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What is socio-ecological research delivering? A literature survey across 25 international LTSER platforms

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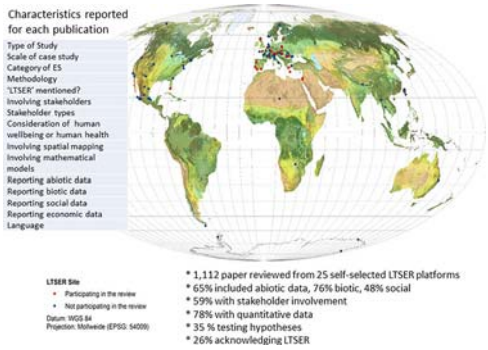
HIGHLIGHTS

- 4983 publications from 25 LTSER platforms were reviewed, of which 1112 were deemed relevant to socio-ecological objectives
- Each publication was assessed regarding disciplinary focus, consideration of human well-being, degree of stakeholder integration and more
- There is a growing trend in socio-ecological research, but progress is uneven and heavily influenced by local constraints and characteristics
- The LTER network must balance between top-down harmonization efforts and the need for platforms to define themselves locally

GRAPHICAL ABSTRACT



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ABSTRACT

With an overarching goal of addressing global and regional sustainability challenges, Long Term Socio-Ecological Research Platforms (LTSER) aim to conduct place-based research, to collect and synthesize both environmental and socio-economic data, and to involve a broader stakeholder pool to set the research agenda. To date there have been few studies examining the output from LTSER platforms. In this study we enquire if the socio-ecological research from 25 self-selected LTSER platforms of the International Long-Term Ecological Research (ILTER) network has produced research products which fulfil the aims and ambitions of the paradigm shift from ecological to socio-ecological research envisaged at the turn of the century. In total we assessed 4983 publically available publications, of which 1112 were deemed relevant to the socio-ecological objectives of the platform. A series of 22 questions were scored for each publication, assessing relevance of responses in terms of the disciplinary focus of research, consideration of human health and well-being, degree of stakeholder engagement, and other relevant variables. The results reflected the diverse origins of the individual platforms and revealed a wide range in foci, temporal periods and quantity of output from participating platforms, supporting the premise that there is a growing trend in socio-ecological research at long-term monitoring platforms. Our review highlights the challenges of realizing the top-down goal to harmonize international network activities and objectives and the need for bottom-up, self-definition for research platforms. This provides support for increasing the consistency of LTSER research while preserving the diversity of regional experiences.

1. Introduction

1.1. Socio-ecology makes its debut in LTER

Long-Term Socio-Ecological Research Platforms (LTSER) comprise the research infrastructure developed to actualize a historical process within the International Long Term Ecological Research (ILTER) network towards transdisciplinary, socio-ecological research. The first long-term ecological research (LTER) network, established nearly 40 years ago in 1980 in the United States, did not have such a transdisciplinary approach at its inception. Its goal, at that time, was to create a network committed to conducting long-term monitoring of environmental indicators and using these data for network-wide research and science-based decision making (Knapp et al., 2012). In its original manifestation, LTER was purely ecological in character, as reflected in the five core research areas specified by the National Science Foundation (NSF), which included primary production, population dynamics and trophic structure, organic matter accumulation, nutrient dynamics and disturbance pattern and frequency (NSF, 1979).

Already in the late 1990s, LTER scientists had begun advocating for a more interdisciplinary approach to research and monitoring within the network, to reflect the growing realization that in the realm of environmental problem-solving, natural and human systems could not be viewed as separate entities (Aronova et al., 2010; Redman et al., 2004). In 2011, about 30 years after the founding of the LTER network in the United States, the NSF reiterated this claim in their evaluation of the national LTER program and its strategic plan. Their conclusions highlighted the importance of LTER collecting and synthesizing social science data along with environmental data in order to produce knowledge useful for addressing complex environmental challenges such as climate change, sustainable development, biodiversity loss, ecosystem management, and environmental hazards (Michaels and Power, 2011). While this report did not recommend a full integration of social science and scientists into the LTER program (as was the case in Europe from the inception of LTER-Europe), it was a major step towards a paradigm shift within the LTER-US network towards socio-ecological thinking (Redman et al., 2004). Today, social research within LTER-US is occurring in two urban LTER sites in Baltimore and Phoenix (Grimm et al., 2000; Grimm et al., 2013; Redman et al., 2004), and also in other LTER sites, such as the Florida Coast Everglades LTER (Childers, 2006, and as reviewed here).

The ILTER network was founded in 1993 and was funded in its early years by the NSF (Vanderbilt and Gaiser, 2017). The ILTER objectives and disciplinary focus were heavily influenced by the US network at the time. However, in the following two decades, ILTER became increasingly committed to the mission of conducting research with both natural and social dimensions, thereby making socio-ecological research an objective of national networks world-wide. This emphasis in the ILTER

network has significantly strengthened over the last decade, reflecting the desire to produce knowledge particularly useful for addressing complex environmental challenges emerging from nature-society interactions and feedbacks (Michaels and Power, 2011; Redman et al., 2004; Sier and Monteith, 2016; Singh et al., 2013b).

The LTER-Europe network was established in 2007, and made its transdisciplinary approach explicit from the beginning by creating a new concept for research infrastructure, the LTSER platform (Mirtl and Krauze, 2007; Mirtl et al., 2013). These platforms encompass classic LTER sites, but also include the broader geographic area that contains them, along with cultural, administrative, historic, economic and other social dimensions of the region. Further, through the Sixth Research Framework Programme of the European Commission in 2004, a Long-term Biodiversity and Ecosystem Research and Awareness Network (ALTER-Net) was launched, which, among its other initiatives, strengthened LTER-Europe with an LTSER approach (Mirtl and Krauze, 2007; Mirtl et al., 2013). Notable advances in LTER-Europe's socio-ecological approach include the publication of an influential article which advocated for a comprehensive shift from LTER to LTSER, set out the theoretical justification for this shift, and developed a blueprint for the physical structure of LTSER platforms (Haberl et al., 2006). This work was followed up by additional publications, including an edited volume focusing entirely on emerging experiences of LTSER platforms across Europe and socio-ecological work done in LTER-US sites (Singh et al., 2013b).

Within Europe, French and Portuguese LTER, as young networks, embraced the LTSER at their inception. French LTER sites took on a socio-ecological character from their establishment in the early 2000s (Mauz et al., 2012), while socio-economic data capacities were a selection criteria for Portuguese sites during the construction of their national network in 2009.

The socio-ecological research conducted in national LTER networks worldwide, as compared to just ecological research, places greater focus on research that can be readily applicable to contemporary environmental challenges, aims to collect and synthesize both environmental and socio-economic data, and attempts to involve a broader stakeholder pool to set the research agenda (Haberl et al., 2006; Mauz et al., 2012). European LTSER platforms, for example, are comprised of geographic regions rather than specific sites; this geographic extent expands the coverage of LTSER research to include developed areas alongside more "natural" areas and to include human populations, which were often excluded from LTER research sites, as these sites were selected in order to monitor natural processes (or indirect human impacts). For example, the LTER site in the Cairngorms, Scotland is a wilderness area (10 km^2, uninhabited valley) that lies within the Cairngorms National Park LTSER, which encompasses 4528 km^2 of diverse landscape and is home to some 18,000 people, or approximately 6% of the Scotland's population (Dick et al., 2016; Maass et al., 2016). In addition, the idea of expanding the socio-ecological research platform beyond the geographic extent of the LTER site reflected an aspiration that LTSER platforms would ultimately represent all the socio-ecological zones of Europe (Metzger et al., 2010). By conducting research at multiple spatial and temporal scales in the context of an international network of researchers and policy makers, LTSER scientists and stakeholders may better understand and address socio-ecological challenges at local, regional, and global scales.

While LTER scientists consider the paradigm shift from ecological to transdisciplinary socio-ecological research to be desirable, two caveats are worth noting. First, it is important to note that the goal is to integrate ecological and social research data and not to replace traditional ecological monitoring and research (ILTER, 2017). Rather, ecological monitoring and research remain at the core of LTER objectives, and the data and knowledge generated are indispensable components of stakeholder-integrated, environmental problem-solving. It is important to note that platforms, in the conception of ILTER, are not stand-alone research units, but contain within their boundaries one or more LTER sites, such that the LTER site provides the ecological data derived from the long-term monitoring infrastructure. In most cases, but not all, the platforms were developed around existing LTER sites. Second, the transition within ILTER from ecological to socio-ecological research has occurred in parallel with the transition occurring in other venues/institutions/initiatives. Over the past several decades, there have been broad trends within academia and within environmental policy and management towards interdisciplinary and transdisciplinary research (e.g. integrating non-academic local knowledge). This trend to integrate a wider base of knowledge offers conceptual and practical advances (Bennett et al., 2017; Orenstein and Shach-Pinsly, 2017; Singh et al., 2013a) and is becoming mainstream in European funding (e.g. European Innovation Partnerships[1]). Such trends have also been widespread among environmental research networks, such as, for example, the Community Conservation Research Network[2] (based in Canada), Future Earth[3] (global, funded in part by the UN), the Resilience Alliance[4] (Stockholm, Sweden), the Institute for Social-Ecological Research (ISOE) (Frankfurt, Germany), and the Program on Ecosystem Change and Society (PECS), supported by the International Council for Science and the United Nations Educational, Scientific and Cultural Organization (UNESCO).[5]

