes from a quantum physicist (Nicolescu, 2002), who addressed the problem of fragmentation of knowledge. In Section 2, we will provide examples of both interdisciplinary and transdisciplinary research in soil hydrology, using the definitions of Section 1.

As suggested in the preface of this special issue, soil knowledge has rapidly evolved in the past decades, largely because of research collaborations among soil science subdisciplines and between disciplines of soils and hydrology, agronomy, engineering, biology (plant and microbial sciences), and climate science, among others. These collaborations have led to scientific outcomes for which "the whole is greater than the sum of its parts," thereby paving the way to further their disciplinary contributions to broader societal issues, to be addressed in Section 2.2. I start, however, by summarizing selected interdisciplinary contributions in the domain of soil science and hydrology in Section 2.1, all of which could potentially lead to transdisciplinary applications.

2.1 | Current contributions to interdisciplinary research

Most illustrative has been the movement in the 1990s for soil physics to transcend its disciplinary field to vadose zone research, leading to the publication of *Vadose Zone Journal* in 2002, strongly advocated for by van Genuchten and colleagues (van Genuchten, 2002). Initiation of the journal in the early 2000s was motivated by the recognition that the vadose zone is fundamental to many scientific and engineering disciplines. However, applications were limited to soil science predominantly, without using the knowledge of related disciplines in other fields. The result was that our understanding of the vadose zone for too long had remained fragmentary and incomplete. Prior to its publication, there was much debate within the Soil Science Society of America (SSSA) about the need for such a multidisciplinary journal, and about the best title for it. The name *Vadose Zone Journal* (VZJ) was selected to clearly show that the intent of VZJ was to seek contributions and readership from across a broad range of disciplines, in addition to the soil and agricultural communities. Over the past decades since its publication, VZJ has become an effective publication outlet across a broad range of disciplines, including soil and geophysics, hydrogeology, soil and geochemistry, microbiology, terrestrial ecology, atmospheric sciences, agro-informatics, and many engineering disciplines. The rapid acceptance of VZJ within the scientific community has been a recognition that vadose zone processes play a prominent role in many interdisciplinary environmental and resource management issues, and that a dedicated vadose zone journal was indeed very much needed and wanted. Clearly, VZJ is filling an important and unique niche in interdisciplinary research through its focus on the critical zone between the earth's land surface and permanent groundwater table.

A second illustrative example of integrating soil science with the broader environmental science is through critical zone (CZ) research. The CZ was defined by the U.S. National Research Council (NRC, 2001) as the earth's research domain that extends through the root zone, deep vadose zone, and groundwater zone and includes the land surface and its canopy of vegetation, rivers, lakes, and shallow seas. Because soil and water are two critical components of the critical zone, their interactions with the other components in the CZ determine the availability of nearly every life-sustaining resource on earth. The integrated studies of the CZ were identified as a compelling research area for the 21st century. Consequently, the National Science Foundation (NSF) has funded nine CZ observatories nationwide in the past 10 years and will continue to support CZ research through funding of a Critical Zone Collaborative Network (CZCN, http://criticalzone.org/national/).

Within the CZ framework, the field of hydropedology provides for an additional synergistic scientific means towards integration of knowledge and serves a key role in interdisciplinary teams to address complex environmental research and policy issues (Bouma, 2006; Guo & Lin, 2016). The interdisciplinary field of hydropedology was defined and advocated for by the unrelenting efforts of Henry Lin throughout his career. Lin et al. (2005) defined hydropedology as "an intertwined branch of soil science and hydrology that encompasses multiscale basic and applied research of interactive pedological and hydrological processes and their properties in the unsaturated zone." The synergistic integration of classical pedology with soil physics, hydrology, and other related bio- and geosciences into hydropedology suggested a renewed perspective and a more integrated approach to studying landscape–soil–water dynamics across scales. The case was made that research on future environmental policy issues requires a joint learning process approach among stakeholders, policy makers, and other relevant partners, and that the field of hydropedology may be ideally positioned to bring science to bear when dealing with land-use policy issues. Unquestionably, Lin's efforts and philosophy over time have led to advancing the field through the bridging of disciplines and transforming soil science to an interdisciplinary research field.

