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Negotiating local versus global needs in the International Long Term Ecological Research Network's socio-ecological research agenda

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Abstract

Over the past decade, long-term socio-ecological research (LTSER) has been established to better integrate social science research and societal concerns into the goals and objectives of the International Long-Term Ecological Research (ILTER) network, an established global network of long-term ecological monitoring sites. The Horizon 2020 eLTER project, currently underway, includes as one of its key objectives to evaluate the performance of LTSER platforms. This article reflects part of this evaluation: six LTSER platforms were assessed through site visits of the lead author, coupled with reflections and insights of the platform managers, who are also co-authors. We provide background for the mission and goals of LTSER, then assess the six international LTSER platforms—Baltimore Ecosystem Study LTER, USA; Braila Island LTSER, Romania; Cairngorms LTSER, UK; Doñana LTSER, Spain; Omora Ethnobotanical Park Cape Horn LTER, Chile; and Sierra Nevada LTSER, Spain. While based on a strong theoretical foundation in socio-ecological research, there has been a steep learning curve for scientists applying the concept in practice at LTSER platforms. We show positive impacts that have been achieved, including contributions to policy, land-use planning, and natural resource management. We explain key aspects of LTSER platforms that have proven challenging, including management, interdisciplinary integration, and stakeholder collaboration. We characterize the tensions between top-down desires for network harmonization, bottom-up demands such as local policy relevance, and platform-level constraints such as time and budget. Finally, we discuss challenges, such as local context dominating the character of LTSER platforms, and the fact that scientists are often disincentivized from engaging in transdisciplinary science. Overall, we conclude that while the international network offers important advantages to its members, a more productive balance between local and global goals could be achieved, and members may need to temper their expectations of what the network can and cannot offer at the local level.

ILTER: producing societally-relevant research for addressing sustainability challenges

For more than a decade, concern about impacts of global environmental change has led intergovernmental entities to initiate programs to advance socio-ecological research. For example, the Program on Ecosystem Change and Society is jointly sponsored by the International Council for Science and UNESCO, ALTER-Net was initially sponsored by the EU and subsequently by its partners, and the Global Land Programme and the

Urbanization and Global Environmental Change programs are both sponsored by Future Earth (a UN initiative). In a similar spirit, researchers of the International Long-Term Ecological Research (ILTER) network, established in 2004, have advocated for and initiated long-term, site-based research on human-nature interactions, alongside conventional ecological monitoring and research, to strengthen their capacity for advancing knowledge relevant to contemporary regional and global social and environmental challenges (Haberl *et al* 2006, Maass and Equihua 2015, Mirtl *et al* 2018). ILTER is one of several global research infrastructures focused on coordinating environmental data collection. Other examples include the Global Biodiversity Information Facility and the Global Earth Observation System of Systems, which collect environmental data, as well as the Man and the Biosphere Program, whose objectives are close to those of ILTER, by aiming to identify, study, and disseminate knowledge about changes in the biosphere resulting from human and natural processes (Rozzi *et al* 2012).

However, despite these efforts to coordinate global environmental data collection and to address causes of global change, environmental quality continues to decline (Maass *et al* 2016). Science struggles to keep pace with biodiversity loss, for example; in some cases, species are lost before they can be described (Lees and Pimm 2015). One study estimated the current number of global species at 5 ± 3 million, of which only 1.5 million are named, with an estimated 0.5%–5% of global species being lost every decade (Costello *et al* 2013). To address global environmental change, work is needed to assure the efficient functioning of global research infrastructures and to maximize their societal impact via education, policy and management.

ILTER forms the umbrella for the national LTER networks of 44 member networks, thus constituting a 'network of networks' (Mirtl *et al* 2018). It aims to become a world-class, global research infrastructure that will contribute societally-relevant information to address global grand challenges, which are articulated by ILTER as: (1) climate change and greenhouse gases; (2) biodiversity loss and land use change; (3) eutrophication and pollution; and (4) environmental protection, sustainable management of natural resources, water, biodiversity, and ecosystems (Haase *et al* 2018, Mirtl *et al* 2018, Maass *et al* 2016). Top-down aims of the international network include implementing ongoing, long-term standardized measures of environmental variables and change, advocating and coordinating research that is directly relevant to addressing the grand challenges, and providing predictive modeling and scenario analysis for decision-making. In addition, this network encourages transdisciplinary team science and encourages its member researchers to engage decision-makers and the general public and to advise on environmental policy and management (Rozzi *et al* 2015).

To support these diverse endeavors, ILTER has established a global research infrastructure for long-term socio-ecological research (LTSER). LTSER platforms are hubs for interdisciplinary and transdisciplinary research and monitoring, based on the conceptual model of the socio-ecological system (Collins *et al* 2011) and with a focus on long-term, *in situ* research to address sustainability challenges (Holzer *et al* 2018). Within ILTER, at least two models for such research have been explored: the first is the LTSER platform, which designates a specific region (urban and/or rural), often containing one or more LTER sites (Mirtl *et al* 2013); the second is the urban LTER, which studies human-nature interactions in a metropolitan area (Grimm *et al* 2000). For simplicity, we denote both as 'platforms' in this article. Platforms aim to integrate ecological research and monitoring with social science research and stakeholder participation to supply knowledge for real-time decision-making and problem-solving.

LTSER establishment and accomplishments

We conceptualize LTSER as a global network of place-based venues for conducting socio-ecological monitoring, research, and knowledge production on topics relevant to societal problem solving at the regional level, and which also align with the broader network goals articulated above. Each platform is both a community of scientists and practitioners, and a consortium of institutions; many platforms are home to one or more long-term ecological research sites responsible for the ongoing monitoring of environmental indicators. The major accomplishment of LTSER is the establishment and proliferation of platforms across the world, all of which apply—to varying degrees—the socio-ecological conceptual framework. Depending on how one applies the concept of an LTSER platform, the number of platforms may be counted at anywhere from 80–115 internationally (Dick *et al* 2018); according to a search of the ILTER global database (i.e. the Dynamic Ecological Information Management System 'DEIMS[10]'), the count is 92. Along with about 700 LTER sites, these LTSER platforms comprise the global infrastructure of ILTER. A recent literature review to examine LTSER research output, which investigated 25 LTSER platforms, revealed that 1112 publicly-available scientific documents relevant to a socio-ecological research agenda in these platforms were published between 2006 and 2017 (Dick *et al* 2018).