1.2. Time for an assessment

There have been few, if any, comprehensive assessments of whether efforts to establish a socio-ecological research infrastructure have been productive in terms of catalyzing active socio-ecological research, increasing the policy-relevance of ILTER and its research, and generating transdisciplinary research publications (Maass et al., 2016). We suggest that, after more than a decade of experience in initiating transdisciplinary research within ILTER, the time is due for a broad review of the contribution of socio-ecological research in ILTER. Specifically, we asked what characterizes the research contribution of ILTER socio-ecological research. To date, there have been few qualitative evaluations or self-evaluations of LTSER platforms (e.g. Gingrich et al., 2016; Mauz et al., 2012) and a limited number of studies that focus on developing integrated methods for evaluating socio-ecological research (e.g. Angelstam et al., 2013; Walter et al., 2007). However, there have been neither formalized evaluations of individual LTSER platforms nor a comprehensive evaluation of national or international LTSER networks. Accordingly, LTER-Europe has initiated a Horizon 2020-funded program to strengthen the research infrastructure of LTER, including LTSER platforms (LTER Europe, 2017). As part of this effort, there is an initiative to conduct a network-wide "audit" of LTSER platforms as part of a larger effort to build capacity for this network at the European level (Haase et al., 2016). This review paper is a contribution to that effort, but goes beyond its geographic mandate to include platforms from the wider ILTER community.

The aim of this paper is to review the types of publicly available journal papers, books and reports (i.e. grey literature) being produced by LTSER platforms, and through analysis of this literature, to assess whether the subject foci of LTSER research addresses the aims of socio-ecological research.

Socio-ecological research, as defined within ILTER, utilizes interdisciplinary and transdisciplinary methods to examine complex cause-effect relationships and feedback cycles occurring between natural and human ecosystems and, intentionally, treating them as an integrated coupled (socio-ecological) system (Collins et al., 2011; Haberl et al., 2006; Mirtl et al., 2013; Singh et al., 2013b). Further, socio-ecological research transcends a disciplinary research agenda by explicitly striving to be more relevant to policy-making and to society at large, and by doing this through inter- and transdisciplinarity. Several researchers (e.g.

[1] http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=eip
[2] http://www.communityconservation.net/about
[3] http://www.futureearth.org/blog
[4] http://www.resalliance.org/
[5] http://www.pecs-science.org/

Haberl et al., 2006; Redman et al., 2004; Singh et al., 2013b) outline the characteristics intrinsic to SE research in general, and LTSER research in particular. These include:

- Focus on knowledge production useful for addressing and solving sustainability challenges;
- Promotion of interdisciplinary collaborations between ecologists and social scientists, and transdisciplinary collaborations between scientists and non-scientist stakeholders;
- Focus on interaction processes between social and natural systems and integration of socioeconomic concerns with ecological monitoring and analysis;
- Application to multiple spatial, temporal, and organizational scales, with interactions between scales;
- Investigation of general themes of "socioecological metabolism, land use and landscapes, governance, and communication" (Haberl et al., 2006).

An LTSER platform should be defined by a majority of these characteristics, and were designed as such. According to Mirtl et al. (2013), LTSER platforms are meant to be multi-scale and multi-level hot spots for interdisciplinary research and data collection characterized by four core attributes: (1) use of a systems approach, (2) focus on ecological processes, (3) temporally long term, and (4) in-situ at different spatial scales.

To address the question of the prevalence and character of socio-ecological research at LTSER platforms, we conducted literature reviews at 25 LTSER platforms following an invitation to all ILTER self-declared platforms. Our overall objective was to answer the question as to whether the new socio-ecological research emphasis within the ILTER network over the past decade has produced research products such as those envisioned by advocates of the paradigm shift from ecological to socio-ecological research (e.g. Haberl et al., 2006; Müller et al., 2010; Ohl et al., 2007; Singh et al., 2010).

2. Methods

2.1. Selecting the sample

The initiators of this research strived to include the entire population of global LTSER platforms in this activity. However, this was challenging because, despite rising from a common theoretical foundation and being part of structured research network, there is great heterogeneity among existing platforms. The three most important sources of heterogeneity are differences in official recognition status within the ILTER network, differences in local research traditions (including, for instance, that the platform concept itself was developed in Europe), and differences in human resources and logistic capacity to join unfunded efforts such as this study. In order to deal with the first challenge, we consulted the ILTER data system ("Dynamic Ecological Information Management System – Site and Dataset Registry" or "DEIMS-SDR"[6]). To deal with the second and third challenges, we co-designed a common protocol for conducting the literature review in conjunction with the participating platform representatives.

DEIMS-SDR stores information usually supplied by site administrators, researchers or national network managers involved in maintaining the research and monitoring capacities. LTSER platforms on DEIMS-SDR (like LTER sites) are described using a dedicated site metadata model. The metadata model is based on requirements defined by target stakeholder groups (e.g. ILTER/LTER) and research projects. It defines metadata elements about the organization (e.g. contact, information, and networks), the location, the characteristics (e.g. climate, habitats), available equipment, and other fields (see Mollenhauer et al. (unpublished manuscript), in this volume for more details).

For this study, all self-declared LTSER sites on DEIMS-SDR were queried (Fig. 1). The managers listed in DEIMS-SDR were contacted and invited to join the literature review and co-design the collection of data. Managers of 25 different platforms joined the effort, primarily representing platforms in Europe. These included three platforms in France; two in each of Austria, Greece, Israel, Poland, Portugal, Romania, and Spain, and one in Belgium, Hungary, Italy, Latvia, Slovakia, Taiwan, UK and the US (Fig. 1 and Table 1).

2.2. The literature review protocol

Following a series of consultations with participating LTSER platform contact points a methodology was co-designed considering scope of review, clarity of the data collection and authorship. It was agreed that only publicly-available reports, books, articles, and papers published since 2006 would be included, thereby ensuring relative temporal comparability between LTSER platforms. This year was chosen because the major efforts of LTER-Europe to formally introduce socio-ecology began at this time and LTER scientists were working on formal structures for defining LTSER platforms (Haberl et al., 2006). It is recognized that many of the newly established platforms had already adopted a socio-ecological approach. The first platform, LTSER Dutch Wadden Sea Area, recorded in DEIMS-SDR was established in 1872 (although it only adopted the "LTSER" title >100 years later). Historically, the biggest surge of platform establishment occurred in the 2000s, when 28 platforms were established, following 16 platforms in the 1990s and nine platforms in the 1980s.

The LTSER platform representatives were responsible for compiling and reporting on the corpus of published work from their platform. Each was responsible for delivering a narrative of their search strategy. These varied somewhat between platforms depending on historical reference libraries and resources. Several platforms have a readily available archive of all publications arising from research in the platform (e.g. Doñana in Spain, Mazia/Matschertal in Italy, Scheldt in Belgium, Tyrolean Alps in Austria, and LTsER Montado, Portugal), or existing archives that required refinement before use (e.g. Zone Atelier Bassin du Rhône, France). Others conducted keyword searchers on literature search engines (e.g. Northern Negev, Israel and Cairngorms, Scotland). Still others used a combination of these approaches (e.g. Hydrological Observatory of Athens, Greece, Eisenwurzen LTSER platform in Austria, Arid Iberian LTSER in Spain, LTSER platform Trnava, Slovakia, and Baixo Sabor LTER, Portugal). All papers, books and publicly available reports in any language from the whole region of the LTSER platform were included (e.g. social, socioecological, ecological, botanical, zoological or methodological papers).

Due to the very large number of publications in some LTSER platforms, the protocol offered a two-stage approach which facilitated a complete literature review of all publications from the platform, but limited in-depth analysis exclusively to LTSER output from the platform. Thus, the LTSER literature consisted of those papers that remained after being filtered through the question, "Does the paper have direct relevance to the socio-ecological character and goal of your LTSER platform?" Only if the answer to this question was affirmative was the full review conducted. Some of the authors initially filtered using either title, abstract and/or keywords while others assessed the whole paper to determine relevance.

