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Recommendations for establishing global collaborative networks in soil ecology

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Abstract

The complexity and transnational nature of environmental issues our societies are facing, and the need to build scientific capacity building in many regions of the world, require the establishment of global collaborative research networks that include a diverse representation of scientists from multiple geographical, cultural and socio-economical backgrounds. This topic is currently gaining relevance in the field of soil ecology, as awareness is increasing that recognizing, addressing, and predicting the changes that soils are facing requires global collaboration. However, the setup, management and operation of research networks imply multiple tasks and challenges that need to be carefully considered. While major issues related to the setup of such networks in ecology have already been described in the literature, here we focus on aspects that are important to make them truly global and inclusive. For doing so, we introduce a series of recommendations to successfully develop research networks that: i) explore ecological questions requiring data with a global coverage and ii) foster the participation of scientists who have been traditionally underrepresented in international research collaborations. These recommendations, which are based on our own experience, also provide practical advice to anyone aiming to initiate (or join) a global collaborative research network to the mutual benefit of all contributors.

Keywords international collaboration | environmental issues | distributed experiments | distributed observations

Introduction

'*Science is a collaborative effort. The combined result of several people working together is often much more effective than could be that of an individual scientist working alone.*'
John Bardeen (Nobel Laureate in Physics 1954)

The global nature of environmental problems such as climate change, desertification and biodiversity loss, to name a few, requires the establishment of research approaches that exceed in most cases the capacity of single/a few countries and research groups, which cover a wide range of environmental and geographical conditions, and that cannot be solved only by synthesizing existing heterogeneous literature (Fraser et al. 2013, Borer et al. 2014). As such, it is not

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surprising to discover the expansion of interdisciplinary and international collaboration in ecology over the years (Goring et al. 2014, Vermeulen et al. 2013, Craven et al. 2019), a general trend shared by other scientific fields (Adams 2012), and the growing interest in developing global networks of ecological experiments and surveys (Table 1). Collaborative research networks such as the Nutrient Network (Borer et al 2014), TreeDivNet (Verheyen et al. 2015), the US Long Term Ecological Research network (Johnson et al. 2010) and BIOCOM (Maestre et al. 2012) have provided key scientific insights regarding how natural and semi-natural ecosystems function and are responding to multiple global environmental change drivers. These networks are also fostering the development of new tools, concepts and experimental approaches to advance our understanding of key ecological phenomena, as Drought-Net is doing regarding the study of ecosystem responses to drought (Knapp et al. 2015, 2017, Lemoine et al. 2016). Collaborative research networks also provide many additional benefits, including the training of a new generation of technicians, PhD students and postdocs (McElmurry et al. 2003, MacNab 2005), networking opportunities for early career and established scientists (Ynalvez & Shrum 2011), the development of long-term scientific collaborations (Johnson et al. 2010), the increase in the quality and impact of the research conducted by their members (Rigby & Edler 2005, Garner et al. 2012), the building of scientific capacity in developing countries (Ali et al. 2012) and the increase in the awareness of the environmental problems or ecosystems being studied across scientists, the general public, science funders, policy makers and land managers/stakeholders (Parr et al. 2009).

Existing articles on international collaborations (e.g., Perz et al. 2010, de Grijs 2015, Parker & Kingori 2016, Gewin 2018) and globally distributed ecological experiments (Fraser et al. 2013, Borer et al. 2014) provide excellent advice and generic recommendations that have been proven to lead to successfully establish global networks in multiple disciplines, including soil ecology. These studies, however, have not focused on topics that may not be relevant when dealing with collaborators from the traditional scientific powers (e.g. Europe, North America, Israel or Australia) but that are critical when collaborating with colleagues working in countries with extremely low rates of funding, having a different cultural/religious background and/or that have problems communicating in English (but see Perz et al. 2010). Indeed, most global networks and monitoring programs focusing on (or including) soil organisms/processes developed to date have a poor inclusion of research sites/scientists from Africa, Latin America, Oceania (other than Australia and New Zealand) and Asia (e.g. Cameron et al. 2018; but see Maestre et al. 2012, Delgado-Baquerizo et al. 2018).

We acknowledge that not all research networks need sites in every country or an even distribution of sites in all regions to address key ecological questions and to provide meaningful generalization of the results obtained. However, not including scientists from underrepresented groups and regions precludes research networks to empower them with the tools, knowledge, contacts and access to foreign funds needed to help solve some of the most pressing environmental issues at their home countries. Indeed, there is a urgent need to better recognize and empower scientists working in Africa (e.g., Nordling 2015) and the global south (e.g., Nurcahyo & Meijaard 2018), and global research networks can play a pivotal role towards achieving this.