ILTER uses various means to stimulate global network development, including international meetings, scholarly exchanges, coordinated international studies

[10] DEIMS, the Dynamic Ecological Information Management System, can be accessed at http://data.lter-europe.net/deims/.

(e.g. Djukic *et al* 2018), and the development of common conceptual frameworks (e.g. drivers, pressures, states, impacts, responses (DPSIR) model), metadata (e.g. van der Werf *et al* 2009), and databases (e.g. DEIMS). The European LTER network, through its current Horizon 2020-funded project, *European Long-Term Ecosystem and Socio-Ecological Research Infrastructure* (eLTER), aims to assess and build capacity for LTSER platforms in Europe. For this purpose, it has convened LTSER researchers from Europe and the Middle East at international workshops to learn from one another and build community. In addition, through its 'Transnational Access' program, eLTER has funded scientists to visit one another's platforms to conduct research, with an emphasis on comparative studies and international collaborations. Over the last three years (2015–2018), 103 scientists have participated in 45 research visits involving 18 different LTSER platforms across Europe and the Middle East (program data provided courtesy of Herbert Haubold).

At the same time that a small group of involved researchers are working to advance LTSER's international network activities, individual platform development is being driven by local demands for decision-making and other socio-ecological issues of local relevance (Orenstein and Groner 2015, Rozzi *et al* 2015, Mirtl *et al* 2013, Rozzi *et al* 2012, Haberl *et al* 2006). In many cases, LTSER platforms were initiated because local researchers saw the need and opportunity to use their scientific research to explicitly address management issues in cooperation with local institutions (Dick *et al* 2018). Socio-ecological research at LTSER platforms prioritizes the inclusion of stakeholders in setting the agenda for research and in the process of doing science (Holzer *et al* 2018, Haberl *et al* 2006). In their review, Dick and colleagues (2018) found that about 60% of the research documented in 25 LTSER platforms had some form of stakeholder engagement. Navigating the concurrent demands of local expectations and international obligations has emerged as a central challenge in LTSER platform development, and thus has become a central theme of the present analysis.

Aims of this paper

While there has been widespread commitment to adopting a socio-ecological research framework throughout the ILTER network, the transition from ecological to socio-ecological research has been gradual and, because of its stated commitment to place-based research, has necessitated the balancing of local demands with network-wide goals (Dick *et al* 2018). This article analyzes the current work at LTSER platforms, including successes, gaps, and aims for the future, especially what may be addressed by administrative and technical changes to the research infrastructure. Our aim is to examine ILTER as a global research infrastructure with a high level of transparency, and to address the following questions:

(1) What types of knowledge are being produced by platforms, and to what types of impacts can they be linked?

(2) What are the key challenges facing platform managers with regarding to platform operations, agenda-setting, and institutional sustainability?

(3) How do platform managers view benefits and limitations vis-à-vis the international network?

Our analysis relies on two bodies of information. First, the lead author visited four of the six selected LTSER platforms—the Baltimore Ecosystem Study LTER, USA (BES), Cairngorms National Park LTSER, UK (Cairngorms), Doñana LTSER, Spain LTSER (Doñana), Braila Island LTSER, Romania (Braila), and Sierra Nevada LTSER, Spain—where she conducted in-depth interviews with multiple types of stakeholders in order to understand platform goals, research priorities, administrative structures, and perceptions of achievements and challenges (see Holzer *et al* 2018). While the lead author did not visit the Omora Ethnobotanical Park Cape Horn LTER (Omora), Chile or Sierra Nevada LTSER, Spain (Sierra Nevada), platform managers were prompted through a series of questions to provide relevant, parallel information in this regard. In addition, six of the co-authors are platform managers, who provide insights based on establishing and maintaining LTSER platforms. Accordingly, claims throughout the paper are those of the authors, based on their professional experience and ongoing research. In short, this work represents an introspective, critical analysis of achievements and gaps in socio-ecological research within the ILTER network and represents the first steps toward identifying and addressing these challenges.

Key findings—research management and process

In place-based research, local conditions dominate the character of LTSER platforms

Each LTSER platform has a unique story of its founding, socio-ecological context, and its own priorities. Similarly, each platform's administration is unique, though all are comprised of inter-institutional collaborations. At the Cairngorms, for example, there are five 'co-directors,' including the Chair, who is from the Cairngorms National Park Authority, a representative of the Crown Estates, a large landholder, and a representative of each of three scientific institutions prominent in the Cairngorms. This core team meets approximately four times a year. They have developed a research strategy and are currently developing a

five-year plan for the platform. The team organizes bi-annual conferences and a variety of meetings in the Park. At Braila, the administration is composed of key local stakeholders and also hosts a scientific council (coordinated by the Research Center in Systems Ecology and Sustainability—University of Bucharest).

Administrative structure is necessarily influenced by the origins and the initiators of the platforms. Successful LTSER platforms are usually established by individuals committed to the LTSER vision, who are equipped with professional standing, communication and networking skills, the ability to work with transparency and flexibility, a sense of humor, a thick skin to withstand criticism, persistence, and humility (Eigenbrode *et al* 2017). These qualities allow platform leaders to move the LTSER concept forward by clearly articulating the added value of LTSER and by persuading others to contribute towards making the LTSER platform a reality. Platform success can be attributed, at least in part, to their commitment and initiative, as has been shown for other types of regional sustainability initiatives (e.g. Horlings and Padt 2013, regarding the agricultural sector). The initiation of LTSER platforms often gains traction around those individuals' professional and institutional networks.