The full review sought to gather basic information about the literature that would identify the socio-ecological characteristics of each publication. Relevant characteristics included whether or not human wellbeing was considered, whether stakeholders were integrated into the research (e.g. as subjects, informants or participants), whether the research had a spatial component, and what type of variables and data were used and/or produced in the research. The literature survey query is included in Appendix A, with an additional column that

[6] https://data.lter-europe.net/deims/

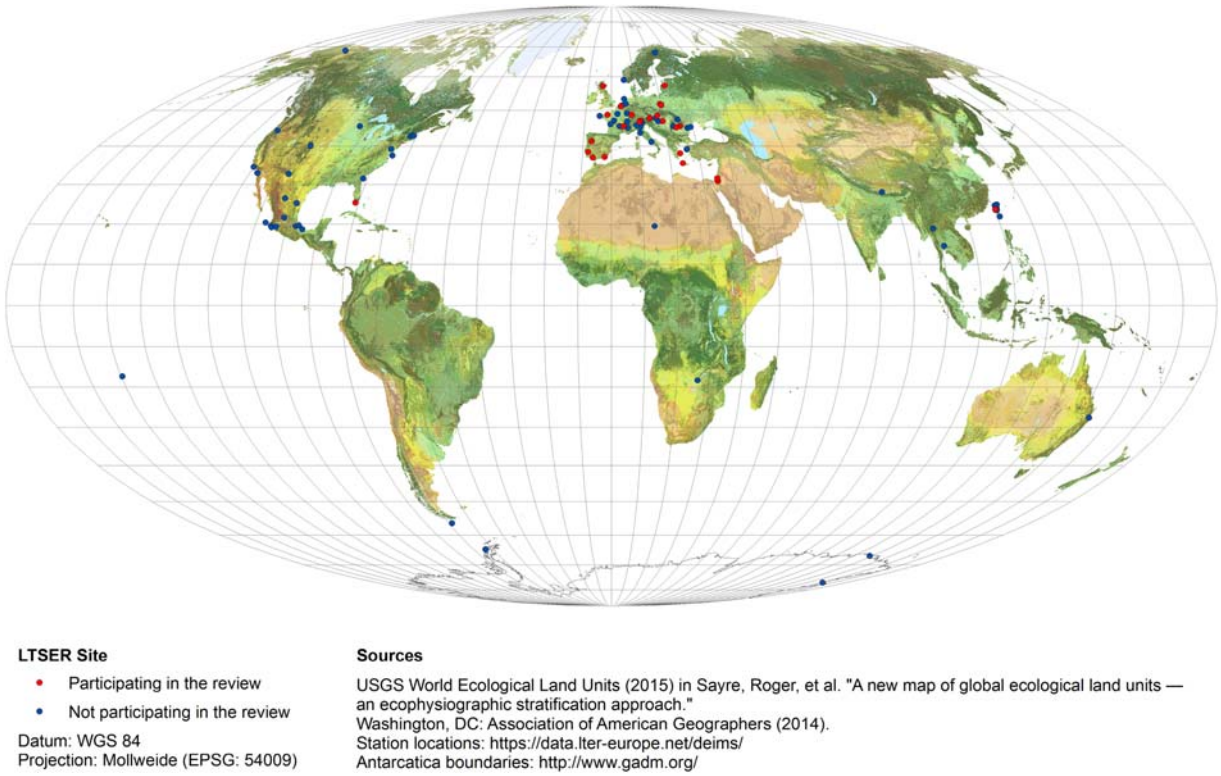

Fig. 1. LTSER platforms identified in the DEIMS-SDR metadata search and annotated according to those participating and those not participating in this review.

explains the relevance of the question for characterization of the research as socio-ecological. The data was collected in Excel format with a binary 0 or 1 response to most questions facilitating data analysis. Given the range of papers reviewed across platforms, the results, unless otherwise indicated, were normalized as percentage of papers reported as relevant to LTSER in each platform.

3. Results

3.1. Literature selected for review

The 25 platforms contributing to the review assessed 4983 written sources, of which 1112 (Table 1) were deemed relevant to the socio-

Table 1
LTSER Platform name, country, short name, DEIMS code, number of papers reviewed and year of first publication of participating LTSER platforms.

Name of LTSER Platform	Country	Short name	LTSER Platform code in DEIMS	Total LTSER relevant publications	Total publications reported	Year of first LTSER relevant publication
Zone Atelier Armorique	France	Armorique	LTER_EU_FR_004	126	126	2006
Zone Atelier Bassin du Rhône	France	Rhône	LTER_EU_FR_006	125	1279	2006
Doñana Long-Term Socio-ecological Research Platform	Spain	Doñana	LTER_EU_ES_001	110	1572	2006
LTsER-Montado	Portugal	Montado	LTER_EU_PT_001	104	238	2009
Baixo Sabor LTER	Portugal	Baixo Sabor	LTER_EU_PT_002	101	135	2008
Florida Coastal Everglades LTER	USA	Florida	FCE	83	573	2006
LTSER Platform Tyrolean Alps (TA)	Austria	Tyrol	LTER_EU_AT_002	74	74	2007
Zone Atelier Environnementale Urbaine	France	Strasbourg	LTER_EU_FR_005	39	40	2011
LTSER Platform Koiliaris Critical Zone Observatory	Greece	Koiliaris	LTER_EU_GR_001	35	35	2010
Cairngorms National Park LTSER	UK	Cairngorms	LTER_EU_UK_059	35	231	2006
The Arid Iberian South East LTSER Platform	Spain	Arid Iberian	LTER_EU_ES_027	32	65	2007
LTSER Neajlov catchment	Romania	Neajlov	LTER_EU_RO_003	32	35	2007
LTSER Platform Eisenwurzen (EW)	Austria	Eisenwurzen	LTER_EU_AT_001	29	36	2011
The City of Lodz LTSER	Poland	Lodz	LTER_EU_PL_025	27	29	2008
LTSER Northern Negev	Israel	N. Negev	LTER_EU_IL_005	25	84	2006
LTSER Engure	Latvia	Engure	LTER_EU_LV_001	25	44	2011
UNESCO/UNEP the Pilica River Demonstration Site	Poland	Pilica	LTER_EU_PL_024	24	39	2006
Scheldt Estuary and its alluvial plains	Belgium	Scheldt	LTER_EU_BE_06	20	251	2008
Bucegi Piatra Craiului National Park LTSER	Romania	Bucegi	LTER_EU_RO_002	17	17	2008
KISKUN LTER	Hungry	Kiskun	LTER_EU_HU_003	14	16	2008
Chi-Kuo branch station	Taiwan	Chi-Kuo	LTER-EAP-TW-8	14	28	2006
IT25 - Val Mazia/Matschertal	Italy	Matsch	LTER_EU_IT_097	8	14	2014
Trnava LTSER	Slovakia	Trnava	LTER_EU_SK_003	6	9	2006
LTSER Platform Hydrologic Observatory of Athens	Greece	Athens	LTER_EU_GR_002	5	11	2010
Negev Highlands LTER	Israel	H. Negev	LTER_EU_IL_017	2	2	2016
Total number of source literature reviewed				1112	4983	

ecological objectives of the platform (recall that the LTSER platforms are almost always superimposed on one or more LTER sites, which explains why the majority of publications arising from the platforms do not have a social component).

Published academic articles were the most frequently reviewed type of published material in most of the platforms, accounting for 71% of the material reviewed (Fig. 2). Six platforms only reviewed published articles, including two of the participating French platforms (Armorique and Strasbourg), both Greek platforms (Athens and Koiliaris), the Taiwan (Chi-Kuo) and Italian platforms (Matsch). Another two, N. Negev in Israel and Trnava in Slovakia, did not review reports. Baixo Sabor, Portugal, was an outlier with regard to the composition of the reviewed material because only 15% of the material reviewed was published in academic articles. This is because the platform was established recently in association with the building of a large hydroelectric dam (Jackson, 2011), and so a large amount of detailed information on the site is available through technical reports on impact assessment and biological monitoring.

Most of the publically available literature reviewed was written in English (72%). The other languages reflected the host country of the platform, including Chinese, Dutch, French, German, Hebrew, Hungarian, Latvian, Polish, Portuguese, Romanian, Slovak and Spanish publications. A French reviewer noted that a large proportion of work focusing on social dimensions had also only been published in French but was not considered publically accessible so was not included in the review.

3.2. Temporal frequency and type of study reported in the LTSER publications

Analysis of the number of articles published across the 25 LTSER platforms since 2006 reveals a steady rise (Fig. 3), with a steeper rise for papers using abiotic and biotic data than for those reporting on social and economic data. There was a consistent trend in focus of the published literature across all platforms and all years, with 40% of the publications focusing on abiotic subject matter and 35%, 15% and 10% focusing on biotic, social and economic variables, respectively.

Overall, 95% of the reviewed documents were exploratory studies, testing hypothesis, conceptual papers, or review articles. The remaining publications (53 documents) were mostly annual reports or management documents. Exploratory studies (45%) and hypothesis testing (35%) were most frequently reported and most commonly reviewed, and conceptual publications and review articles accounted for around 10% each of the remaining items (Table 2). Most of the published literature that was reviewed was comprised of quantitative research (54%) or mixed quantitative and qualitative (24%). Only 12% of the material reviewed was classed by the authors as solely qualitative and 9% was deemed to be none of these categories (e.g. review or conceptual papers) (Table 2).

3.3. Characterization of the LTSER literature

3.3.1. Acknowledgement of the LTSER platform

Analysis of the occurrence of explicit mention of the LTSER platform in the literature reviewed found that authors seldom acknowledged the fact that the work was conducted in an LTSER platform. Overall, 74% of the publications did not mention the LTSER platform (Table 2). There was, however, marked difference between platforms. Six of the platforms found no mention of the LTSER platform in the literature reviewed, while two reported that all the literature reviewed acknowledged the LTSER platform (Fig. 4). For example, the Bucegi Piatra Craiului National Park, Romania reviewed 17 publications and found that all mentioned the LTSER platform and the Negev Highlands LTSER platform, established in 2016, found both its publications which were relevant for this review mentioned the LTSER platform.

