Received: 8 August 2022 | Revised: 16 February 2023 | Accepted: 28 April 2023
DOI: 10.1002/ppp3.10390

OPINION

Plants People Planet PPP Open Access

Empowered through our diversity: How to bring in a new age of plant science collaboration

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Funding information
L.N. is supported by the Marie Skłodowska Curie Individual Fellowship (MYFUN, Grant number: 835472). E.M. is supported by the Swiss Confederation through the University of Lausanne.

Societal Impact Statement

Climate-change and land-use intensification are degrading ecosystems globally, impeding their services to humans (e.g., food security and human health). The United Nations 13th and 15th Sustainable Development Goals (SDGs) call for action to protect and restore ecosystems. Only transdisciplinary research can unravel the multitudes of interacting ecosystem parts that could help accomplish these SDGs. However, a major challenge will be overcoming material, social and other types of barriers that prevent collaborations. This study explores some of these challenges and seeks the views of the community through a survey to help develop a new age of plant science collaboration.

Summary

In this opinion article, we explore the problem of missed opportunities for collaboration in fields related to plant science. Lack of awareness of the scientific output, which can be gained from transdisciplinary collaborations, as well as the opportunities they can provide for early-career scientists, may contribute to this. Here, we name communication barriers as particularly inhibitory to the formation of collaborations and propose possible solutions to overcome these barriers. Eventual action towards these solutions needs to be based on the opinions of the community. We thus intend this article to initiate a dialogue among researchers across the many disciplines of plant science about the feasibility of these proposed solutions. The questionnaire included with this article, intended for the broad plant research community, we believe could help us gain the necessary information to proceed in addressing communication barriers to transdisciplinary science collaborations. We provide a theoretical framework, examples and timely topics as discussion points to inspire participants of the questionnaire to contribute their voice to shaping a new age of plant science collaboration.

KEYWORDS
global change, interdisciplinary science, plant–soil interactions, science collaborations, science communication

Lena Neuenkamp and Erica McGale contributed equally to this work.

1 | INTRODUCTION

1.1 | Transdisciplinary collaborations in plant science: the magic and the difficulty

In times of rapid environmental change and approaching putative climate-tipping points, a comprehensive understanding of the mechanisms that drive ecosystem consequences and their response to environmental change, such as climate change, is of the utmost importance (Berdugo et al., 2020; Traill et al., 2010; Turner et al., 2020). Understanding the dynamics of plant communities as primary producers, as well as their complex biotic interactions, is central to dissecting ecosystem responses to environmental change (e.g., Tomiolo et al., 2020). Yet, disentangling the dynamics and ecosystem impacts of ecological interactions is a complex task, demanding that researchers scale up from the organism to ecosystem levels, and from single points in time to long-term trajectories (e.g., Ochoa-Hueso et al., 2021; Ostle et al., 2009; van der Putten et al., 2013). It is rare to have expertise in all the organisms, as well as access to all the methods, tools and resources, necessary to explore all the lines of questioning (Box 1). As a solution, transdisciplinary collaborations among plant science and related fields (hereafter for simplicity: the plant science community) offer the needed lenses from multiple research specialties to enable thorough dissections of ecological interactions and their relationship with ecosystem processes (e.g., Lekberg & Helgason, 2018).

Collaborations that unify and increase the coverage of research efforts in plant science have extended benefits: Not only will the results support efforts to slow biodiversity loss and ensure vital ecosystem functioning and service provisioning, but increased collaborations also especially benefit early career and marginalized researchers that might have limited access to research funding (Adams, 2013; Wang et al., 2017). Access for every plant researcher to an extended collaboration network connects each one to more data, methods and expertise. This gives researchers more opportunities to create and participate in putatively high impact, transdisciplinary publications, which are pivotal for the field and individual researcher establishment. Output from existing global research networks such as the Nutrient Network (NutNet) or the Drought-Net Research Coordination Network (RCN) serve as good examples of the potential of large-scale collaborator networks, albeit specialized in particular sub-topics of the plant science field (https://nutnet.org/; https://drought-net.colostate.edu/).