Here we present a set of recommendations based on our personal experience to successfully develop research networks in (soil) ecology that explore questions that require data with a global coverage and that aim to provide training and capacity-building opportunities for scientists traditionally underrepresented in these international collaborations. Therefore, we focus on those aspects that may be more limiting to include researchers from regions that do not have access to research funds and/or the scientific expertise commonly available in Europe, Australia, China or North America, and that can facilitate the establishment of truly global (geographically speaking) and diverse (from the cultural and socio-economical point of view) research networks.

Recommendation 1: Do you need to create a new network?

The establishment of a global collaborative research network implies multiple (and 'big') tasks and challenges, which should be carefully considered before initiating such a scientific endeavor. Thus, the first issue to consider is to ask from the beginning if it is really needed to start a new network from the scratch or if the focal questions can be addressed using any of the existing global networks (see examples in Table 1), at least as a backbone that can then be strategically extended to include underrepresented regions of the globe. Albeit the latter option would require to reach agreements with the managers of these networks, it has multiple advantages and can save substantial amounts of time and resources. In any case, reaching out to principal investigators (PIs) of well-established networks can help to receive advice that may go beyond the topics treated in this paper.

Table 1. Examples of international/global networks of experiments and observations in ecology. The list is not exhaustive and prioritizes networks that are currently running.

Name	Objective	Webpage	Representative publication
BIOCOM	Evaluate the relationships between community attributes and ecosystem processes in global drylands	http://biocom.maestrelab.com/	Maestre et al. (2012)
Nutrient Network	Understand productivity-diversity relationships and the impact of fertilization and grazers on the structure and functioning of grassland ecosystems	http://www.nutnet.umn.edu/	Borer et al. (2014)
BIODESERT	Assess how simultaneous changes in climate and grazing pressure affect biotic attributes and ecosystem multifunctionality in global drylands	http://biodesert.maestrelab.com/	-
GypNet	Study plant-soil interactions, flora and the different dimensions of biodiversity in gypsum ecosystems	https://gypnet.weebly.com/	-
Zostera Experimental Network	Explore the relationship between ecosystem structure and functioning in Zostera-dominated ecosystems	http://zenscience.org/	Duffy et al. (2015)
Drought-Net	Advance our understanding of the determinants of terrestrial ecosystem sensitivity to drought	https://drought-net.colostate.edu/	Knapp et al. (2017)
Kelp Ecosystem Ecology Network	Assess the impacts of global change on kelp forests	http://www.kelpecosystems.org/	-
Warming and Removal in Mountains	Study the ecosystem-level responses to the direct and indirect effects of warming in mountain ecosystems	http://classenlab.com/our-research/warm/	Hendershot et al. (2017)
DarkDivNet	Explore the dark diversity of plant communities	https://www.botany.ut.ee/macroecology/en/darkdivnet	Pärtel et al. (2019)
Tea Bag Index	Create a global soil map of litter decay rates and test relations between environment and decay globally	http://www.teatime4science.org/	Keuskamp et al. 2013
TeaComposition	Investigate long-term litter carbon dynamics and its key drivers at present and predicted climate scenarios using a standardized protocol	https://www.teacomposition.org/	Djukic et al. (2018)
MIREN	Understand the effects of global change on species' distributions and biodiversity in mountainous areas	http://www.mountaininvasions.org/	Kueffer et al. (2011)
TreeDivNet	Explore the relation between tree species diversity and ecosystem functioning in major forest types worldwide	http://www.treedivnet.ugent.be/	Grossman et al. (2018)
SoilTemp	Compile global soil temperature and associated species data for use in ecological modelling	https://soiltemp.weebly.com/	-
Soil BON	Observe, understand and predict soil biodiversity across spatial, temporal and taxonomic scales	https://geobon.org/bons/thematic-bon/soil-bon/	-
GLORIA	Build globally applicable indicators for comparing magnitudes and velocities of changes of different biodiversity components across the major terrestrial biomes and climatic zones	https://www.gloria.ac.at/	Gottfried et al. (2012)

As highlighted by Borer et al. (2014), whether we create a novel network or use an existing one, it is important to have a critical mass of collaborators and sites. This is important because if no others join the network existing sites may already allow to achieve novel scientific insights and to fulfil its objectives. So do not start the experiments/surveys and make everyone work until you have secured a minimum number of collaborators/study sites for your network.