Other soils initiatives that have promoted collaborative soil physics research across environmental and agricultural disciplines include agricultural systems research and through the International Soil Modeling Consortium (ISMC). Ahuja, Ma, and Timlin (2006) made a strong case for the need of TDres to synthesize disciplinary knowledge in agricultural systems and to identify knowledge gaps when addressing environmental issues and food security globally, through process-based agricultural system modeling at the whole-system level. Vereecken et al. (2016) laid the basis for the ISMC to integrate and advance soil systems modeling, data collection, and observational capabilities. Among modeling expertise within the soil disciplines, ISMC's goal is to address major scientific gaps in key soil processes, and to promote integration of soil modeling expertise in related disciplines (e.g. climate, hydrology, and ecology), as well as integrating societal and environmental considerations when modeling soil and ecosystem functioning. By doing so, the consortium's mission is "to improve the role of soil modeling as a knowledge dissemination instrument in addressing key global issues and stimulate the development of translational research activities." Hence, there is a clear goal to contribute to societal issues and to venture into trans-science, by evaluation of outcomes of public-domain whole-system computer models by their intercomparison, and to serve as a communication tool between science and society.

2.2 | Opportunities for TDres

Surely, though, the last step of contributing to transdisciplinary science is to broaden interdisciplinary research by engaging with society, to collaborate with nonacademic partners and stakeholders, and to be involved in policy making by strongly impressing the disciplinary science into the decision and policy making process, at either local, regional, or global scales. This is not something that we as scientists have learned to do, and it is not necessarily rewarded in academics (though likely more appreciated and rewarded by national and international research organizations). Some progress has been made, however, and I will suggest some specific areas of TDres research which ensure that our science expertise be included in the decision-making process.

For as long as I can remember, the SSSA supports a Science Policy Office (SPO) in Washington DC, with their staff engaging with congressional staff in science and technology policies. The SPO focuses on federal issues related to food, agriculture, and natural resources research and engages society members with policymakers to advance our sciences. It funds a congressional science fellowship every year, facilitates meetings with congressional representatives, and assists its members in advocating for their science.

The Global Soil Partnership (GSP) was established in 2012, with its administrative office at FAO, Rome. Its mission is to position soils in the global agenda, with the objective to improve soil governance and to promote sustainable soil management globally. It does so by developing strong interactive partnerships and enhanced collaborations between a wide range of stakeholders, including government organizations, universities, and soil science societies, UN agencies, nongovernmental organizations (NGOs), and others. Among its achievements, it has established the Intergovernmental Technical Panel on Soils (ITPS) and created regional soil partnerships. The GSP developed an initiative for the harmonized global mapping of soils, specifically for soil salinity mapping (Omuto, Vargas, Mobarak, Mohamed N, & Yigini, 2020), and produced the Status of the World's Soil Resources report (FAO, 2015).

In addition, I should refer to the concept and synthesis of soil security by McBratney, Field, and Koch (2014). They define soil security as "an overarching concept of soil motivated by sustainable development, concerned with the maintenance and improvement of the global soil resource to produce food, fiber and fresh water, contribute to energy and climate sustainability, and to maintain the biodiversity and the overall protection of the ecosystem." The authors successfully argue that soils play an integral part in the global sustainability challenges of food and water security, sustainability of energy use, climate change, biodiversity, and ecosystem services. The purpose of the soil security concept is for soils to receive global attention, in part by connecting with the public and recognizing the need for a policy and legal framework that advocates for soils, their conservation, and protection.

This brings me to a plea by Bouma and Montanarella (2016), recommending a systems approach to land-use studies, by which soil scientists contribute collaboratively with other relevant stakeholders to the land-related UN Sustainable Development Goals (SDGs). Though soils are not specifically listed, 5 of the 17 SDGs are strongly soil related (SDG 2, food; SDG 3, health; SDG 6, water; SDG 13, climate; and SDG 15, sustainable development, including by addressing land degradation and biodiversity loss). Because the SDGs (https://www.un.org/sustainabledevelopment/sustainable-development-goals/) have a clear societal focus, they offer a unique opportunity for soil science to be involved as national governments are implementing policies to achieve their respective targets. Bouma and Montanarella (2016) make the case that soil scientists are well positioned to be effective communicators in the stakeholder–policy–science arena, not only because they have done so in the past through soil surveys, land classification, and extension services, but also because soils makeup a cross-cutting theme in the five soil-related SDGs.

Another obvious example of linking our soil science expertise with advising and involvement with policy making is through the global climate science agenda, driven by the Intergovernmental Panel on Climate Change (IPCC). I note that their recent report on climate and land (IPCC, 2019) highlights interactions and feedbacks between our changing climate, land degradation, sustainable land management, and food security. As a more recent path for TDres, NSF is soliciting collaborative research in the food–water–energy nexus, driven by food and water security and the need for sustainable energy. As pointed out by Hatfield, Sauer, and Cruse (2017), it is imperative that soils are going to be included in these discussions and in the decision-making process. Much of the discussion on food, water, and energy has ignored the fact that the soil resource is an essential component of any of these three key elements that sustain humankind, yet it remains largely unrecognized, including by policymakers at all levels.