Databases on particular plant science disciplines, such as CropPol for crop pollination (Allen-Perkins et al., 2022), can be very useful to centralize resources for specific researchers and therefore bring them to a common location. Broader databases such as ResearchGate (https://www.researchgate.net/) also connect scientists globally. It is difficult, however, to quantify the success of these databases in connecting scientists and facilitating collaborations that generate increased output as they often do not occur on the site. This additionally applies to publication, protocol and data repositories (e.g., Web of Science, https://www.webofscience.com/; re3data Global Registry of Repositories, https://www.re3data.org/ and STAR Protocols, https://www.cell.com/star-protocols/home). Despite the role of these platforms, databases and repositories in changing the landscape of the continuity, transparency and contextualization of methods and results, they miss the crucial point of encouraging the development of collaborations before the sampling efforts are conducted and the papers have been published. The latter represents a key moment in transdisciplinary research, where resources, ideas and samples can be coordinated.

Integrating research questions from different collaborators at the start of a project is increasingly recognized as useful, and even more so for early-career researchers. For instance, creating plans for multiple analyses of the same samples to test effects, which may be caused by various factors of interest to multiple groups, would promote sustainable use of resources in terms of, for example, numbers of field sites, manpower and equipment, as well as a thorough analysis of the effects of mechanisms and functions across multiple hierarchical scales. Platforms such as the Open Science Framework (OSF, https://osf.io/) incorporate this concept through functions that include transparency and feedback at all points in the research process and during project planning. Yet, this approach still lacks, or rather, does not facilitate, the 'spontaneous' hopping onto sampling campaigns, nor the ability to easily find data to be re-analysed through a different lens, which would allow the sustainable (i.e., both physical and monetary) maximisation of research impact.

Despite the advantages of transdisciplinary collaborations, they are missed by many researchers for a multitude of reasons, and even if they are available in a non-negligible array of freely accessible platforms, repositories and social sites, successful transdisciplinary collaborations are still missed. Even if the remaining inconveniences to join projects and share data were addressed, the assumption that the parties involved could freely and easily communicate despite their different backgrounds would likely not hold. Notably, all aforementioned platforms, whether specific or broad in scope, lack a method to ensure a commonly understood 'language' for all potential interested users, especially when within the vast plant science community. For platforms on specific topics, this makes it quite hard for new researchers to join, integrate and benefit, and for broader platforms, this may prevent researchers with related topics but diverging terminologies from finding each other. Experimental and methodological communication barriers remain largely unaddressed; even when researchers share a discipline, they may not be studying or discussing about the same level of analysis (Box 1). This article aims to describe this problem, propose a scientific method forward and provide an infrastructure with which to receive feedback from the people for whom these problems must be addressed: those in the plant science community.

Box 1. Reasons for missed transdisciplinary crosstalk and collaborations.

We see two major communication barriers that, if overcome, could lead to more transdisciplinary research collaborations: experimental and methodological.

Experimental barriers

General approach

Researchers approach experiments from their experience. Many are specialized in either in vitro, glasshouse or field experiments, non-exhaustively. For these three, the set-ups, replication and other considerations needed for a successful design are very different (Brent et al., 2017). Unfamiliarity with different experimental set-ups may be relieved by joint efforts of people with different experiences, who may also see the advantages of each set-up for investigating a particular question or for addressing difficulties across set-ups. For example, highly variable results may occur in all experiments for many reasons, but strangely, mainly field researchers make use of effect size (Sullivan & Feinn, 2012) to interpret these results in an informative way.

Questions of interest to particular disciplines

Plant scientists are usually even further subdivided than by their general approach. Within field researchers, there are experts in natural versus agricultural, managed versus unmanaged systems (**Box Figure**). Within this, they focus on one or few scales of ecological organization. Even further, two plant scientists studying the same scale of organization, within the same setting, in the same types of experimental set-ups, may not be studying the same level of analysis. Consider, for example, the different levels of analysis even covered by the word 'function': a function could be how something works or exists, or why, or a function might not even fit in these categories and could be accidental depending on the context (Jax & Setälä, 2005; Sherman, 1988)