Recommendation 2: Use simple and affordable protocols

Every network should have a clear research question (or a few questions) being addressed, which should also be answered using an easy, low-cost experimental/observational methodological design well-tailored to the ecosystem/s being investigated (Borer et al. 2014). Do not try to ask too many questions at once, or a very complicated one (e.g., with too many interaction factors), as this can overcomplicate the practical establishment of the network and discourage many members to join. Based on our experience, we advise to use broad, but relevant, questions (e.g. the relationship between ecosystem structure and functioning along environmental/human pressure gradients), which can be addressed using a general set of response variables (e.g. basic but reliable description of plant/animal communities based on taxonomical expertise and analysis of soil properties, either in the lab or using easy-to-implement indicators in the field; e.g. Tongway & Hindley 2004a, Herrick et al. 2010). We must not forget that data gathered using simple, general designs and response variables can often be analyzed in multiple ways to answer a myriad of specific questions, as the dozens of scientific articles derived from networks such as NutNet (https://t.co/M8ZjMCmPVb) or BIOCOM (https://t.co/s69xbgJ190) exemplify, and that the network and/or its samples can be used as a platform for future, and more detailed studies using more sophisticated/costly laboratory or statistical analyses if funds become available for doing so.

Recommendation 3: Plan ahead carefully

Be aware of the fact that a global network of coordinated distributed experiments or observations needs your full attention and dedication to be successful. Never underestimate the time it takes to design, launch and maintain such a network. Global research networks need to be well prepared and thought through because multiple scientific, logistic, economical, legal and even personal issues need to be taken into account (some key ones will be discussed in the following recommendations). This includes, for instance, to get informed about the requirements needed to conduct fieldwork in all the regions involved in your network, to recognize the cultural and socio-economical differences between network members, and to be aware of local, national and international regulations regarding the transportation of (soil) samples and the use/publication of data coming from multiple countries. Given their importance, legal issues are discussed in more depth in Recommendation 7, and guidelines to foster the participation of underrepresented regions/scientists are given in Recommendation 10.

As an example of the time and effort it takes to plan and execute a global collaborative research network, we present here the case of the BIODESERT network (Table 1), which involves fieldwork in more than 300 field plots scattered across 26 countries from six continents and the reception and analysis of thousands of soil/plant tissue samples in a centralized laboratory in Spain. Planning the field survey and developing/testing the field protocols by the PI took over six months; contacting the partners and assembling the network (work done by the PI) took another four months; conducting fieldwork took over 3.5 years (work done by more than 100 network members), and the processing and analysis of 739 soil samples in the laboratory (>30 different physico-chemical and biological variables measured in each of them) has taken over a year of two technicians working full time (plus additional help by other technicians and students in particular moments). Of course, the time needed to design, plan and execute a global network may change substantially depending on factors such as the type and complexity of the work that needs to be done, the number of sites that will be included, the amount of resources available, the number of people involved and the possibility of having dedicated people working full time on the network. Therefore, examples that have worked for a given network may not work for others.

Recommendation 4: Be responsive to build trustful relationships

Building trust is an essential aspect to ensure the success of any international collaboration (Vangen & Huxman 2003, Bagshaw et al. 2007, Parker & Nigori 2016). For doing so, it is critical to clearly communicate from the very beginning what participants can (and should not) expect from being part of the network, and to have a fluid and responsive communication with all of them (Perz et al. 2010). Network members, no matter their origin or status, want to be taken seriously. If they ask questions, which for sure they will do no matter how clear the network protocols are, they show involvement, which you want to have. Hence, it is extremely important that you reply to emails/phone calls as soon as possible (or at least on a regular basis). Not doing so can lead to general frustration among network members, can discourage them to being part of the network, and can cause negative sentiments related to the network that may be spread in the community, e.g. at conferences and workshops. If your workload does not allow you to do so, you should consider having another member of your lab or within the network to be in charge of communication issues. In addition to answering in a timely fashion to any request by network members, it is also a good idea to keep them informed regarding how the work is going and to communicate important milestones using email updates or newsletters. We favor the use of email over other communication forms such as Twitter or blogs because not all these communication channels are accessible everywhere. There is no need to send an email every week, but bi-monthly or seasonal emails work very well according to our experience.