3.3.2. Stakeholder involvement in research

Involvement of stakeholders varied from zero to 100% within the reported research. The Italian (Matsch) and Latvian (Engure) platforms found that no stakeholders were reported to have been involved in the 8 and 25 studies reviewed from their platforms, respectively. The Hungarian (Kiskun), Romanian (Bucegi) and Israeli (H. Negev) participants reported that stakeholders were involved in all 17, 17 and 2 publications reviewed, respectively. The other platforms all reported a heterogeneous mix of stakeholder involvement. Overall, stakeholders were involved in 59% of the studies reviewed (Table 2).

Considering only the 656 studies which reported stakeholder involvement, the most frequent single group cited were private sector representatives mentioned in 43% of the reviewed literature (Fig. 5). Governmental organizations where involved in around 25–35% of the studies, while representatives of organized civil society (NGO and lobby groups) were the least represented as a group (mentioned in <15% of the studies reviewed).

3.3.3. Research addressing human wellbeing and health

There was the broadest possible variation in responses regarding the percentage of papers at each of the 25 LTSER platforms that addressed human wellbeing and health. Two platforms (Kiskun, Hungary and Bucegi, Romania) reported that all the studies reviewed directly addressed human wellbeing, while Matsch, in Italy, reported that none of the eight articles reviewed either directly or indirectly considered human health or wellbeing. Despite that the articles reviewed were not concerned either directly or indirectly with human health or wellbeing, the Italian reviewers judged that all eight publications studied some aspect of ecosystem services (Fig. 6); six were concerned with provisioning services and two with biodiversity. The Italian platform was also one of seven platforms which considered all papers focused on some aspect of ecosystem services (Fig. 6). Only, two platforms (Eisenwurzen, Austria and Trnava, Slovakia) classed all the reviewed publications as considering no ecosystem service.

3.3.4. Research methodologies employed in LTSER publications

All platforms reported that some (average 29%) of the literature reviewed from their platform involved spatial mapping directly, other than simply to show location of site (Table 2). Seventeen also reported that spatial mapping was reported indirectly in their publications (e.g. used only to display results). The Hydrologic Observatory of Athens, Greece, considered that all six papers (i.e. 100%) involve spatial mapping, while 60% involved some form of process or mathematical models (any type of model but excluding statistical models such as principle component analysis, ANOVA etc.). Two platforms reported there was no literature which cited process or mathematical models associated with their platform: the Hungarian Kiskun LTER, and Negev Highlands LTSER in Israel. These platforms reviewed 14 and two articles, respectively. Overall, models were involved in 37% of the literature reviewed and spatial mapping in 47% of the reviewed literature (Table 2). Apart from the three platforms which reported no modelling studies, there was a trend of platforms which reported a high proportion of publications which involved spatial maps to also involve process or mathematic models.

3.3.5. Research foci of reviewed publications

A high proportion of the literature reviewed (65%) reported or discussed abiotic characteristics in a manner directly important to the aim of the publications (Table 2). Both Greek platforms reported that every publication from their platforms reported or discussed abiotic data directly, while the LTSER platforms in Lodz, Poland and the Cairngorms in Scotland reported the least occurrence of literature reviewed focused on abiotic characteristics (15% and 17% respectively). Both these latter platforms, however, reported that around a third of the publications consider abiotic data indirectly (e.g. to characterize the setting).

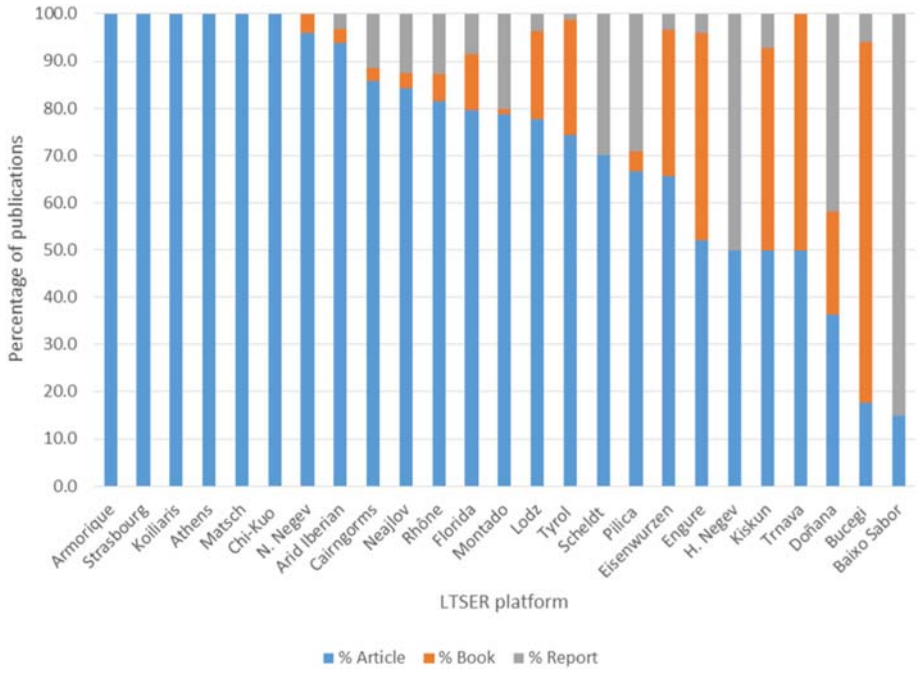

Fig. 2. Proportion of 'Published academic article', 'Book or book chapter' or 'Report (publicly accessible)' reviewed from 25 LTSER platforms (see Table 1 for explanation of the platform codes and number of papers reviewed).

Overall, 76% of the published literature reported biotic characteristics either directly or indirectly (Table 2). In contrast to the 100% of published literature reporting abiotic data in the LTSER Platform Hydrologic Observatory of Athens, Greece, none of the five papers reviewed reported biotic data (Fig. 7). In contrast, the UNESCO/UNEP Pilica River Demonstration Site, Poland, reported the highest proportion of publications (83%) reporting biotic characteristics of the site ($n = 24$).

Just under half of the 1112 publications reviewed were considered to report or discuss the social characteristics of the platform in a manner directly important to the aim of the publication, and 52% were considered not to mention social data (Table 2). The Hungarian (Kiskun) and Slovakian (Trnava) LTSER platforms reported that all of the 14 and 6 articles, respectively, reported studies in which social data was directly relevant to the aims of the paper. The two Greek platforms, the Northern Negev, Israel, Bucegi, Romania and Baixo Sabor, Portugal, reported no literature in which social data was directly important to the aims of the publication reviewed, but all considered that social data was indirectly relevant e.g. to characterize the setting. The Italian LTSER platform considered that none of the eight papers/reports reviewed mentioned social data (Fig. 8). The inclusion of economic data reported in the literature to a large extent mirrored the occurrence of social data (Fig. 9). In general, the platforms which did not report literature studying social process or data also reported few publications featuring economic data.

A clear trend between the platforms emerges when the number of publications which were scored as mentioning social and economic data either directly or indirectly are plotted against each other

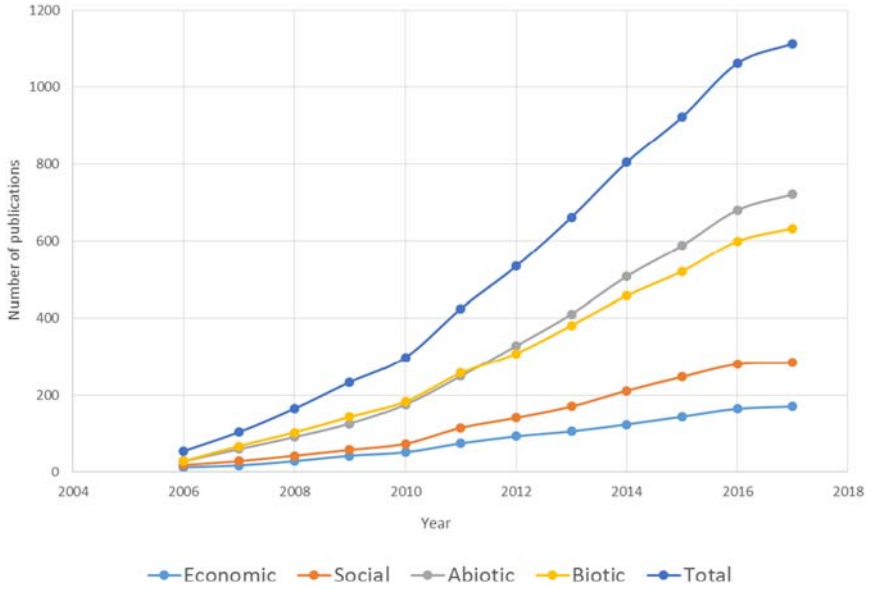

Fig. 3. Cumulative number of papers and reports published between 2006 and June 2017 from 25 LTSER platforms reporting the focus of the publications as social, economic, biotic or abiotic data. Note: A paper can occur in multiple categories. In total 1112 publications were reviewed.

Table 2
Proportion of literature reviewed as relevant to each category for each questions (pertaining to only those papers that passed through the filter question "Does the paper have direct relevance to the socio-ecological character and goal of your LTSER platform?" (n = 1112).