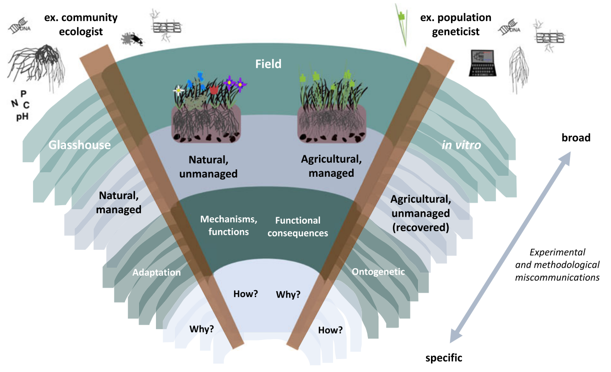
Methodological barriers

Design and purpose of method

Different disciplines require different sampling methods to address their questions (**Box Figure**). Certain types of sampling are not necessarily useful across disciplines, but compromises or plans to incorporate other types of sampling in advance could enable cross-disciplinary usefulness (Burrascano et al., 2021) and could save money and time for the groups involved. This can be particularly useful for field work (Brent et al., 2017; Miller et al., 2021) or sequencing projects.

Naming conventions

Methodological specializations lead to diverged terminology as a further roadblock (Aubin et al., 2020; Chaudhary et al., 2022). For example, the beginning of flowering in plants is called flowering time in ecological disciplines, growing degree days for plant agriculturalists and anthesis to botanists.



Box Figure: Broad to specific miscommunication can occur across the various experimental and methodological specializations of plant scientists. A broad discipline that researchers may be specialized in is whether they mainly perform glasshouse, field or in vitro tests (as non-exhaustive examples). Within this, they will study certain types of ecosystems (natural vs. agricultural and managed vs. unmanaged). For example, a community ecologist may perform glasshouse mesocosm experiments on plant communities to study, as one example, management strategies for the persistence of natural ecosystems (i.e., natural and managed), and then may take further work to field settings to expand on their understanding. They would, however, perhaps be less informed in in vitro experiments for single molecule or gene manipulation. The questions asked within certain ecosystems can be at different levels of analysis, where 'how' questions may relate to mechanisms, functions, shifts in ontogeny, etc., whereas 'why' questions address consequences related to fitness, adaptation, evolution, and more. These further subdivide the approaches of plant scientists. ex., for example.

2 | ADDRESSING THE MAJOR COMMUNICATION BARRIERS

Plant science needs more unity in baseline communication. This communication also needs to be time efficient. The rapid evolution, evaluation and continued discussion on current project databases and collaboration platforms indicates that existing resources do not satisfy the needs of researchers. As recently as 2020, Aubin and colleagues discussed important considerations needed for an effective platform of ecological research projects. Those considerations included among others are the need for highly insular and specific datasets both to be able to conserve their uniqueness and innovation while simultaneously touting an accessible language to encourage the participation of others in projects other than their own (Aubin et al., 2020). Whether the need for better communication can be satisfied by a new platform, an add-on to a current platform, an independent tool that can be implemented to all existing tools or others, the best medium to tackle communication barriers is not yet clear. Gaining information from a consensus of plant science researchers would be an effective strategy for pursuing an effort to meet their needs. Such an approach would also align with the scientific workflow—gathering data to answer a question.

Here, we encourage participation in a questionnaire (see Supplementary Notes S1) in order to gather the data necessary to make an informed conclusion on this subject. To guide participants in imagining tangible solutions, we illustrate our questions using a fictive online platform with certain proposed solutions for plant community researchers. We additionally use the metaphor of a transportation system to help visualize these solutions in accordance with the current state of the plant science community. The format of a fictive platform in the questionnaire should not limit possible solutions, but rather provide an infrastructure within which surveyed researchers can potentially realize their needs and ideas.

3 | TRANSPORT AND INTEGRATION OF KNOWLEDGE ACROSS THE CURRENT PLANT SCIENCE COMMUNITY

For any sort of knowledge-transport network to function well, its many components, coming from different backgrounds, need to converge with clarity into a single or set of linked paths in order to prevent inefficiencies and frustration. This requires that many existing hubs of information, equivalent to a diverse array of existing groups of researchers, topics, histories of experience and publications and new research motivations, connect ideally on one, unified, well-developed network (e.g., a circular network like in Figure 1a). Sometimes, smaller groups of people—researchers—have different sets of connections, away from a central network, but also in a smooth manner, allowing opportunities for discovery (Figure 1b). Meanwhile, others may have developed local networks that are non-centralized and therefore more segregated (e.g., connections built over time that were pieced together as in Figure 1c).