Recommendation 5: Optimize the functioning of the network

The amount and complexity of tasks involved in running a global research network, from preparing field protocols to dealing with legal issues importing/exporting samples, exceed the capacity of one individual, particularly given the busy schedule of most researchers/academics around the world. Thus, we advise you to form a team with a clear work division, so they take over tasks reflecting their talents, expertise and former experiences and can more effectively deal with any issue arising during the development of the network (Perz et al. 2010). As an example, in the BIODESERT network (Table 1), we have dedicated persons to deal with the following aspects of the survey: i) location and preliminary suitability assessment of the field sites, ii) reception and permits/legal issues to import/export soil and plant samples, iii) doubts about any aspect of the field survey, iv) reception and curation of data files sent by network members and v) any other questions that may arise about the work involved and the functioning of the network. These different roles of people should be clearly communicated to the network, so its members know who they should contact when questions/doubts arise.

While this may not work for everyone, in our experience the functioning of the network can be optimized if all the samples and data, together with further auxiliary data (e.g. those coming from climatic stations, GIS layers, etc.), are centralized. This is something that we certainly advise to do. Regardless if this occurs or not, all the samples should be analyzed in the same laboratory to avoid calibration issues between laboratories, which are found even when clear and standardized protocols are used (Petric et al. 2011) and that can increase the variability of the data and obscure/complicate statistical analyses. Storing all samples from the project in the same laboratory also reduces costs and can facilitate future projects and analyses of these samples. However, it is important that every network member keeps some of the soil/biological samples to avoid potential losses during the shipping, which occur more often than one can imagine when using national postal services or trusted courier companies. This, of course, requires that network participants have appropriate storage facilities and infrastructure (e.g. a freezer for storing frozen samples, which may not be available everywhere).

Recommendation 6: Form scientific advisory and conflict resolution boards

It is always a good idea to get advice by experienced colleagues when designing and running a global network. We recommend to establish a scientific committee with experts on the key topics being addressed in the network. Their members can provide advice on critical aspects such as experimental design and the variables to be measured, and can also help to solve issues/problems that can arise during the development of fieldwork and/or data analysis/writing.

We must keep in mind that, even in networks where everyone behaves correctly, issues may arise regarding topics such as data/intellectual property and first and co-authorship of manuscripts (Dance 2012, Chawla 2015; see also Recommendation 8 below). Thus, we also recommend to form a panel addressing potential conflicts that may arise during the development of the network. To become and stay truly global, advisory and conflict resolution board members should represent different cultural and scientific backgrounds, so that a better understanding of the topics covered by the network and/or personal/mentality differences is facilitated. Importantly, the members of the network need to feel well represented by the board.

Recommendation 7: Be aware of legal issues

Legal issues are a key, but often overlooked, aspect that must be considered from the inception of any global network, particularly when working with soil samples. All network participants must be informed about them before starting doing actual work in the field. We must note that strict national rules may apply when importing/exporting soil/biological samples and international agreements signed by a growing number of countries, such as the Nagoya Protocol on Access and Benefit-sharing (Buck & Hamilton 2011), the Cartagena Protocol on Biosafety (Gupta 2010) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, Phelps et al. 2010), regulate the access, handling, share, transport and benefit of biological/genetic data and organisms. All these regulations must be respected; not doing so is not only ethically reprehensible but also can lead to breaking the requirements of funders. For instance, the European Union requires all the projects it funds to strictly abide to national and international laws, particularly when dealing with biological samples and/or fieldwork done in developing countries. Furthermore, researchers may face civil and criminal responsibilities in some countries if they export samples without the proper permits (e.g. Dalton 2002).

Fulfilling legal requirements takes a substantial amount of work and time, hence we advise to have (a) person/s being in charge of dealing with them. As an example, for receiving international samples in one of our labs in Spain where we are centralizing the samples from the BIODESERT network (Table 1), we had our laboratory inspected and approved by an inspector from the administration in charge of agricultural issues. In addition to the exporting permits to ship soil/plant tissues to Spain (when needed depending on each country), to clear customs and to receive the samples we needed a general permit from the Ministry of Agriculture for the project, a declaration (for every shipment) ensuring that no protected species (species under the CITES regulation) are being imported and a specific permit for every individual plant/soil shipment that must be requested in advance to this Ministry. Dealing with these issues, and ensuring that all the paperwork was done for every shipment received, has taken an estimated three months of a dedicated technician over the course of 3.5 years.