The unique structure of each platform necessarily has implications for its performance. The Sierra Nevada platform, for example, was founded and is managed by a joint group of scientists and environmental managers, who have taken a multi-faceted approach towards addressing scientific and managerial challenges. This constellation of initiators comprises a transdisciplinary community of practice, whose work is built upon an initial stakeholder mapping process and a literature review of existing site-based research in order to inventory knowledge and research directions to date. The multi-faceted approach was exemplified in the community's response after forest fires in 2005. Instead of responding with a typical recovery project that would have been limited to actions such as dead wood removal and pine replanting, scientists and managers came together to create a broad, long-term restoration plan that engaged private businesses, local stakeholders, and others. The social benefits of this approach are already evident: awareness on the part of residents regarding local environmental challenges has increased, and locals are supportive of restoration efforts.

Integration of social and ecological research is a gradual process

A core goal of socio-ecological research is the integration of ecological and social data to monitor, describe, and explain interactions within the socio-ecological system (Haberl *et al* 2006). All platforms, or their affiliates, conduct monitoring of biotic and abiotic environmental indicators; these programs have been ongoing. In accordance with the overarching goals of LTSER (Haberl *et al* 2006, Redman *et al* 2004), we examined the degree to which platforms have succeeded in integrating social research into their activities. Overall, the introduction and integration of social research at platforms has been very gradual, which may be expected since this type of transition faces known challenges (outlined by Strang 2007, among others). Platforms have integrated social research by employing a variety of methodological and management approaches, including the development of a unified research strategy (Cairngorms), application of socio-ecological conceptual models (e.g. Collins *et al* 2011), co-location of ecological and social data, mapping of social and ecological variables, and hosting transdisciplinary discussions (Baltimore, Braila). At other platforms, socioeconomic research is still lacking (Doñana, Sierra Nevada).

In the aforementioned literature review by Dick and colleagues, the authors found a steady rise in LTSER publications overall, with a steeper rise for papers using abiotic and biotic data than for those reporting on social and economic data (Dick *et al* 2018), suggesting that LTSER platforms remain focused on the natural sciences. These trends were consistent over time; 40% of publications focused on abiotic topics, 35% on biotic, 15% on social, and 10% on economic (Dick *et al* 2018). Table 1 reports the experiences of the case platforms vis-à-vis integration of ecological and social research.

Stakeholder integration processes differ significantly from platform to platform

Collaboration and knowledge co-creation with diverse stakeholders is of central importance to the work of LTSER (Mirtl *et al* 2013, Haberl *et al* 2006). However, while this goal is articulated broadly at the network level, individual platforms may emphasize more individualized goals for stakeholder integration. For example, stakeholder integration objectives at the Sierra Nevada platform include the following:

- To integrate terms, concepts, and methods from diverse disciplines and fields into ecological science;
- To enrich scientific questions with the aim of addressing scientific and societal challenges;
- To create a community of practice that engages scientists, land managers, and others, to discuss wicked problems, deliver knowledge products (e.g. books, manuscripts, etc), and funnel knowledge to relevant decision-makers.

As another example, a major focus of the Omora platform is their educational programming, so educational institutions are key stakeholders. The Omora platform has memoranda of understanding with schools, the Chilean Navy, municipalities, and the local indigenous community, each outlining their

Table 1. Integration of social and ecological research at LTSER Platforms: Research focus areas, degree of interdisciplinary integration (as reported by platform managers), and examples of integration.

LTSER Platform	Research focus areas	Degree of interdisciplinary integration 1 (low)—10 (high)	Examples of interdisciplinary integration
Baltimore Ecosystem Study (BES)	(1) Watershed studies; (2) Biodiversity (aquatic, vegetation, birds, insects, mammals, soil invertebrates); (3) Disease vectors and sentinel species (mosquitoes); (4) Locational and land cover change; (5) Residential ecology; (6) Environmental justice	9	Co-development of research to identify multi-scale, socio-ecological 'hot spots' of land transformation and nutrient uptake to reduce nutrient loss to estuarine systems and comply with environmental regulations
Cairngorms LTSER	(1) Natura 2000 habitats and species in a context of changing climate, development, recreation and land use; (2) Natural capital and ecosystem services; (3) Recreational activities	10 (when specifically funded to do socio-ecological research, e.g OpenNESS a European Union EU FP7 project (Grant agreement #308428)).	Periodic platform conference that convenes stakeholders across disciplines and sectors as participants and presenters; research focus on access, recreation, and use combines social and environmental research, as well as researchers and practitioners; stakeholder meetings bring together researchers and local stakeholders (e.g. Dick *et al* 2017, Carmen *et al* 2018)
Doñana LTSER	(1) Adaptive management for biological conservation; (2) Biodiversity and ecological long-term monitoring and research; (3) Socio-ecological and sustainability; (4) Wetlands ecology and water management; (5) e-Infrastructures for biodiversity research	6	Results from the following projects: AlterNet, Spanish National Ecosystem Assessment, ACI-Comités, EnvEurope, AdaptaMed and EcoPotential (See Maass *et al* 2010 for more details)
Braila Island LTSER	(1) Long-term ecosystem studies; (2) Analysis of biogeochemical fluxes; (3) Land use changes and modeling; (4) Analysis of links between environmental changes and social systems (e.g. fuzzy cognitive mapping); (5) Scenario-building for sustainable development; (6) Long-term land use change and ecosystem services	9	Research outcome from OpenNess, BESAFE, SPIRAL, SOBIO, and BIOFORUM projects; a Life-Nature project for the development of an adaptive management plan for the area
Omora LTSER	(1) Biocultural Ethics Camp; Field Environmental Philosophy program; (2) Long-Term Ornithological and Forest Bird-Banding Program; (3) Freshwater ecosystems and responses of invertebrate life cycles to global warming	9	Multi-Ethnic Bird Guide prepared and published by multiple authors (Rozzi *et al* 2010), as well as participatory long-term bird-banding, educational and ecotourism programs (Rozzi and Jiménez 2014)
Sierra Nevada LTSER	(1) Adaptive management for biological conservation; (2) Biodiversity and ecological long-term monitoring and research; (3) Socio-ecological and sustainability research; (4) Adaptive management of Mediterranean mountain ecosystems; (5) e-Infrastructures for biodiversity research; (6) Building a stable science-management interface	5	Assessment of the role of Sierra Nevada and other protected areas as contributing to human well-being. This study assessed the impact of protected areas using social indicators (Bonet-García *et al* 2015)

partnership and agreement, and the platform maintains a close association with the local university (Rozzi *et al* 2006). Because the Omora LTSER is in a very remote location, there is only one nearby school, and it has a close relationship to the platform; students visit the platform three times a week. Navy and personnel working in public services can take a certificate workshop in LTSER research, where they learn to use

scientific equipment. A major socio-ecological impact has been achieved through the transfer of scientific knowledge into sustainable tourism practices, such as the innovative activity of 'ecotourism with a hand-lens' (Rozzi *et al* 2008). The platform's leaders see these relationships as more than outreach and education, but rather, as a process of developing a cadre of citizen scientists with whom to collaborate in conducting research.