Finally, I would like to give an example of TDres that is close to my academic home. California Central Valley (CV) residents largely depend on groundwater for their drinking water supply; however, over the many decades of fertilizer and manure applications to irrigated cropland, groundwater quality has been severely degraded by nitrate contamination. There has been a long history of seeking ways to reduce nitrate contamination of groundwater; however, it was only about 10 years ago that a decisive process was initiated that ultimately will lead to safe drinking water for the valley's residents.

In 1999, the Central Valley Regional Water Board (RWB) created the Irrigated Lands Regulatory Program (ILRP) to ensure that discharges from commercial irrigated land did not affect beneficial use of the water. The RWB allowed the >30,000 growers representing over 2.4 million ha (6 million acres) of irrigated land to combine resources by forming water quality coalitions. These coalitions assist with permit compliance and serve as the intermediary between the growers and the RWB. The focus of the program was initially on discharges to surface water, while the RWB turned to scientists to learn more about potential discharges to groundwater.

Through the 2008 senate bill SBX2 1, the legislature requested that the State Water Board assess nitrate sources, groundwater nitrate status, and communities affected by nitrate in drinking water through a pilot study in the southern part of the Central Valley and in the Monterey County portion of the Salinas Valley. The study area represented 40% of California's irrigated cropland. This assessment was proposed to identify improved source management practices, groundwater remediation options, and alternative water supplies for nitrate-affected communities. In 2010, the State Water Resources Control Board contracted with University of California Davis through the Center for Watershed Sciences to perform the work and to identify options for implementation of promising actions. Colleagues Thomas Harter and Jay Lund with their co-investigators completed the so-called UC Davis Nitrate report in 2012 (Harter et al., 2012). Outcomes included findings of widespread groundwater nitrate contamination that had accumulated over decades, the identification of improved nutrient management practices, and an outline of options for alternative water supplies and treatment with cost assessments. The report also included a list of policy options to reduce nitrate loading to groundwater, providing communities with safe and reliable drinking water in the future. In parallel, the ILRP expanded its program in 2012 to include monitoring and reporting on groundwater discharges from all irrigated land in the Central Valley. The State Water Board made a range of recommendations to the legislature and incorporated them into their policy making after convening various taskforces, including a Nitrogen Tracking and Reporting Task Force, convened by California's Department of Food and Agriculture (CDFA). This specific multi-stakeholder, 28-member task force included membership by university researchers, cooperative extension, RWBs, other state agency representatives, grower associations, NGOs and others. The task force developed a set of recommendations through consensus building and included benefits for both the growers and society. After vetting of these recommendations by an Agricultural Expert Panel, convened by the State Water Board, it was recommended for growers to develop a nitrogen management plan (NMP) at the farm scale and to implement practices over the long term that will minimize excess nutrient applications relative to crop yield. This led to the requirement for growers to document, analyze, and make available the nitrogen consumption ratio, defined as the ratio of field applied (A) to crop removal (R) or A/R. In the coming years, coalitions will be developing specific approaches, targets, and timelines to improve nitrate discharges to groundwater in ways that will ultimately protect water quality for drinking water.

This specific example illustrates how the University of California Davis nitrate report was instrumental in moving forward policies and regulations for improved nitrate management in California that were long overdue. In part, this was successful because the political climate was right, as well as because of substantial demands by environmental justice groups.

3 | IMPLICATIONS OF TDRES FOR HIGHER EDUCATION AND EARLY-CAREER SCIENTISTS

The transition towards transdisciplinary approaches has implications for higher education through curriculum needs, career advancement, and the training of students to be relevant in their research work and to realize that successful careers involve a life-long learning process. As explained by Evans (2014), to be successful in TDres and be receptive to new demands and real-world problems, universities must build capacities that prepare students for transdisciplinary interactions. This is done, for example, by developing curricula that are contextualized for such societal demands, (e.g., general education and science and society coursework), and through learning of evolving methodologies and communication skills. To train students for TDres, they must be immersed in group environments that discuss real-world problems, promote collaborative thinking, and learn project management skills. In this regard, I reference the opinion paper by Singha, Sullivan, Li, and Gasparini (2020), recommending that senior scientists mentor the next generation of researchers and train them to develop into successful research partners in critical zone research fields.