Legal regulations change from country to country and, no matter how simple or complicated they are, must be taken very seriously. In our experience, many colleagues are not aware of legal issues regarding the sharing of biological data and/or samples, and require information and partly guidance and help to fulfil legal obligations for this. Hence, the person/s dealing with this important network task must be informed and prepared to help network members that need it; not doing so may result in losing important collaborators and regions of your network.

Table 2. Key issues regarding the use of resources and data that require having clear regulations from the onset of a research network.

Topic	Questions to be addressed	Advice
Data	Will the data be kept closed or open as papers are published?	Publish the data as they are published and/or publish a data paper describing the database
	Where (and how) are the data stored?	Centralize data and, once published, deposit data in a public repository such as figshare (https://figshare.com/), Zenodo (https://zenodo.org/) or Dryad (https://datadryad.org/) following best practices for data storage (e.g. Hart et al. 2016)
	How network and non-network members (if applicable) can have access/use the data?	Have clear written guidelines about how data will be used within the network
Samples	How the samples will be stored?	Centralize sample storage
	Can the samples be used for side/add-on projects?	Define the procedures that network and non-network members (if applicable) need to follow to use the samples for additional or follow-up projects
Intellectual property and publications	How many co-authors will be included?	Define whether there will be a limit in the number of co-authors included in the publications arising from the network
	What will be the order of co-authors in a manuscript	Decide order depending on contributions (e.g. intellectual, data, inputs during writing); being equal, use alphabetical order
	What are the requirements to be a co-author?	Indicate clearly what is needed from each collaborator to be included in the publications derived from the network and define opt-in versus opt-out approaches
	What if I have a novel idea? Can I use the data from the network to test it?	Be open to share the data with anyone having original ideas/analyses that could be implemented using the data from the network. Set up a publication committee that oversees the different publications planned/under way and that can solve potential conflicts that may arise
	How can I see the results of the network that have been published?	Establish a repository where all publications from the network will be available

Recommendation 8: Develop clear policies about the use of network resources and the publication of results

Every network should have clear rules about data ownership and access, data use by network members, co-authorship rules and other intellectual issues (Table 2, Perz et al. 2010). Given their importance for the professional career development of scientists, publications are of particular importance in any research collaboration. Thus, the rules governing co-authorship issues (Table 2) should be clearly established and, most importantly, be fair and recognize the variety of work done by all network members (from the provision of data to the writing of the manuscript). Different networks already established provide very good models about how to implement effective policies to deal with publication issues, and we personally like the opt-in/opt-out approach being pioneered by the Nutrient Network (Borer et al. 2014) as a role model (so we will not repeat it here; for further reading see also networking means and tools in Eisenhauer et al. 2019). Having clear and fair co-authorship rules not only contribute to the proper functioning of the network, but also promote the engagement of network members (see Recommendation 9 below) and foster and maintain their trust (Parker & Kingori 2016).

In addition to data, an important resource not often considered when developing or running a network is how biological/soil samples being generated during the fieldwork, which are amenable to additional analyses, will be dealt with (Table 2). Clear rules must be established about how these should be handled to avoid potential conflicts derived from, for example, exhausting them.

Very importantly, specific rules on the functioning of the network have to be clearly formulated and circulated from the very beginning (de Grijs 2015), so everyone can abide to them (or not join the network if they are not acceptable). Again, be aware of cultural differences among participating researchers, as academic life and conventions regarding issues such as data use and working hours and holidays change in different regions around the world, and national or regional funding agencies may also have rules or requirements that must be followed. Having a fluid communication between network members and being flexible when discussing network rules is crucial for overcoming potential barriers arising from these issues (Monteiro & Keating 2009, Parker & Kingori 2016).

Recommendation 9: Foster active engagement within and beyond the network

Fostering the active engagement of members is crucial to ensure the success of any international collaboration (Nix & Zacharia 2014). Doing so not only increases the overall productivity and scientific impact of the network, but also improves the 'group-feeling' and commitment of its members. Together with a fluid and regular communication (Recommendation 4), the organization of workshops (to be held before or within major ecological conferences or remotely to maximize attendance or as a stand-alone meeting if resources can be secured to facilitate the travel of members without resources), the opening of the data to anyone within the network with original ideas (and the capacity to implement them), the use of web seminars, synthesis projects, and add-on experiments and surveys are approaches very useful to promote the engagement of network members. If funding is available, summer schools and workshops on specific topics (e.g. data management and storage) organized by the network can also go a long way to build scientific capacity, to establish long-term collaborations, to improve the qualification of young scientists and to increase the reliability/quality of data collected by network members (Barret et al. 2011).