Potential benefits of interactions with practitioners (e.g. land use and natural resource managers), as identified at the Baltimore platform, include: identifying, informing, and enriching research questions; sharing administrative data; obtaining assistance with interpreting results and providing unique perspectives; accessing public, private, and community lands and water for sampling; framing and assessing major policies and plans; and improving the effectiveness and efficiency of communicating science and informing decision-making.

The Cairngorms platform has learned from experience that platform collaborators should aim to deliver knowledge to satisfy four different groups of actors: research funders; the Cairngorms National Park Authority (who will most often be the primary 'user' of the research); LTSER stakeholders who have been involved in the research and may have an interest in influencing it; and the researchers themselves, whose career development and personal ambition cannot be neglected. Considering and satisfying all four actors is indispensable for a sustainable LTSER platform, and yet there are recognized tensions between the interests of these four types of actors.

Just as platform management and leadership have a direct bearing on platform performance, so does stakeholder participation and involvement. Issues related to funding, local politics, and the make-up of the research team may strongly influence which research endeavors are prioritized. The process of collaboratively setting the research agenda, conducting research, and organizing knowledge-sharing activities (like regular meetings, conferences, research exchanges, and informal lunchtime talks) may open channels of communication that can build trust, strengthen working relationships and social networks, and, in general, develop social capital. All these characteristics are crucial for the successful operation of the LTSER platform, but they are also valuable in and of themselves.

Data harmonization, common indicators and data-sharing

Discussions about standardizing data collection, metadata, and growing the capacities of a common database for the ILTER network are ongoing (Adamescu *et al* 2010, Mirtl *et al* 2018). LTER-Europe has advanced standardization of data collection and data-sharing practices through several projects, including two Horizon 2020-funded projects, eLTER and EcoPotential. eLTER is now developing a best practice guide for data selection and monitoring, while EcoPotential aims to build capacity for Earth observation systems, such as monitoring protocols, interpretation tools, data services, and models for ecosystems within protected areas (including both ecological and socio-ecological indicators) (Provenzale and Nativi 2016, Provenzale *et al* 2016). In addition, many LTSER affiliates are hopeful that ILTER's common database, DEIMS, will constitute a user-friendly data repository and data-sharing platform, and the network is currently working towards this goal (Díaz-Delgado 2016, Mirtl *et al* 2018).

Although data collection, analysis, and harmonization has been a long-term objective of the LTSER network, it has proven to be one of the most difficult challenges to address, primarily due to the place-based nature and local/regional emphasis of LTSER. Based on ongoing discussions, we can make preliminary recommendations to address this challenge: (1) relevant global spatial data e.g. land-use/land-cover change, should be collected by a single research team using a consistent methodology, which can then be provided to individual LTSER platforms; (2) expectations for metadata should be redefined and tailored to the socio-ecological nature of LTSER platforms; and (3) more stringent, yet more limited, data demands should be established for individual platforms, to aid platforms in producing harmonized datasets for a limited number of socio-ecological variables.

Regarding the first recommendation, data may be collected at the continental scale by a single institution using remote sensing and geographic information systems methodologies. These indicators include land-use/land-cover change, population density, blue-green infrastructure intensity, agriculture productivity, and others (Maes *et al* 2015) and can be provided as a service to platforms for long-term monitoring and cross-platform research.

The second recommendation, changing expectations for metadata, follows from a long-standing commitment to establish a set of common indicators. The creation of a common set of indicators for LTSER platforms in Europe continues to challenge network scientists—partly due to lack of funding and partly due to lack of consensus, but mostly because socio-ecological research is a bottom-up initiative driven by local concerns; by definition, the research agenda, focus, and capacity are determined at the local level. Therefore, recent discussions around this issue have highlighted the need to negotiate between local and global needs within ILTER, aspiring to a set of common indicators, while explicitly recognizing the place-based character of individual platforms and their research programs. Indicators tailored to socio-ecological research, but which could be collected across platforms, might include indicators of 'sense of place,' property ownership structures, stakeholder demographic profiles, and

governance structures. These social, political and economic variables are necessary to provide context for understanding trends in quantitative variables, such as population density and distribution, recreational activity intensity, ecosystem services, hydrological processes, biodiversity, primary productivity, etc[11].

Regarding the third recommendation, we take a lesson from the experiences of ILTER to harmonize the collection of ecological monitoring data. Here, too, harmonizing data collection has been challenging, and a recent proof-of-concept study has introduced a single variable, organic matter decomposition rates, to show how harmonized data collection across ecosystem types can be achieved (Didion *et al* 2016; also see https://teacomposition.org). While data harmonization across the LTSER has been elusive thus far, the network has recently made strides in articulating data needs and streamlining expectations, which we take as signals of progress.

Key findings—outputs and outcomes

Land use planning, conservation, and sustainable development

Because LTSER platforms aim to produce knowledge for sustainable decision-making and land-use planning, we report policies and practices that were initiated or altered as a direct result of LTSER research (table 2). This type of transdisciplinary work often involves research that is co-produced and used by policy makers working at local, national, and international scales (Rozzi *et al* 2012). These examples are meant to provide a sense of the diverse types of societal accomplishments that can be linked to LTSER activities.