Despite existing networks and collaborations, each one may not be entirely visible to the next. Connecting all of the existing networks, as well as entities that continue to be isolated (Figure 1d), would be ideal, but may be piecemeal (Figure 1, red lines). In fact, many efforts have been made to centralize information in databases such as bioRxiv, ResearchGate and Dryad, to name a few, but visibility and availability of datasets, projects and contacts of interest, which in theory could all be potential collaborations, is not a guaranteed solution to realize those collaborations. It has been shown that even if a researcher comes across open-access data that was collected by a familiar method but by other researchers, there exists an uneasiness about the data. The latter is stemming from unfamiliarity in using this data; this has led to the fact that even publicly available data already open to cross-disciplinary uses and collaborations are currently rarely taken advantage of (Pasquetto et al., 2019).

This is understandable if we think of a train station: A person who has never travelled to Paris may see that there are several trains a day to Paris, but the availability of the connection is not the only thing that drives a person to take this route. Information about the

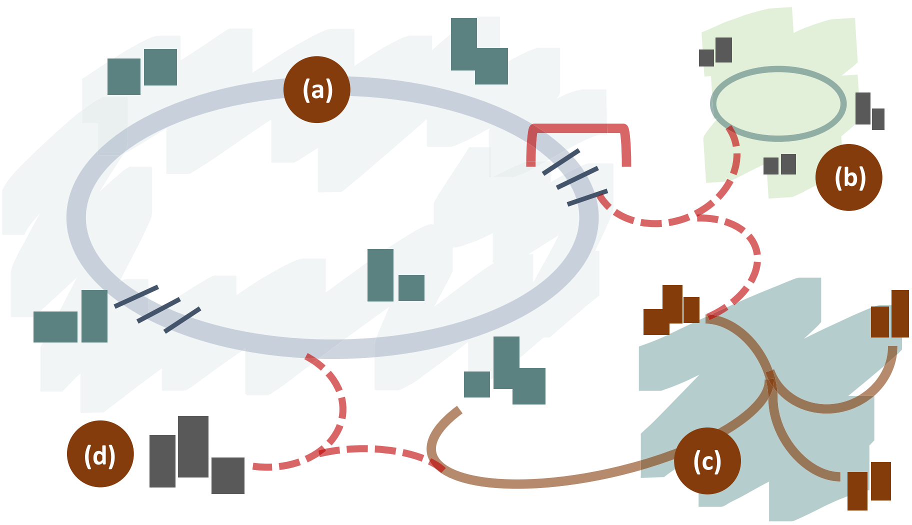


FIGURE 1 Schematic of 'knowledge-transport' among groups of researchers, represented here by towns connected or not-connected on transport networks. Different levels of connection are considered. Some research groups may already be connected (a) to a large, centralized network (large blue ring), (b) to smaller centralized networks (e.g., early career researchers; smaller blue rings indicate centralized networks with smaller scope), (c) to local networks but in a non-ideal manner (i.e., non-centralized, indicated by brown, less organized lines) or (d) to no other group of researchers in particular. Solutions for among-community connections must be considered to foster effective collaboration (dashed, red lines). Perhaps intersections among all communities at a theoretical 'central station' (red bracket) could be a solution, though it could also be problematic by implying a power dynamic from where the station is located (e.g., giving power to the biggest existing network).

destination and route, in a language that the observer can understand, is necessary to motivate a person to take a journey, including if that journey takes the shape of participating in a new research project or in the reuse of data. In summary, besides factual access to collaborations, good communication is another aspect substantially influencing whether a train ticket to Paris is bought or not, or in other words a collaboration opportunity is taken or not.

4 | PRACTICAL CONSIDERATIONS

Besides identifying theoretical and physical communication barriers, the next task is determining the technical tools needed to overcome these communication barriers. Though we do not propose an actual new platform, we use the theoretical idea of a new platform to brainstorm the importance of certain technical solutions for the plant science community.