Question	Responses (% of total sources reviewed)					
Type of study	Hypothesis	Exploratory	Conceptual	Review		
	35	45	9	9		
Scale of case study	Local 0 - 999 km^2	Landscape 1000 – 9999 km^2	Regional 10,000 > 99,999 km^2	National >100,000 km^2	International	Not applicable
	53	22	7	2	10	6
Category of ES	Provisioning	Regulating	Cultural	Other	N/A	
	30	30	18	23	34	
Methodology	Qualitative	Quantitative	Mixed	N/A		
	12	54	24	9		
'LTSER' mentioned?	In title	In abstract	In keywords	In text	In acknowledge-ments	In references	In annex/ appendix	N/A
	2	3	2	16	9	5	2	74
Does the paper involve /conceptualize involving stakeholders?.	Stakeholders participated in the research process (co-design, co-delivery)	Stakeholders were the subject of the research (provided data)	The research was in response to requests by stakeholder/s and results were directed towards stakeholders	Stakeholders discussed generally	N/A	
	15	18	22	19	41	
Does the paper consider human wellbeing or human health?	New knowledge directly reported in paper	Human wellbeing knowledge used indirectly e.g. using reported data or conclusions from other work to frame paper/report	No			
	15	25	61			
Does the paper involve spatial mapping?	Spatial maps used directly in paper/ report to collect data	Spatial maps included but not used directly i.e. used only to display results	No			
	29	18	53			
Does the paper involve mathematical models?	Directly reported in paper	Using a published model e.g. INVEST, ESTIMAP, etc.	No			
	28	9	63			
Does the paper report abiotic data?	Directly important to the aim of the paper/report	Indirectly e.g. only to characterize the setting	No			
	65	17	18			
Does the paper report biotic data?	Directly important to the aim of the paper/report	Indirectly e.g. only to characterize the setting)	No			
	57	19	24			
Does the paper report social data?	Directly important to the aim of the paper/report	Indirectly e.g. only to characterize the setting	No			
	26	22	52			
Does the paper report economic data?	Directly important to the aim of the paper/report	Indirectly e.g. only to characterize the setting	No			
	15	24	60			

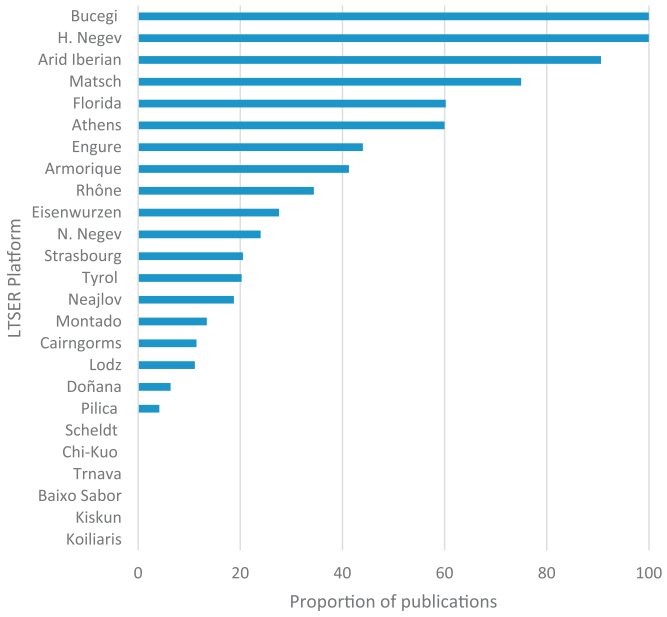

Fig. 4. Proportion of the literature reviewed ($n = 1112$) in 25 platforms where in the publication explicitly mentioned the LTSER platform (see Table 1 for explanation of the platform codes and number of papers reviewed).

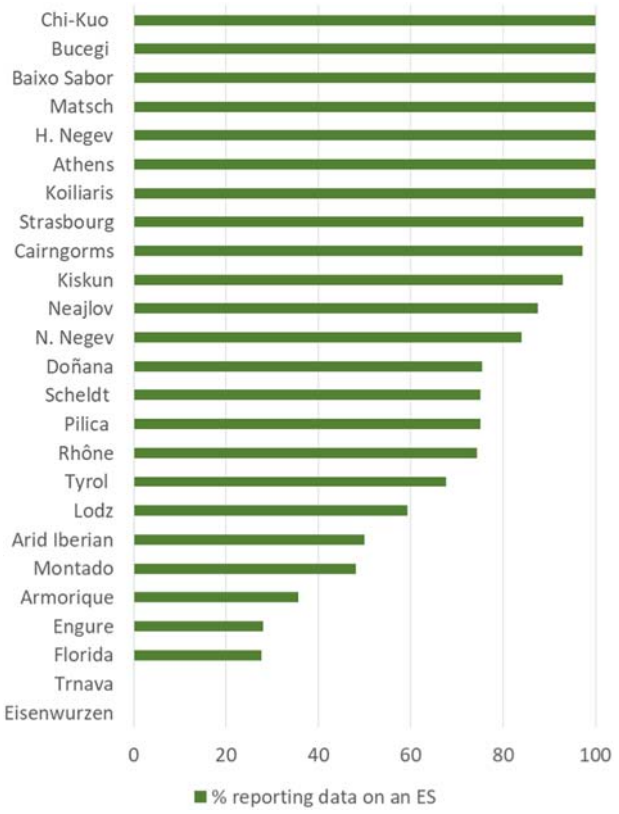

Fig. 6. Proportion of publications reviewed (n = 1112) which reported on at least one ecosystem service (see Table 1 for explanation of the platform codes and number of papers reviewed).

(Fig. 10). There is a group of LTSER platforms which reported that <20% of the publicly-available literature from their platforms was focused on socio-ecological aspects of the platform, and at the other extreme was a group of platforms which considered that over 80% of their studies reported social and economic aspects.

4. Discussion

In this study we conducted a review of the publicly-available literature from 25 LTSER platforms around the world. The review process was co-designed with LTSER managers who responded to an open invitation to the ILTER community. The results reveal two prominent themes which we expand upon in this discussion. First, we consider the methodological challenges revealed through this exercise, and discuss them as a product of the tensions inherent in balancing bottom-up and locally-driven research initiatives with top-down desire for harmonization and integration across the global research network. Second, we

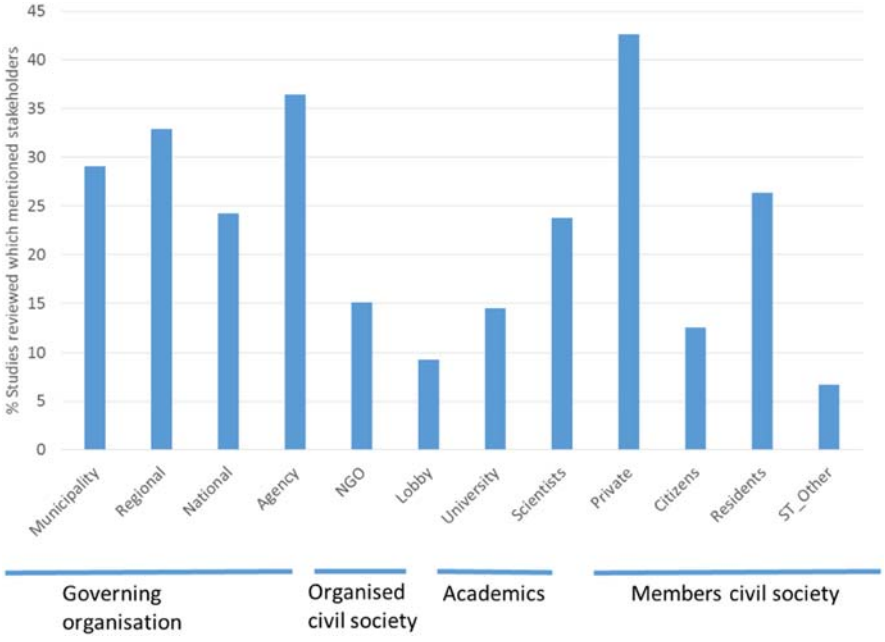

Fig. 5. Proportion of the type of stakeholder mentioned in literature reviewed from 23 LTSER platforms (656 studies reviewed; research from two platforms did not mention stakeholders at all).