There is evidence that students and early-career scientists increasingly want to participate in problem-solving projects that have strong societal outcomes. When teaching, many of us note the student's heightened level of engagement. I like to reference a recent opinion paper by a group of early-career scientists (Gaieck, Lawrence, Montchal, Pandon, & Valdez-Ward, 2020), expressing their concerns about political decisions regarding environmental research funding, and strongly advocating for increased participation in science policy. They make the case that scientists have a civic responsibility to advocate for science and offer ways to improve science communication with policymakers.

In addition to the support provided by our professional societies, the American Association for the Advancement of Science (AAAS) is offering various ways and activities to be engaged in the science-policy area by building effective science-policy connections. Typically, our research publications are not framed in a language that is easily accessible or useful to policymakers when needed. In their analysis of global engagement of science in policy (AAAS, 2017), various recommendations are presented to prepare coming generations of scientists for increased science policy demands, focusing on communication of technical information, and knowledge sharing. These include the establishment of science policy fellowships and internships, and other ways to engage scientists in policy processes (such as details and rotations within public agencies). However, this can only occur if academia acknowledges the merit of public engagement and rewards its faculty and students for doing so.

As I reflect on my own academic career, I was not trained to conduct TDres, and instead it was impressed on me to develop into a strong disciplinary academician who publishes in highly recognized disciplinary journals. However, as I advanced my career, I was lucky to be guided by mentors who encouraged multidisciplinary collaborations that evolved into interdisciplinary research in my later career. Although my progression towards collaborative research appeared unintended, one could argue instead that a more directed approach is required to be successful in TDres. I note though that a strong disciplinary background is a prerequisite for disciplinary contributions to have a significant impact on the outcomes of TDres. Therefore, I would advocate for early-career scientists to evolve career-wise from disciplinary to interdisciplinary and transdisciplinary, with heightened transdisciplinary collaborations only after a strong disciplinary research record has been built.

As pointed out by one of the reviewers, being involved in TDres may not be simply right for everybody, as there are barriers to be overcome. Interdisciplinary collaborations often start with competing objectives if not convened carefully. Early on, there has to be agreement on mutually beneficiary outcomes that facilitate progress throughout the transdisciplinary process. Often there are misunderstandings of meanings of technical and/or socioeconomic terminologies that need to be understood by all involved in transdisciplinary teams.

4 | CONCLUDING COMMENTS

As documented above, the field of soil hydrology is making great strides in sharing their knowledge outside their immediate scientific field, transcending disciplinary boundaries. Despite this progress, Or et al. (2011) in their white paper called for SSSA members to strengthen their engagement in central issues addressed by the scientific community, in areas of climate change, food security, and the environment, calling for their active involvement through TDres. Both through the society's Science Policy Office as well as through AAAS, there are a variety of ways for students and scientists to be involved. At academic institutions, curricula need to be devised that support transdisciplinary thinking, so that students are prepared to be involved in TDres in their professional careers. In addition, academia need continue to find ways to encourage and reward university faculty for their activities at the science–policy interface.

Because of the complex natural world, the problem solving of environmental issues demands collaborations across disciplines and must include relevant stakeholders and policy makers. However, in most cases, the scientist has limited capacity and experience in providing answers in such questions of public policy. It is here that TDres becomes very relevant, engaging science with the public and its stakeholders and representatives in the debate, so that the best decisions are being made, given the scientific knowledge available. This requires enormous trust in the science by the public, but outcomes also depend on the political structure in which the decision maker operates. For example, irrespective of the transparency of society, solutions to the recent COVID pandemic outbreak have varied greatly among countries, despite the overwhelming unified scientific facts globally. Whereas scientific concepts are clearly supported by factual data, politicians may discard them as the scientific data may not agree with one party's agenda, thereby blurring the line between science and politics. I personally note that information streams increasingly are fed by social media without review and fact checking, and that there is enormous need for quickly available and accessible science-based information to support trans-science demands.

There is, however, also good news. The Pew Research Center (Pew Research Center, 2020; a nonpartisan fact tank located in Washington DC that informs the public about the issues, attitudes, and trends shaping the world; https://www.pewresearch.org/about/) summarized their findings on U.S. public opinion with respect to science issues and their effect on society. They found that except on issues of climate and energy, public attitudes on other science-related issues are nonpartisan (e.g., on public health and genetic engineering). Moreover, close to three-quarters of the American public supports science and agrees that it has a positive effect on society, now as well as in the future. Also, it was reported that public confidence and trust in science has increased over time, with almost 60% of U.S. adults favoring for scientists to take an active role on policy issues.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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