Education and training

LTSER-initiated training opportunities vary between platforms. All six platforms included in this analysis have affiliations with academic institutions, and therefore have links to degree-granting graduate programs. Some platforms have programs for high school students (e.g. Baltimore, Doñana, Sierra Nevada). Other platforms have project-based opportunities that allow students to carry out research projects inside the protected area (e.g. Braila, Cairngorms, Doñana). Omora hosts year-round courses at a local school and is the main field site for graduate programs at the University of Magallanes and other Chilean and US universities. Omora also organizes an annual three-week field environmental philosophy course and ad-hoc training workshops on sustainable tourism, environmental ethics, environmental education, and biocultural ethics. These courses and workshops enjoy participation from a diverse constituency, including members of the Yahgan indigenous community, policy makers, tourism operators, artists, philosophers, and scientists (Rozzi *et al* 2012). In this way, the platform has become a destination for educational tourism, as well a catalyst for the integration of scientific knowledge into environmental policy and decision-making.

In addition, research exchanges—including international visits where scientists visited each other's LTSER platforms, as well as network-level meetings (e.g. the ILTER annual meeting in 2014 held in Chile and the LTSER training workshop in 2018 held in Israel)—were universally felt to be valuable for exchanging ideas, cultivating scientific community, and learning about other platforms, methodologies, research questions, and management strategies.

Key findings—core challenges

Incentives are lacking for scientists to engage in interdisciplinary and transdisciplinary research

Interdisciplinary and transdisciplinary teamwork is a key feature of LTSER (Haberl *et al* 2006) and brings clear benefits to platforms. For example, at the Sierra Nevada platform, interdisciplinary teamwork has allowed researchers to address scientific questions beyond their specific fields of expertise. Scientists were able to increase their visibility when participating in the activities promoted by the LTSER platform. Additional benefits were made available to scientists regarding data management since the participants were able to store, document and curate their own datasets by using the tools created by the operators of the LTSER platform.

While there has been a push from some large funding institutions (like the EU's Horizon 2020 initiative and the National Science Foundation's program on Convergence Research in the US) toward incentivizing transdisciplinary research, there are often barriers for scientists to prioritize these types of activities (Klein and Falk-Krzesinski 2017, Bromham *et al* 2016, Díaz-Delgado *et al* 2016, Brandt *et al* 2013). Incentive structures at academic institutions and the career goals and personal ambitions of individual scientists have an important bearing on scientists' decisions about allocating their time and resources. Reward systems in academia continue to emphasize (single- or first-authored) publications in specific journals, rigid timelines, and the need for scientists to spend a large amount of time dedicated to obtaining short-term funding (typically 1–4 years). These phenomena, as well as mandates for scientists to avoid making direct policy recommendations, are at odds with the desire for collaborative, interdisciplinary research to address wicked problems on behalf of society (Hallet *et al* 2017, Goring *et al* 2014). In addition, the time devoted

[11] These indicators were discussed during an LTSER workshop in March, 2018 in Israel, where 25 LTSER researchers, both established and novice, representing 16 member networks, discussed the challenges associated with place-based, socio-ecological research within a global research infrastructure.

Table 2. Examples of socio-ecological outcomes linked to LTSER platform research.

LTSER platform	Research example	Outcome of research
Baltimore Ecosystem Study (BES)	BES developed novel methods for high-resolution land cover mapping (<1 m) and integration with existing environmental, social, and economic data systems	The City, State, and Region of greater Baltimore established urban tree canopy goals, and the State established a no-net forest loss policy
Baltimore Ecosystem Study (BES)	Understanding the factors that inhibit or encourage neighborhood revitalization and environmental restoration in the urban core	BES data and models are being used to support a deconstruction/land restoration program that may include a $27 million social impact bond for the creation of ~180 jobs and deconstruction of 2500 vacant homes over five years
Baltimore Ecosystem Study (BES)	Existing BES data and publications	The City of Baltimore created a Green Network Plan that more fully weighs environmental justice considerations in planning activities
Braila Island LTSER	Facilitated a public process and provided scientific consultation	(1) Resulted in an adaptive management plan for the protected Small Island of Braila; (2) Site was declared a Ramsar site (no. 1074, 2001)
Cairngorms LTSER	Developed a research strategy for the LTSER (whose boundaries are synonymous with the Cairngorms National Park)	Resulted in improved coordination of research projects and more widespread awareness among stakeholders of current research and data available on LTSER issues in Cairngorms National Park
Doñana LTSER	Ongoing research; development and testing of DPSIR model to address socio-ecological research (Haberl *et al* 2009)	(1) Recent expansion of the protected area inside the platform to allow better landscape connectivity and reduce water demand (from 1059 km^2 to 1217 km^2); (2) Co-design of long-term socio-ecological monitoring program with stakeholders
Omora LTSER	Beginning in 2000, the research team led an initiative to create the UNESCO Cape Horn Biosphere Reserve (CHBR). In 2015, the team began the process of creating the Diego Ramirez Archipelago—Drake Passage Marine Park.	In 2005, this initiative resulted in the protection of 5 million hectares of marine (3 million ha) and terrestrial (2 million ha) ecosystems for multiple uses, including science, education, artisanal fishery and sustainable tourism. As of 2018, the southernmost archipelago of the Americas and 14.4 million hectares of oceanic ecosystems, including large seamounts, are under protection. Adjacent areas have been designated for industrial and artisanal fishery enterprises.
Sierra Nevada LTSER	Research on well-being at a time when EU funds were invested in rural Andalusia	Significant increases in well-being were documented in municipalities between 1989 and 2009. This increase was significantly higher in municipalities that fell within the Sierra Nevada protected area (Bonet-García *et al* 2015).

by scientists to outreach activities, while often encouraged by institutions in theory, are viewed as a distraction from the primary work of research scientists—conducting research and producing academic papers (Varner 2014).

Changing academic incentives and prerequisites for promotion has the potential to improve the situation (Klein and Falk-Krzesinski 2017). Since quantitative performance criteria continue to dominate assessment of academic performance, we caution that sometimes even novel quantitative performance criteria that go beyond conventional measures of impact, such as educational outcomes, dataset creation, and social media outputs, may lack the explanatory depth of qualitative indicators (Delahais and Toulemonde 2017). However, some meaningful qualitative measures of assessing scientific output are already in practice. For example, at the Baltimore platform, some of whose scientists are employed by the US Forest Service, evaluates scientists every five years. Scientists provide lists of their publication outputs, and, in addition, they must point to practical outcomes that are associated with their work. They are required to provide names and phone numbers of individuals involved in 'using' their research. These sources are contacted and asked to verify whether the research was actually used and influential. Since LTSER aims to cultivate a scientific process that more highly values knowledge exchange with stakeholders, is more connected to societal challenges, and is more oriented toward transdisciplinary work, it may be valuable to consider how different criteria of evaluation and promotion can help to advance ILTER's mission.