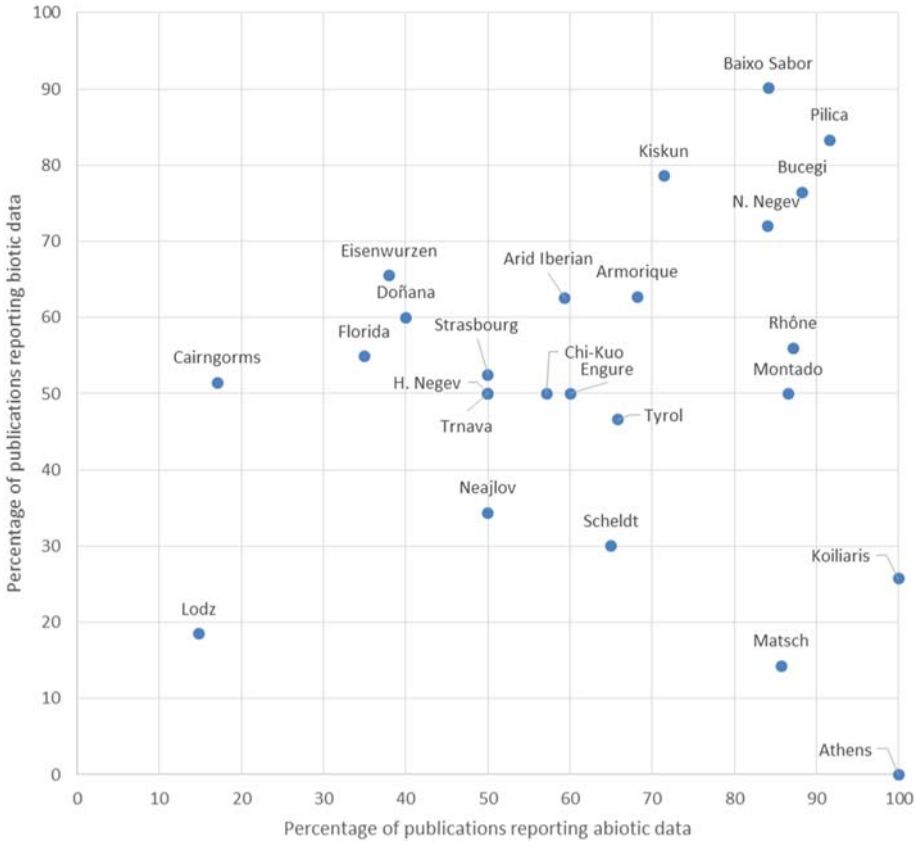

Fig. 7. Proportion of published literature from 25 LTSER platforms which reported or discussed biotic or abiotic characteristics of the LTSER platform in a manner directly important to the aim of the publication (see Table 1 for explanation of the platform codes and number of papers reviewed).

consider the findings and their implications for the status of transdisciplinary, socio-ecological research within the ILTER network.

4.1. The inherent challenges in harmonizing a network of bottom-up initiatives

All platforms participating in this review exercise have adopted a socio-ecological research approach and have begun to conduct socio-ecological research. However, as might be expected with a paradigm shift in a large research network, the actual transition has been slow, uneven, and profoundly influenced by local circumstances. Variability in research characteristics between platforms is expressed both spatially and temporally, with the adoption of socio-ecological research occurring in different years, and the transition occurring at different rates. The degree to which socio-ecological research is conducted in the platforms is often due to the disciplinary composition of the platform research team, which normally continues to be comprised of primarily natural scientists in general, and ecologists in particular, reflecting the origins of these LTSER platforms. One can review the institutional affiliations of the authors of the current work to further understand the disciplinary expertise of the platform managers and scientists.

The journey to creation of the LTSER platforms has been varied, reflecting the need to attune the aims of ILTER to the aspirations of the LTSER local institutions, their primary funders, and local stakeholders. Many of the platforms were created because local researchers in LTER sites saw the need and opportunity to enhance integration of the science and to more explicitly address management issues in collaboration with local governance institutions. For example, the Cairngorms LTSER platform arose when researchers from the LTER site teamed with other locally active researchers and representatives from the national park authority to share knowledge relevant to the sustainable management of the park, in addition to the knowledge from the LTER site, which focused on long-term ecological monitoring of abiotic and biotic parameters. This expanded team signed a memorandum of understanding in 2013 to form the LTSER platform, which has given rise to an increased number of publications reporting social and economic data as areas wider than the 10 km^2 LTER site were included in the research (e.g. Orenstein et al., 2017). Similarly, the Chilean LTER network adopted LTSER as an overarching framework in 2008 to integrate the activities of several LTER sites across the country and to advance the social relevance of the network's research (Anderson et al., 2010).

Other platforms considered social and economic aspects from their creation. For example, the Pilica River LTSER platform in Poland was established in 1996 to combat the decline in drinking water quality. Ecohydrological systemic solutions for water resources management were implemented in collaboration with local stakeholders. From its inception, the management team strove to re-establish positive social-ecological-economic feedbacks (Mirtl and Krauze, 2007; Wagner et al., 2009). Similarly, the Hungarian platform (Kiskun) was established in 1995, together with the Hungarian LTER Network, with the aim of studying the living environment, to detect and monitor its changes, to understand and model the underlying causes and mechanisms, and to use the knowledge acquired to help preserve the biodiversity and associated ecosystem services.[7] These platforms are examples that noted a large percentage of publications reporting either directly or indirectly social and economic studies (Fig. 10).

Other platforms arising from the traditional LTER are well-equipped to make a transition to socio-ecological research because, even as LTER sites, they focused on particular management issues, albeit currently from a biophysical perspective. These include the Northern Negev LTSER platform in Israel, the Koiliaris Critical Zone Observatory in

[7] See DEIMS-SDR; https://data.lter-europe.net/deims/site/lter_eu_hu_003

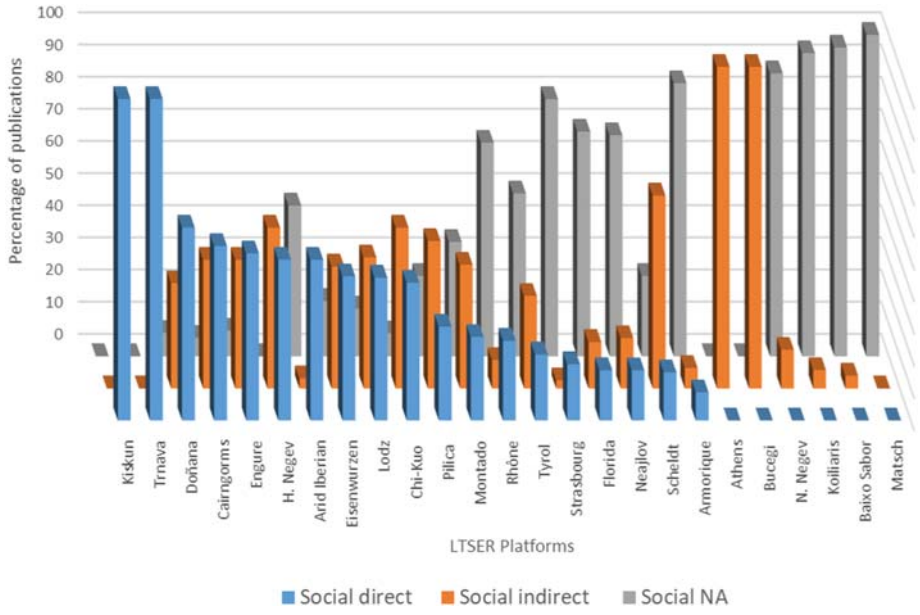

Fig. 8. Proportion of papers reviewed from 25 LTSER platforms that were considered to report social aspects either 'directly' important to the aim of the publication,' indirectly' (e.g. only to characterize the setting) or 'not applicable' (e.g. no mention of social data). See Table 1 for explanation of the platform codes and number of papers reviewed.

Greece, and Mazia/Matchertal Vally in Italy. Both the Northern Negev and the Koiliaris platforms have focused on how grazing, agriculture, and climate change impact ecosystem dynamics in semi-arid and Mediterranean climate zones. The Matsch LTSER platform in Italy, established in 2008, has focused primarily on effects of land-use and climatic changes (especially drought) on mountain ecosystems within a human-influenced catchment. Despite being focused on management, all three of these platforms noted a low percentage of publications reporting social or economic data (Fig. 10) perhaps reflecting a stronger natural science focus of the research teams.

Older platforms, with their roots in LTER research, are complemented by younger platforms, which from their inception focused on understanding the interaction between social and biophysical systems and their feedbacks. Several of the platforms were developed, from their inception, as socio-ecological research hubs. One such example is the French "Zone Atelier Environnementale Urbaine" (Strasbourg) established in 2010, which, as the name suggests, is an urban LTER. The objective of the LTER is to "co-build knowledge with local urban planners to face current and future environmental issues in a sustainable urban development strategy," and their research staff work closely with urban planners, local authorities and other actors to deal specifically with urban environmental and quality-of-life issues (e.g. Kohler et al., 2017; Schmitt et al., 2015; Selmi et al., 2016). Another example - the City of Lodz LTSER - emerged from the need to co-design the process of integrated revitalization of the city, starting from rehabilitation and reviving its water resources (biotic-abiotic component research),

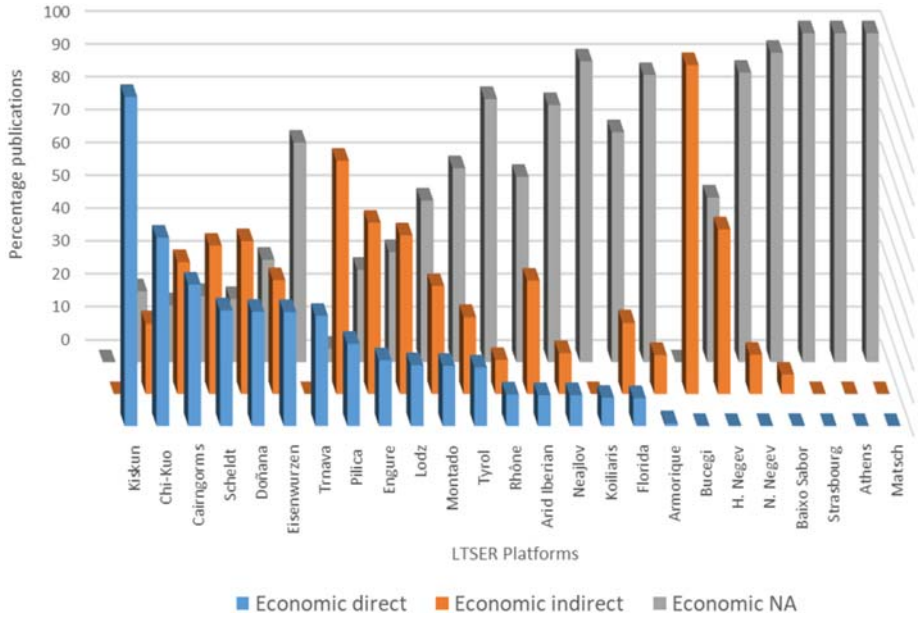

Fig. 9. Proportion of publications reviewed from 25 LTSER platforms that were considered to report economic information either 'directly' important to the aim of the publication, 'indirectly' (e.g. only to characterize the setting) or 'not applicable' (e.g. no mention of economic data). See Table 1 for explanation of the platform codes and number of papers reviewed.