To increase awareness of the network, and to foster the recruitment of additional members, having a network webpage and disseminating network news using generalist (Twitter, Facebook and/or Instagram) and science-focused (e.g. ResearchGate) social media and blogs are particularly useful. The use of a Google Scholar account, as done by networks such as NutNet (https://t.co/M8ZjMCmPVb) or BIOCOM (https://t.co/s69xbgJ190), is also useful to post the publications of the network and to track their scientific impact. These measures can be complemented with more traditional approaches, such as articles in regular scientific (e.g. Pärtel et al. 2019) and popular science (e.g. Maestre 2016) journals presenting the network.

Recommendation 10: Facilitate the involvement of underrepresented groups and regions

We must be aware of the fact that even in the 21st century, science still faces problems to embrace a holistic set of perspectives, philosophies and contributions, including the important contributions by women, people of color, ethnic groups and from the global south (Ramirez et al. 2018). This issue must be recognized and deconstructed to foster our ability to solve the world's most pervasive and challenging ecological problems (Tallis and Lubchenko 2014, Ramirez et al. 2018). In a similar manner that there is a growing literature showing that the performance of a company increases when it increases the diversity of its workers and board of directors (Sághy Estélyi & Nisar 2016), we should be proactive to maximize diversity among the network participants and board members (Bagshaw et al. 2007). This will not only be to great benefit of the network and will make the science it produces more impactful (AlShebli et al. 2018), but will also contribute to increase its influence by serving as a role model to other networks that may arise in the future.

As noted above, many global network initiatives carried out to date in (soil) ecology are poorly represented in large areas of our planet, such as Africa, Latin America and Asia (excluding China) (Cameron et al. 2018). This is not a surprise given the lack of scientific tradition and research funding in many countries, which has often resulted in the absence of infrastructure (e.g. accessible scientific collections for reference of regional biodiversity) and trained scientists ready to implement experiments or to conduct surveys *in situ*, communication barriers -many researchers across the world do not speak/understand English-, lack of time for doing research due to the high teaching loads professors typically have in the Global South and other cultural and/or political barriers (Pryor et al. 2009, Barret et al. 2011). As a result, most existing networks are not truly global regarding the geographical area covered nor the diversity of its members. We would like to emphasize that this is not a drawback *per se*; as noted above, not all the networks need to have a global scope/coverage to provide meaningful and generalizable results. But when the questions explored require having data with a global coverage and/or when capacity building/training is a major objective, a research network should be inclusive and particularly target local scientists from traditionally understudied groups and regions. This has multiple benefits: they have comprehensive and specific local ecological/biological knowledge (Brook & McLachlan 2008), which is crucial when dealing with aspects such as vegetation or arthropod surveys, add additional perspectives and insights about how to answer the questions being explored, which increases the scientific impact of the publications resulting from the network (AlShebli et al. 2018), and by doing so the network contributes to the building of scientific capacity and to train students and technicians where it is (often) more needed (Parker & Kingori 2016).

We firmly believe in the power of ecological research networks to transfer research skills to partners from developing regions, a priority already highlighted in fields like medicine (Chu et al. 2014) and something that is highly appreciated by our colleagues working in developing countries (Parker & Kingori 2016), and in the need to make them active network members. This transfer requires substantial efforts and changes in the way we often conduct work in developing countries (e.g., avoiding doing ‘helicopter science’ or ‘sample safaris’ *sensu* Nordling 2015) and interact with colleagues from these regions (e.g., we must be ready to learn from -and not to only to teach- them; Adams 2010). There are multiple things we can do to facilitate the development of a truly global work. One of the first, as highlighted in Recommendation 2, to consider is to use simple and cheap to implement protocols, such as tea bags (Kuiskamp et al. 2013), dummy caterpillars (Roslin et al. 2017), ecosystem assessments that only require basic field equipment (such as quadrat, a tape and a soil corer; Maestre et al. 2012) or the implementation of straightforward experimental treatments like the addition of nutrients (Borer et al. 2013). The elaboration of protocols with abundant graphical material is critical (see Tongway & Hindley 2004b or Oliva et al. 2011 for good examples). Language, together with cultural differences, can also be an important barrier to promote an effective participation of members from developing countries. The translation of protocols can thus facilitate the participation of scientists from underrepresented regions. However, these translations have to be carefully checked, as non-identical methods may lead to non-comparable results. Having members in the network that can provide assistance in languages such as Spanish, French, Chinese and Russian, in addition to English, can be also highly useful to foster participation of colleagues from underrepresented regions, to clarify any doubts in the implementation of field protocols and to make sure every network participant understands the work that needs to be done.