Users come to a centralized location for transdisciplinary collaborations with the broadest sense of a need. They might be interested in acquiring data, samples, knowledge or experience (Figure 2a) or in contributing to any of the aforementioned categories (Figure 2b). After specifying an interest, drop-down menus of subcategories could include visuals, common and historical terms related to the search and more, to allow field-specific terminology to be generalized across fields. This would hopefully allow researchers using different terms for similar topics to understand each other (Figure 2c). Users could have the opportunity to give feedback on the accuracy of these filtering mechanisms, as well as modify their journey through brief feedback mechanisms (e.g., occasional 1- to 2-question pop-up surveys when using the filtering; Figure 2d). Feedback frequency could be determined through the questionnaire of researcher's opinions to reduce the possibility that this mechanism would inconvenience them. Similarly, options could be available in each need category (Figure 2a) to specify expectations from different collaboration types in terms of mentorship, commitment, co-authorship and more (Figure 2e). These options should be customized to protect the interests of researchers who would want to join the platform. Input from the questionnaire participants on these key onboarding features would ideally bring assessment of the prerequisite quality parameters they expect when seeking and entering into collaborations.

Though these initial features suggest general protections as part of a theoretical platform, the difficulty of equitable interactions when finding, establishing and maintaining transdisciplinary collaborations is an unavoidable, necessary, point of discussion. Questions of discrimination, exclusion, advantage and the best practice to promote equity