There are often temporal, spatial, and value mismatches in setting the research agenda

Scientific research needs regarding spatial and temporal scales may be at odds with any number of other considerations, including management needs, social

relevance, funding mechanisms, and other potentially conflicting interests and limitations. Ecological legacies and time lags can have important effects on the socio-ecological system, and yet they are often undetected in short-term research or not considered in policy making. An example of a land-use legacy became apparent at the Sierra Nevada platform when researchers determined that more intense land uses in the past led to a lower likelihood of regenerating native forest in the present (Navarro-González *et al* 2013). In this case, there was a gap between the knowledge and decision-making process of land managers, who didn't take a historical perspective into account, as compared to scientists, who felt it was important to factor land-use legacy into current decision-making. Essentially, this issue represented a difference of perspective, which may be remedied through dialogue and collaboration.

The Baltimore platform dealt with issues of spatial scale mismatch in that they started out with a regional perspective, but eventually needed to adopt a multi-scale approach in order to simultaneously address questions at a regional scale, dynamics within and among municipal jurisdictions, neighborhood-level dynamics, household-level dynamics, and even differences between how front and back yards are managed in residential areas. The Baltimore platform has managed these issues of scale by engaging scholars and practitioners from different fields and taking an adaptive approach to conceptual models and methods.

In addition, there are often mismatches between societal needs and scientific activities at LTSER platforms. At the Sierra Nevada LTSER, for example, most scientific activities are carried out on a project-to-project basis. Principal investigators define their research programs through a set of short-term projects that are motivated by curiosity and funding availability. This approach can provide knowledge about the functioning of socio-ecological systems, and it is a 'profitable' approach in that it yields results within a short timespan (e.g. 2–4 years). On the other hand, while long-term data collection is in line with ILTER expectations and it yields valuable outcomes and scientific insights in the long term, prolonged funding is rarely guaranteed (Nisbet 2007). This mismatch between research preferences and funding opportunities discourages many scientists from embracing long-term monitoring work. It is for this reason that the LTSER network is working with governments, particularly the EU government, to develop long-term funding mechanisms for long-term research.

There is also often a dissonance between scientists and environmental managers regarding their expectations and objectives that can persist when these different stakeholders fail to develop a common language. To illustrate this point, conceptual frameworks used by scientists and managers were mapped at the Sierra Nevada LTSER. Results revealed that while scientists were interested in describing the structure and functioning of SESs, managers were more concerned with addressing complex problems involving multiple stakeholders. In other words, it is not a straightforward task to reconcile a curiosity-driven approach with a problem-solving one. These dissonances between stakeholder interests may be characterized as 'positionality,' defined as the 'motivations, interests, and assumptions in a social situation, as well as the roles, identity, and power one exhibits relative to others in that situation' (Cheng and Randall-Parker 2017). It has been suggested that these types of epistemological differences may be mitigated by efforts to explicitly name and respect different interests, assumptions and conceptual frameworks, and that such reflexive work is essential to advancing collaborations for natural resource management (Cheng and Randall-Parker 2017). Accordingly, a potential solution to this problem is to foster communities of practice where stakeholders have meaningful, ongoing opportunities to share and discuss their perspectives, interests, and needs.

There are often mismatches created by the discrepancies between different methodological needs for ecological and socioeconomic questions, and this may be related to the scale of environmental management and the scale of the ecological and social processes themselves. Such mismatches can also be mitigated by social learning and the development of flexible institutions that can respond to the changing socio-ecological system and institutional players in real time (Cumming *et al* 2006).

Finally, there is the added complexity created by drivers of environmental and social change happening simultaneously at multiple scales (Braila) (Takeuchi 2014). Like the other incongruities, lags, and mismatches mentioned in this section, these discrepancies can be addressed by articulating the phenomenon, and then by convening stakeholders from diverse disciplines and interests to collaborate toward long-term solutions, both for research and knowledge production, and for applying knowledge in environmental management actions.

Funding procurement and the influence of funding requirements

LTSER adds value by formalizing existing activities, often enhancing opportunities for research partnerships and strengthening and leveraging eligibility for funding sources. The Cairngorms platform, for example, was invited to participate in an international European research project in part because it was an LTSER, which, in turn, helped partners win a £3.6 million development grant (see Dick *et al* 2018b, a publication resulting from this grant).

Funding requirements for large projects can have significant influence on agenda-setting at the local level. For example, EU Innovation requests for proposals explicitly require stakeholder engagement throughout a project (e.g. Horizon 2020 Responsible

Research and Innovation[12]). This requirement ensures that scientists communicate and consult with non-scientist stakeholders about their research from the outset of a project. This approach can have the additional effect that stakeholder perspectives and/or public education are meaningfully included in a research process that otherwise would not have included such an element. In other words, the specifications of large grants can be an important impetus for inclusion of socio-ecological research components and can draw otherwise uncommitted researchers and other stakeholders into a transdisciplinary, socio-ecological discourse. This phenomenon highlights a significant benefit of a global-scale network—the ILTER network's administration has access to and can work with governmental/intergovernmental agencies to craft the language of requests for proposals. If such changes can be made, this can be profoundly beneficial for research networks to procure funding for their local and regional platforms.

The problem of relying on short-term funding cycles to support long-term research has been widely acknowledged (Likens 1989). To the authors' knowledge, the Baltimore platform is the only platform that has a relatively long, 6-year renewable funding cycle. In this case, the BES research team must articulate how they are addressing long-term questions and phenomena that cannot be effectively addressed with short-term funding.