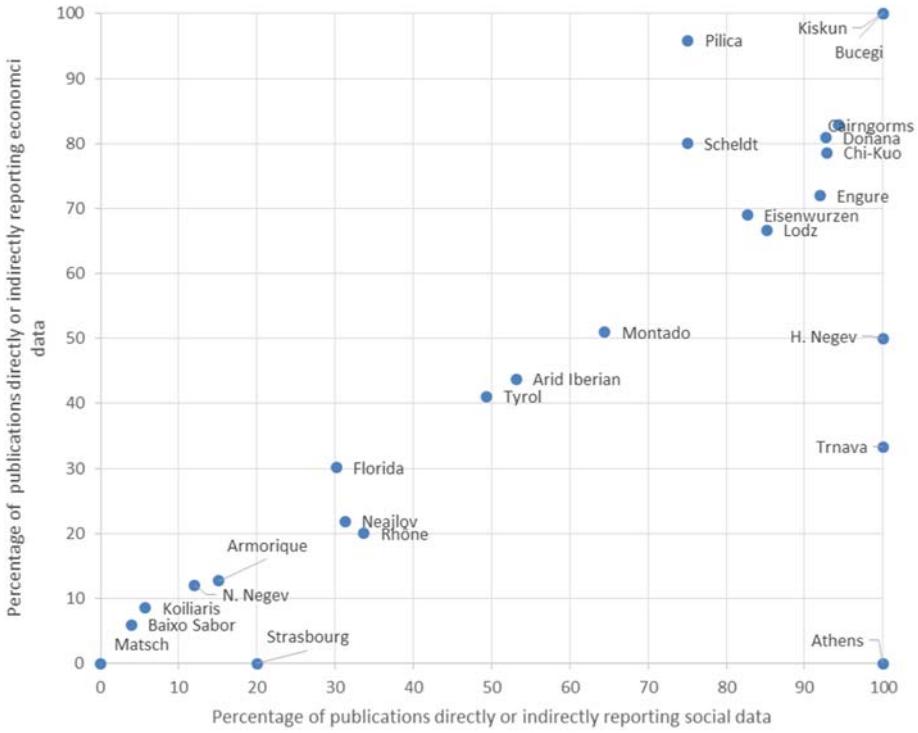

Fig. 10. Proportion of published literature from 25 LTSER platforms ($n = 1112$) which reported or discussed either directly or indirectly social and economic aspects of the LTSER platform (see Table 1 for explanation of the platform codes and number of papers reviewed).

through general climate adaptation issues (ecosystem engineering, biotechnology) up to the processes of developing place ownership, participatory approaches and social inclusion mechanisms.

In Portugal, the LTsER Montado platform featured, from its establishment, site-based research in state or private production farms, co-building knowledge with land owners/managers. Also in Portugal, the LTSER Baixo Sabor platform, established in 2009, has had a clear focus on environmental sustainability, aiming to understand and to mitigate the long-term consequences of river damming on freshwater and adjacent terrestrial ecosystems, with attention to interactions with socio-economic and environmental drivers at different temporal and spatial scales. Other examples, including the Spanish Arid Iberian platform and the Israeli Negev Highlands platforms also fall into this category. Despite the fact that all of these platforms adopted a socio-ecological framework at their inception, the number of publications reporting social and/or economic data varies from low percentages to around 50% of all publications (Fig. 10).

Perhaps due to the relatively recent adoption of the socio-ecological framework, few research publications note that their work is being conducted in an LTSER platform (Fig. 4), despite the fact that all participating research platforms explicitly embrace a socio-ecological approach and have registered their sites in DEIMS-SDR as such. Some authors note that this may be due to the fact that some platforms are just one of several administrative frameworks that describe the platform (e.g. some are also national parks or research sites under diverse auspices). Observation of the results of this review with regard to publications reporting the use of social and economic (Figs 8 and 9) data also reveals extreme geographic diversity between platforms, with some platforms reporting a large proportion of publications using this data, and an equally large proportion reporting very little use of social and economic data. Here, too, authors explain that the timing of the adoption of the socio-ecological framework and the disciplinary composition of the research team influence the results.

We recognize that despite extensive documentation and definitions in DEIMS-SDR, LTSER platform administrators and researchers describe their platforms using different categories from those defined in the database. It is the LTSER platform staff that determines the status of the platform (i.e. self-declaration), including what characteristics qualify the site to be a socio-ecological platform. Self-reported status in DEIMS-SDR has not been verified and not all information is necessarily up-to-date. These issues, common to all self-reporting databases, are the subject of a European-based effort to strengthen and harmonize the coordination and infrastructure within LTER-Europe (LTER Europe, 2017). For the purposes of this review, we initially contacted the broadest group of potential LTSER platforms (115), and as noted, participants were comprised of the 25 platforms who chose to contribute. It is relevant to note that the ILTER network activity reported in this paper received no financial support, and approximately 10 platforms that had initially responded positively to the invitation to participate later withdrew citing resource constraints.

In addition to the intrinsic differences in history among the platforms themselves, there were also challenges in following a unified protocol for this review. A common protocol was developed and followed by the group, rather than relying on a systematic review, to facilitate the loose collaborative nature of ILTER research platforms. The responses to questions regarding human wellbeing and to ecosystem services highlight the confusion inherent in working within a large, interdisciplinary network, where terminology may be interpreted differently by different researchers. Further, this confusion emphasizes the challenges associated with conducting remotely-organized literature reviews.

Network management is in a constant state of compromise between the desire for a unified, harmonized research approach within the entire network, and the realistic realization that each individual platform has (and should have) its own character and research priorities, as determined by the composition of the research team, and the local environmental and political needs and realities (Mirtl et al., 2013). The individual funding mechanisms and local priorities and constraints often translate into local interests taking priority over international network protocols.

In recent years, there has been a drive in the ILTER community to standardize abiotic and biotic variables collected at sites in order to

enhance cross-site research (see Haase et al., 2018 this volume). The results from this study highlight the use of maps both for data analysis and to display results and engage land managers. Landcover maps are recommended by Haase et al. (2018) as essential variables/observations for LTER sites and this study would support the reporting of this variable for LTSER platforms. The precision of the maps, however, can significantly influence their utility for management purposes. For examples, Dick et al. (2016) found that CORINE land cover data was considered by LTER site managers to be too coarse to assess changes in ecosystem services in their site over a 20 years period. A conversation on the creation of a standard set of socio-economic variables is currently a focus of an EU H2020 project 'eLTER H2020'.

Systematic reviews aim to provide consistent and rigorous results on research questions, offering an evidence-based framework for decision-making. However, Roberts et al. (2015) highlighted the problems with systematic reviews, particularly those conducted by the Cochrane Collaboration (Chalmers et al., 1992), noting that published reviews are often biased, out of date and excessively long. The structured methodology has been developed and implemented in the conservation and environmental management area (Pullin and Stewart, 2006), but in many cases it also fails to provide a solution for managers because no clear effect is found to be statistically significant.

The protocol of this review allowed authors to meditate upon the nature of their research program as reflected in their respective publications and compare those to the theoretical foundation of ILTER's socio-ecological research program. While we assess this to have been a productive and knowledge-generating activity, it was not without challenges, including the varying interpretations that authors gave to terminology and intent of each of the survey questions. This is another problem inherent in interdisciplinary research.