Network PIs should, whenever possible, secure some funds to provide punctual financial support for groups in regions without access to research grants. This includes small pots of money to do fieldwork and to cover shipping costs, which often cannot be covered by local scientists in developing countries. The amounts of money needed for this will, of course, depend on the nature of the surveys/experiments, the remoteness of the area and the number of sites to be studied, but in our experience transferring small pots of money to local groups can go a long way, and will increase the number of sites in traditionally understudied regions.

We must also understand and respect the local contexts, issues and needs faced by network collaborators, which vary greatly from across the world (Parker & Kingori 2016). Not doing so is behind the failure of many research programs set up in developing countries (e.g. Andersen 2016), and can preclude the successful expansion and implementation of a network in underrepresented regions.

Recommendation 11: Facilitate gender equality

Although there is a long list of studies that we could cite to substantiate the need to have gender-balanced research teams and networks (e.g. Shannon et al. 2019), we here provide an example from our own observations that made us aware how gender representation changes along the scientific career. In the Jena Experiment (http://www.the-jena-experiment.de/), a large research consortium studying the ecosystem consequences of biodiversity loss funded by the German Research Foundation (Weisser et al. 2017, Eisenhauer et al. 2019), we noticed that the percentage of female scientists drops sharply from the level of PhD students (75%) to postdocs (42%) to PIs (35%, a percentage that still is far above the proportion of female professors at many German universities). Please note that these numbers are not supposed to be representative, but just an example. It is therefore crucial to develop and implement means to facilitate gender equality in important scientific initiatives such as global collaborative networks in (soil) ecology.

In addition to actively recruit women and ban any type of harassment/inappropriate behavior within the network (Gewin 2018), be aware of funding opportunities to increase diversity and to foster gender equality within the consortium. For instance, the German Research Foundation offers funds to support women and to foster gender equality through various means, such as individual mentoring programs, scientific workshops only for female researchers and flexible support (career-limiting issues that female researchers may experience due to pregnancy, maternity leave, and childcare duties are very individual; Eisenhauer et al. 2019). In this direction, facilitating issues such as child care during presential network meetings can go a long way to promote the participation of women in international research collaborations (Gewin 2018).

Recommendation 12: Have bullet-proof, tested, protocols

Having tested protocols is a critical point for the success of any research network. Protocols should be clear and detailed, and contain accurate estimations of the time commitment to fulfil the different tasks required (see Oliva et al. 2011 and Pärtel et al. 2019 for good examples). There is nothing more frustrating for the network PI and participants if the protocol contains points that are unclear and lots of email exchange is required to properly fulfill the required tasks and repeated sampling is necessary. In addition, protocols should be also 'bullet-proof' to ensure that they can provide valuable data for achieving the objectives of the network. No matter how good you think your protocols, data handling rules and sheets are, do test traits with international colleagues in different areas, paying particular attention to those tasks that can be more difficult to implement in the field or that can be more difficult to be understood, particularly for non-native English speakers.

Conclusion

Setting up and running a global research network is a really demanding task that, at the same time, can be highly rewarding both from the personal and professional points of view. The possibility of interacting with and learning from colleagues from all around the world, the key insights and new knowledge gathered from the problem being addressed by the network and the possibility to contribute to build scientific capacity and to train students, technicians and postdocs are very powerful arguments to encourage the widespread adoption of global network approaches in (soil) ecology. In addition, some of the most important global challenges that we are facing, such as climate change, biodiversity loss and land degradation and desertification, can only be effectively addressed through international collaboration. Hence, we certainly advise our fellow (soil) ecologists to consider initiating (or joining) global research networks, and we hope that the recommendations highlighted above, together with the available literature on this topic (e.g. Perz et al. 2010, Borer et al. 2014, de Grijs 2015, Fraser et al. 2013), will be helpful to do so with the least amount of effort possible.

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