Another challenge is that there are rarely financial resources dedicated to the platform as such. In many cases, financial support comes from one of the institutions that were involved early in the platform's development, often supported by government funding. In Europe, for example, support has often been provided based on participation in EU projects (e.g. EnvEurope, OpenNESS, EcoPotential, ALTER-net). Working toward continuity in funding is an ongoing priority for LTSER platform managers.

A way forward

Time and effort dedicated to LTSER activities demonstrate that LTSER researchers find their participation valuable and the network to be beneficial. Official LTSER recognition is useful in that it formalizes and legitimizes activities that may have been carried out anyway, provides access to international funding sources, and/or provides a framework perceived to be objective, since it is a network initiated and led by scientists, and its core mission is conducting science.

As detailed in the earlier section about harmonizing data, discussions at a recent LTSER workshop conveyed demand for the development and implementation of common methods and indicators to assess interactions and changes in the socio-ecological system over time and across global ecosystems. Some of the enthusiasm around LTSER may be attributed to confidence in the network to drive and assist in the standardization and sharing of data. Participants also valued this workshop (and by extension, the network that organized the workshop) as an opportunity to cultivate a community of scientists and researchers. Meeting the challenges involved in producing actionable, transdisciplinary science means that LTSER researchers stand to benefit from the exchange of ideas and mutual support that can come from a scientific community that thinks and works like them in many ways (i.e. an 'epistemic community' *sensu* Haas 1992).

A global network that aims to be representative of global socio-ecological systems should make a point to develop understanding and respect for the different epistemologies, histories, power dynamics, and realities of its human constituents. There still exists a strong geographical bias toward conducting socio-ecological research in Europe and North America, which is reflected in ILTER; indeed, more than 90% of the network's LTER sites are located in the Northern Hemisphere (Rozzi *et al* 2012, Li *et al* 2015) (figure 1). There is also a bias within the ILTER network regarding authorship; more than 90% of ILTER publications are generated by researchers from the Northern Hemisphere, including studies conducted in the Southern Hemisphere (Li *et al* 2015). Often in international research projects, Southern Hemisphere researchers are asked to provide logistical support and information about their local socio-ecological systems without being invited to participate as authors in publications (Rochmyaningsih 2018), although this trend is beginning to change. As the aim of this article includes providing constructive feedback to the LTSER network, we must point out the lack of LTSER platforms in South America, Africa, and Asia, a phenomenon that has been acknowledged (e.g. Mirtl *et al* 2018) but not yet remedied. In addition to their criticism regarding this shortage of LTSER platforms in the Southern Hemisphere, the Omora platform has also pointed out the need to broaden the spectrum of social disciplines included in LTSER (Rozzi *et al* 2012). To remedy both ILTER's bias in spatial coverage and the desire to achieve socio-ecological integration and sustainable development goals within the network, preliminary investigations are taking place to develop collaborations with UNESCO Man and the Biosphere and the Biosphere Reserve network since that network has more complete global coverage than ILTER and the networks share some similar goals.

While ILTER is a global infrastructure and should therefore be concerned with representativeness and equity at multiple levels, its activities do not, and should not, all occur at the global level. The idea of 'nested enterprises' suggests that socio-ecological challenges require study and action at multiple levels

[12] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

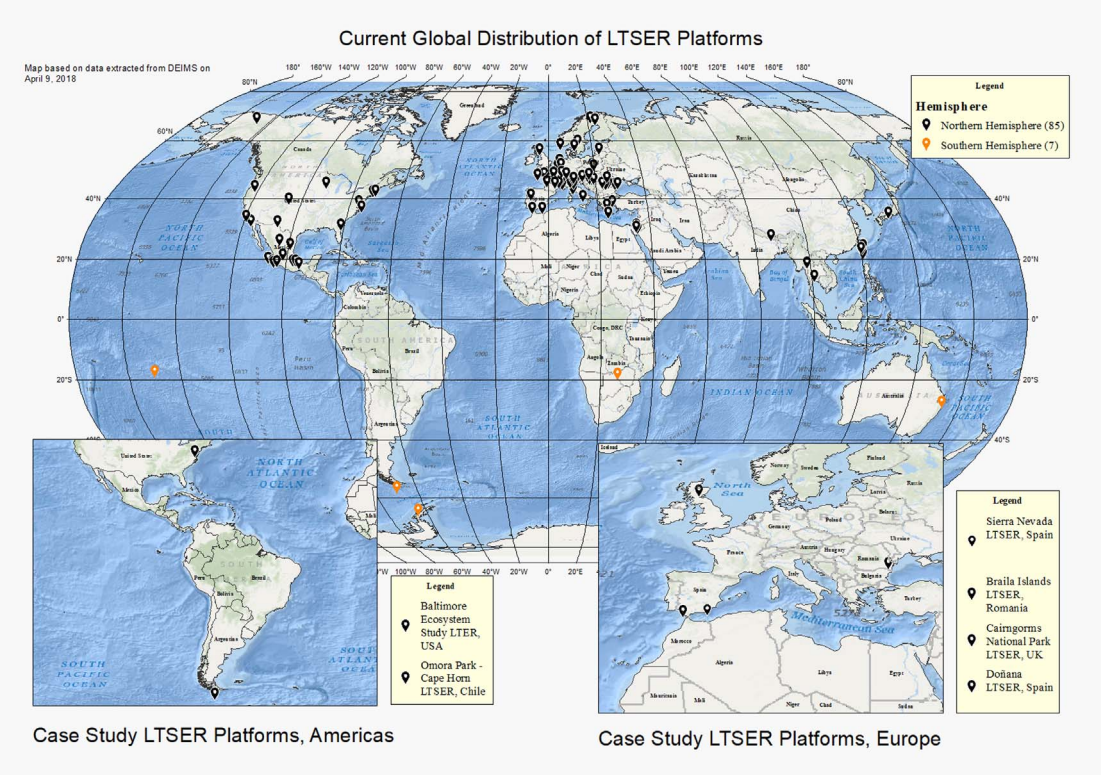

Figure 1. Global LTSER platforms. Note that the vast majority of platforms are located in the Northern Hemisphere with only a few in the Southern Hemisphere. LTSER case study platforms—Baltimore Ecosystem Study, USA (est. 1997), Cairngorms National Park LTSER, UK (est. 2013), Doñana LTSER, Spain (est. 2008), Braila Island LTSER, Romania (est. 1995), Omora Ethnobotanical Park Cape Horn LTER, Chile (est. 2000), and Sierra Nevada LTSER, Spain (est. 2007)—are highlighted in insert maps. Data retrieved from DEIMS on 9 April 2018.