4.2. ILTER meandering towards socio-ecology

ILTER, as a global network, has been slowly implementing the lessons of past decades by integrating a broader range of disciplines and knowledge sources into its research programs at the national level in order to produce more environmental policy-relevant research. However, the origins of ILTER as a primarily *ecological* monitoring and research network remains a strong influence on contemporary research despite the increasingly strong rhetoric and proclamations in favor of a paradigm shift to include social monitoring (Haase et al., 2018). There is a rise in the amount of research focused on social and economic data, but this rise is slower than the rise of research focused on biotic and abiotic data (Fig. 3). Overall, we would have expected higher percentages of studies with social and economic aspects, considering that all the reviewed publications were deemed relevant to the goals of the LTSER platform. This suggests that despite the adoption of a new socio-ecological paradigm, the network continues to be primarily monitoring ecological processes, but is clearly progressing to complement these data with social and economic data. Further analyses of national research contexts could help to better understand the degree of social science involved. For example, French platforms benefited from the existence of national interdisciplinary research programs launched in the 1980's (e.g., Billen et al., 2007). In the future, there will still be a need to strengthen cooperation between biological and physical scientists and socio-economic experts leading to an integrated approach to LTSER research. The integrated approach is well-declared in the theoretical foundation, but it is still relatively poorly applied in real practice. Progress must continue to be made on this account, but we are reminded and encouraged by Mauz et al. (2012) that, "Looking at LTSER as a process towards scientific ideals helps us grasp the iterative nature of scientific change."

The reviewers engaged in the current study suggested several reasons why so few publications explicitly mentioned LTSER (Fig. 4). The most common explanation is that most LTSER platforms have been established only recently, and there was a lag in the publication of papers using the newly adopted socio-ecological framework. Secondly, even for those platforms that were established a decade ago, authors don't always find it necessary to note the LTSER framework, but rather refer to the LTER sites within the platform (as when the LTSER platform was superimposed on existing long-term research sites, e.g. the Northern Negev LTSER in Israel) or refer to another administrative name for the platform (e.g. when the platform is only one of several administrative frameworks for an area). Thirdly, the particularities of institutional publishing rules may require of LTSER researchers to prioritize other affiliations, particularly when LTSER platforms were engaged in studies with multiple sites that weren't all platforms, for example 5 LTSER platforms were case studies in the EU funded OpenNESS project but are not acknowledged as such (Carmen et al., 2017, Dick et al., 2016, 2017a, 2017b, Saarikoski et al., 2017). And finally, as noted, the platforms themselves often operate under more than one administrative framework, and so research may be attributed to other administrative titles.

ILTER's socio-ecological program embraces the integration of stakeholders into the research, and approximately 60% of the research engaged with stakeholders directly or indirectly (as the research initiators, subjects or partners), although fewer than half of the publications refer to stakeholders explicitly (Fig. 5). Interestingly, the most common stakeholder type were from the private sector (e.g. industry, agriculture, services or trade), suggesting that there already exist significant public-private partnerships within the LTSER platforms addressing environmental challenges. In some publications, platform scientists counted stakeholders that gave opinions regarding priority environmental problems (López-Rodríguez et al., 2015), provided professional input regarding ecosystem services (Dick et al., 2017a, 2017b; Orenstein et al., 2012), or were otherwise the focus of the given study. Indeed, in transdisciplinary research, the scientist should be negotiating their position as both a provider of knowledge and a stakeholder with normative values and opinions.

Discussion among the participants of this review revealed a recurring theme regarding the transition towards socio-ecological research: The shift has only taken place recently, and that is why both the subject matter of the research and the professional nomenclature used in publications often lack a direct reference to social aspects of local research. Ecosystem service research, focus on human wellbeing, and spatially-oriented research were all considered in this review to be proxy measures of socio-ecological research, and these characteristics were well-represented overall within the reviewed publications.

5. Conclusions

This literature review was considered an important exercise for helping individual platforms evaluate and benchmark their positions relative to their colleagues in the international network. We are reminded, however, that research output in the form of research publications is only one measure of platform activity. Determining effectiveness of a research program is a notorious problem in evaluation studies; assessments most often measure *outputs*, which are clearly defined products such as scientific papers. However, *outcomes*, which are changes in policy and practice that are linked to the program being evaluated, and *impacts*, which are changes linked to the program over a longer time frame, may be meaningful proxies for "effectiveness" that are rarely considered (Koontz and Thomas, 2006) and may be considered for inclusion as part of future evaluations. As time progresses, and the socio-ecological research framework becomes more embedded in the ILTER research program, the next clear step in evaluating the socio-ecological paradigm shift in ILTER will be to assess outcomes and impacts. Despite the shortcomings of this study, it is clear that there is an increase in the number and diversity of socio-ecological research efforts being conducted in LTSER platforms.

With regard to facilitating the adoption of socio-ecological research, we suggest that platform researchers should focus on the diversification of the composition of their teams and on a greater integration of

stakeholders in determining the platform research program. This has important funding implications, because it calls for funneling resources to support social processes (e.g. focus group discussion, stakeholder interviews, and community meetings), whereas tradition LTER funding was channeled towards scientific research and monitoring equipment. Likewise, so far, researchers are most able to secure funding for novel and cutting-edge research, rather than for facilitating long-term stakeholder-driven processes (Tewksbury and Wagner, 2014). Increased top-down funding support could help remedy this situation.

For the sake of future assessments, we also recommend a protocol of explicitly noting the association of the research within the context of an LTSER platform. Finally, with regard to the tension between top-down "harmonization" efforts and inherent "bottom-up" character of LTSER, we recommend that ILTER researchers turn this potential threat into a strength of the network, using activities such as the current review as an opportunity for catalyzing discussion regarding adoption of common theoretical and methodological frameworks, but also to support the imperative that platforms must be able to function within their own socio-ecological venue as they see fit, as determined by local researchers and other stakeholders. Finding this balance will also be influenced by funding mechanisms, and whether they are primarily local or whether there is financial support for network-wide efforts towards harmonization among the platforms.

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Appendix A. Format of the literature survey query form with an additional column that explains the relevance of the question for characterization of the research as socio-ecological

Question number	Question	Relevance for characterizing the research as socio-ecological
1	Year of publication	To determine if frequency of LTSER papers increased over last 10 years
2	Title of publication	
3	Does the paper have direct relevance to the socio-ecological character and goal of your LTSER platform?	Question to filter only papers that are relevant to socio-ecological research
4	Language	
5	Type of publication (1) Article (2) Chapter (3) Report	
6	Number of authors	Is the interdisciplinary nature of LTSER focused papers reflected in more authors
7	Name LTSER Platforms	
8	Country	
9	Type of study (1) Hypothesis driven (2) Exploratory (3) Conceptual (4) Review (5) Not applicable (e.g. conceptual or review paper)	
10	Scale of case study (1) local 0 - 999km^2 (2) landscape 1000–9999 km^2 (3) regional 10,000 > 99,999 km^2 (4) national >100,000 km^2 (5) International (6) Not applicable	Scale of SE research should generally be large enough to include natural and heavily modified (e.g. anthropogenic) systems
11	Category of ES (1) Provisioning (2) Regulating (3) Cultural (4) Other e.g. biodiversity not linked to specific ES (5) Not applicable	SE research should focus on socioecological metabolism; SE research should focus on interconnected social and ecological systems; SE research should be policy relevant.
12	Methodology (1) Quantitative (2) Qualitative (3) Mixed (4) Not applicable	SE research uses a diversity of methodological approaches, but unlike a purely ecological approach, it should also employ the methodologies of the social sciences and the humanities – including qualitative and mixed-methods approaches.
13	'LTSER' mentioned? (1) In title (2) In abstract (3) In keywords (4) In text (5) In acknowledgements (6) In references (7) In annex/appendix (8) Not mentioned	
14	Does the paper involve/conceptualize involving stakeholders?	Full integration of stakeholders (e.g. local residents, business interests, policy makers) is a fundamental component of transdisciplinary

Appendix A (*continued*)

Question number	Question	Relevance for characterizing the research as socio-ecological
	(1) Stakeholders participated in the research process (co-design, co-delivery) (2) Stakeholders were the subject of the research (provided data) (3) The research was in response to requests by stakeholder/s and results were directed towards stakeholders (4) Stakeholders discussed generally, not directly involved (5) No	research.
15	Stakeholder type (10 possible categories of stakeholder types)	A diversity of stakeholders is necessary for transdisciplinary research
16	Does the paper consider human wellbeing or human health? (1) New knowledge directly reported in paper (2) Human wellbeing knowledge used indirectly e.g. using reported data or conclusions from other work to frame paper/report (3) No	SE is a normative discipline with an explicit objective of improving human wellbeing.
17	Does the paper involve spatial mapping? (1) Spatial maps used directly in paper/report to collect data (2) Spatial maps included but not used directly i.e. used only to display results (3) No	SE research often has a strong spatial component, for example, by using maps as boundary objects for community discussion, or for conducting participatory stakeholder mapping.
18	Does the paper involve mathematical models? (1) Directly reported in paper (2) Using a published model e.g. INVEST, ESTIMAP, etc. (3) No	Important for characterizing the nature of the research
19	Does the paper report abiotic data? (1) Directly important to the aim of the paper/report (2) Indirectly e.g. only to characterize the setting (3) No	Important for characterizing the nature of the research
20	Does the paper report biotic data? (1) Directly important to the aim of the paper/report (2) Indirectly e.g. only to characterize the setting (3) No	Important for characterizing the nature of the research
21	Does the paper report social data? (1) Directly important to the aim of the paper/report (2) Indirectly e.g. only to characterize the setting (3) No	Important for characterizing the nature of the research
22	Does the paper report economic data? (1) Directly important to the aim of the paper/report (2) Indirectly e.g. only to characterize the setting (3) No	Important for characterizing the nature of the research

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