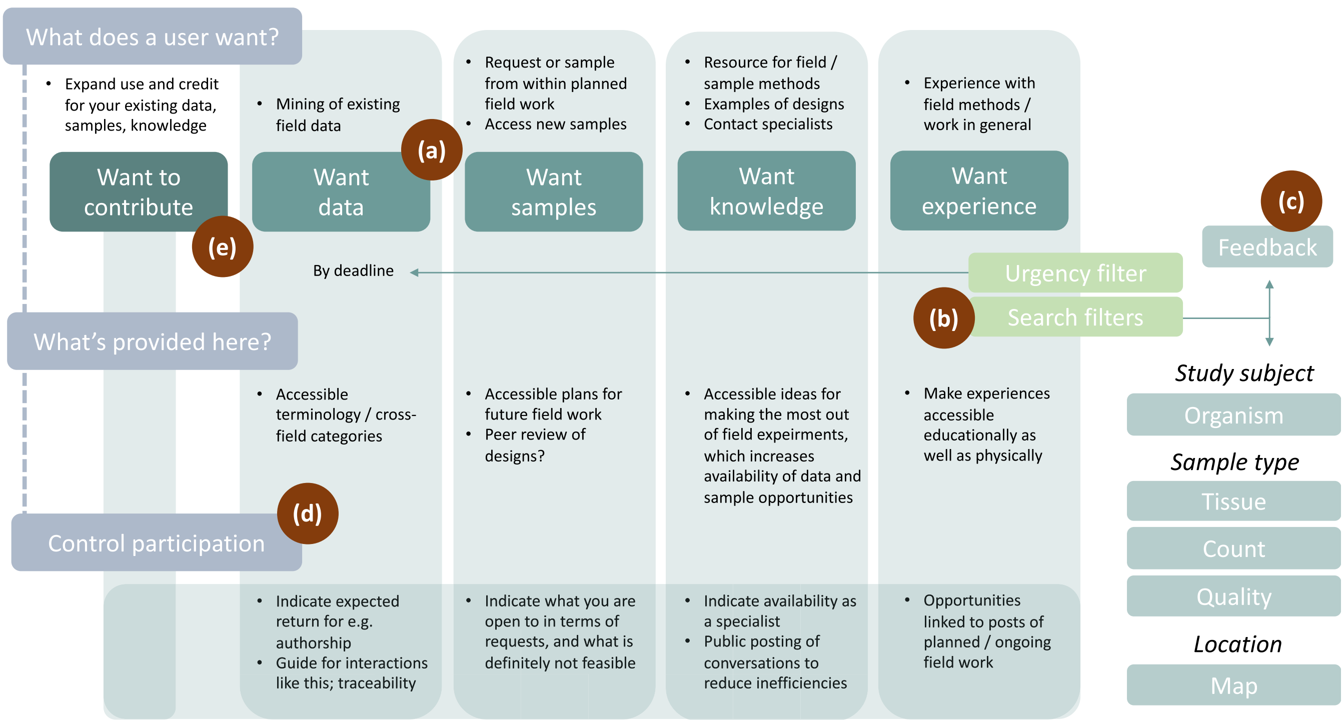


FIGURE 2 Schematic of functions in a theoretical platform that can be evaluated for their usefulness in enabling transdisciplinary collaborations. (a) Upon entrance to a platform, researchers can find a multitude of options to fit their needs: either in finding data, samples, knowledge or experiences, or (e) in contributing data, samples, knowledge (methods or past physical and theoretical experiences) or opportunities to participate in new research projects (e.g., physical field experience). Descriptions of each of the latter categories is provided in vertical fields in the figure. Other potential functions can include (b) filtering and (c) feedback mechanisms. (d) The consideration of each participant's expectations for a good practice of collaboration should be an essential part of the platform, but the question remains whether this should be guided by the platform, or individually controlled and personalized.

must be asked from the community and are hence included in the questionnaire. An accumulation of best practices or an analysis of the largest barriers to equitable access to transdisciplinary collaborations could very well be a result of the questionnaire proposed from this article. One concrete example could be a summary of the experiences of the researchers with the Nagoya Protocol on Access and Benefit-Sharing (https://www.cbd.int/abs/). This 'good practice' procedure was intended to ease international collaborations by providing a structure for sharing genetic resources across countries in a fair and equitable manner. One hundred and thirty-eight countries or unions currently have ratified the Nagoya Protocol, offering an expansive opportunity for feedback from researchers within these countries' plant science networks that may have interacted directly with this Protocol. In general, participants of the questionnaire can give essential insight into their experiences, including input on pain points of a theoretical or existing platform that have not been touched upon in this article.

5 | CONCLUSION

Responses of plant-ecosystem interactions to environmental changes and the consequences of these responses for ecosystem functioning and service provisioning need to be studied simultaneously through several lenses (e.g., natural and agricultural) to increase our understanding of their complexity. Transdisciplinary collaborations enable this, leading to a fine-scale mechanistic understanding of biological processes in concert with their relevance across hierarchical scales. This kind of foundational knowledge is needed to build a clearer picture of the future of ecological systems in the face of climate change. As Lekberg and Helgason state, we need to combine old and new tools to achieve this goal (Lekberg & Helgason, 2018). We suggest that communication barriers have an immense impact in preventing tools from efficiently allowing transdisciplinary opportunities for plant science researchers to materialize (Box 1). Considering that we do not possess a detailed comprehension of researcher needs in order to propose a concrete solution to collaboration barriers, we propose the surveying of the plant science research community for input on the best solution to these barriers (see Supplementary Notes S1).

We offer a theoretical infrastructure within which the creativity and feedback of surveyed researchers could potentially draw inspiration, deliver constructive criticism or offer new ideas. In this way, we also support the idea of sustainability, that is, building off of ideas of existing databases, whether mentioned here, proposed in other works or proposed in the questionnaire results (Assante et al., 2016; Cliffin, 2011; Honecker et al., 2020). The proposed questionnaire may in itself be a time investment of the community; however, it could go a long way for plant science research to ensure informed support for future work. We hope the potential for this questionnaire to provide real solutions to plant science communication barriers will lead to more open doors in terms of transdisciplinary collaborations (see Supplementary Notes S1).

AUTHOR CONTRIBUTIONS

Lena Neuenkamp: Conceptualization; methodology; writing—original draft; writing—review and editing; visualization. **Erica McGale**: Conceptualization; methodology; writing—original draft; writing—review and editing; visualization.

ACKNOWLEDGEMENTS

The authors thank Jamille Viray for providing the beautiful drawing of the graphical abstract. Moreover, the authors thank for their funding by Bundesbehörden der Schweizerischen Eidgenossenschaft and Marie Sklodowska-Curie Actions (MYFUN, 835472), and the two anonymous reviewers as well as the handling editor for their constructive comments.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Neuenkamp, L., & McGale, E. (2023). Empowered through our diversity: How to bring in a new age of plant science collaboration. *Plants, People, Planet*, 1–7. https://doi.org/10.1002/ppp3.10390