in order to address their inherent complexity. Many natural resource depletion phenomena have horizontal impacts (e.g. harvesters may exhaust a resource in one location and then move on to take the same resource in a different place), as well as vertical relationships to other systems (Brondizio *et al* 2009), supporting the case for cross-platform, comparative research. In the case of ILTER, this may mean that certain activities, like standardization of metadata, maintenance of a shared database, training in and enforcement of data-sharing policies, and centralized funding distribution, should be mandated and managed by a centralized ILTER administration, whereas local activities often take place in a bottom-up fashion, with LTSER platforms experimenting with different strategies for stakeholder participation, knowledge exchange, and evaluation, to fit local/regional needs. Networking and comparative research may continue to occur horizontally, through communications and meetings (see figure 2). For the international infrastructure to work, it must not demand too much of its constituents, who are often overwhelmed by obligations to their institutions of employment and local partners. Like many thriving networks, every hub need not contribute in the same way; however, each partner should find roles and activities that can help maintain the continuity and strength of their links in the web.

We conclude on an optimistic, though cautionary note. The benefits of a global network of place-based socio-ecological research platforms include: (1) research capacity for studying global grand challenges at multiple spatial scales and across diverse socio-ecological systems; (2) designated hubs for the advancement of applied conceptual frameworks for socio-ecological research; (3) a stimulus for global knowledge exchange, professional development, and research collaborations; (4) the development of socio-ecological research protocols and data collection for enabling global comparative research, and; (5) advocacy within international political bodies and funding agencies for advancing the socio-ecological research agenda and adapting funding requirements and discourse. Since socio-ecological research is, by definition, motivated at the grassroots, local level through stakeholder participation (Holzer *et al* 2018, Mirtl *et al* 2018 Haberl *et al* 2006), there will always be inherent tensions between expectations of the international network and the individual platforms. Recognizing this tension and embracing it as a necessary characteristic of LTSER is a prerequisite for advancing the research goals of ILTER, which, in turn, it is hoped, will translate into real-world strategies to mitigate and solve planetary grand environmental challenges. There have been notable successes so far (table 2), and while best practices can help serve as models for individual platforms, every platform needs its own leaders and collaborations to adapt strategies to work

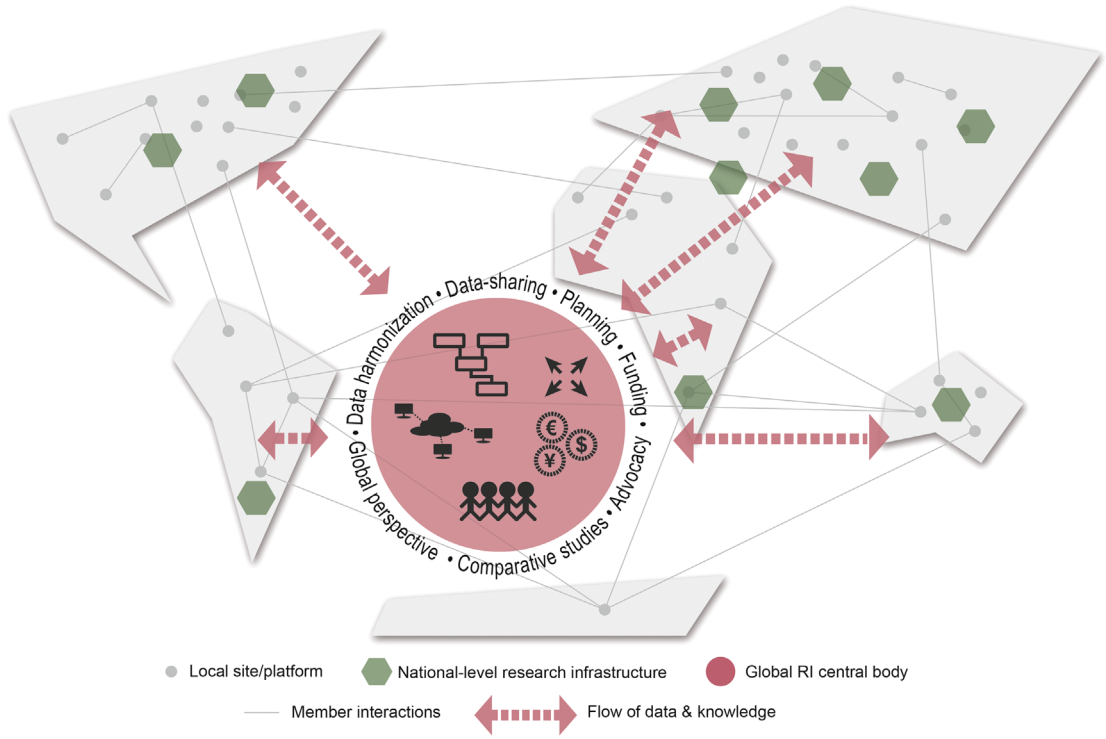

Figure 2. Schematic of ILTER as a global, multi-scale research infrastructure for socio-ecological research. The circle represents a centralized ILTER administration, and graphics within the circle represent the potential benefits provided by a centralized infrastructure. Shapes represent continents of the world, hexagons represent national networks, and dots represent LTSER platforms or LTER sites that are part of the global network. Lines represent 'horizontal' relationships and communications between network members. Arrows represent benefits such as data, knowledge, work-hours, and communications that are exchanged between the central administration and its members throughout the network. This is a schematic; the number of points, lines and arrows do not represent the quantity of these components that exist in the real world. Created by Ronit Cohen-Seffer.

locally. Ultimately, building a global research infrastructure is an attempt to harness collective data, knowledge, and wherewithal to operationalize what we know about sustainability to address socio-ecological challenges at local to global scales.

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