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Chilean long-term Socio-Ecological Research Network: progresses and challenges towards improving stewardship of unique ecosystems

Red Chilena de Investigación Socio-Ecológica deLargo Plazo: Avances y desafíos para el manejo responsable de ecosistemasúnicos

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Abstract

Ecosystems provide a variety of benefits to human society and humanity's utilization of ecosystems affects their composition, structure, and functions. Global change drivers demand us to study the interactions between ecological and social systems, and advise strategies to protect the large fraction of Chilean unique ecosystems. Long-term research and monitoring are vital for meaningful understanding of human impacts and socio-ecological feedback, which occur over multiple spatial and time-scales and can be invisible to traditional grant-sponsored short-term studies.

Despite the large fraction of unique ecosystems, Chilean government agencies have not established long-term monitoring programs to inform and guide management decisions for use, conservation, and adaptation to climate change. Responding to this void, the Chilean Long-Term Socio-Ecological Research Network (LTSER-Chile) was created, comprising nine study sites funded by a variety of private and public institutions, that broadly seeks to understand how global change is altering biodiversity and ecosystem functions. The LTSER-Chile is currently in a phase of institutional consolidation to achieve its objectives of alignment with international efforts, fill the need for high-quality, long-term data on social, biological and physical components of Chilean ecosystems, and develop itself as an open research platform for the world. Despite the wide diversity of ecosystems ecncompased by LTSER-Chile sites, several common variables are monitored, especially climatic and hydrographic variables and many ecological indicator variables that consider temporal fluctuations, population and community dynamics.

The main challenges currently facing the LTSER-Chile are to secure funding to maintain existing long-term monitoring programs, to persuade public and private decision-makers about its central role in informing and anticipating socio-ecological problems, and to achieve greater ecosystem representation by integrating new long-term study sites. This will require a more decisive political commitment of the State, to improve the stewardship of our unique terrestrial and marine ecosystems, and the realization that sound ecologically-sustainable policies will never be possible without a national monitoring network. We argue that the State should build on LTSER and several other private and university

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initiatives to provide the country with a monitoring network. In the absence of this commitment, the LTSER system is subject to discontinuity and frequent interruptions, which jeopardizes the long-term effort to understand the functioning of nature and its biodiversity.

Keywords Long-term studies, Terrestrial and marine ecosystems, Social systems

Resumen

Los ecosistemas entregan una variedad de beneficios a la sociedad humana y la utilización de los ecosistemas por parte de la humanidad afecta su composición, estructura y funciones. Los forzantes del cambio global nos exigen estudiar las interacciones entre los sistemas ecológicos y sociales, y desarrollar estrategias para proteger los ecosistemas únicos del país. La investigación y el monitoreo a largo plazo son vitales para una comprensión significativa de los impactos humanos y las interacciones socio-ecológicas, que ocurren en múltiples escalas espaciales y temporales y pueden ser invisibles para los estudios tradicionales de corto plazo, patrocinados por subvenciones. A pesar de la abundancia de ecosistemas únicos, las agencias gubernamentales chilenas no han establecido programas de monitoreo de largo plazo para informar y guiar las decisiones de manejo vinculadas con el uso y conservación de los ecosistemas y la adaptación al cambio climático. En respuesta a este vacío, se creó la Red Chilena de Investigación Socio-Ecológica de Largo Plazo (LTSER-Chile), que comprende nueve sitios de estudio financiados por una variedad de instituciones públicas y privadas, que buscan comprender de manera amplia cómo el cambio global está alterando la biodiversidad y las funciones de los ecosistemas. LTSER-Chile se encuentra actualmente en una fase de consolidación para lograr sus objetivos de alineamiento con los esfuerzos internacionales, satisfacer la necesidad de datos de largo plazo y alta calidad de componentes sociales, biológicos y físicos de los ecosistemas chilenos, y desarrollar una plataforma de investigación abierta al mundo. A pesar de la variabilidad de los sitios LTSER-Chile se monitorean algunas variables comunes, especialmente climáticas y ecológicas, considerando fluctuaciones temporales, dinámicas poblacionales y comunitarias. Los principales desafíos que enfrenta actualmente LTSER-Chile son: asegurar el financiamiento para mantener los programas de monitoreo de largo plazo existentes, persuadir a los tomadores de decisiones públicos y privados sobre su rol en informar y anticipar los problemas socio-ecológicos y, lograr una mayor representatividad de los ecosistemas mediante la integración de nuevos sitios de estudio de largo plazo. Esto requiere un compromiso político más decisivo del Estado, para mejorar la gestión de nuestros ecosistemas terrestres y marinos únicos, y la comprensión de que las políticas sólidas y ecológicamente sostenibles nunca serán posibles sin una red nacional de monitoreo. El Estado debe basarse en LTSER-Chile y otras iniciativas privadas y universitarias para proporcionar al país una red de monitoreo. En ausencia de este compromiso, la investigación de largo plazo se expone a la discontinuidad de sus sistemas de monitoreo, los cuales son parte de un esfuerzo para comprender el funcionamiento de la naturaleza y su biodiversidad.

Background

Awareness of global change and its drivers has existed for at least two decades [36]. Factors such as anthropogenic climate change, land-use change, habitat alteration, invasion by non-native species, over-exploitation and pollution of terrestrial and marine ecosystems [17, 27] demand us to study the interactions between ecological and social systems [7, 31, 33] to build adaptation capacities to confront the ongoing changing environmental conditions [20].

Ecosystems provide benefits to human society [9, 32, 20], and the understanding of their functioning is essential for management practices to ensuring both long-term social well-being [10, 23, 33, 38] and intergenerational environmental justice. Humanity's utilization of ecosystems affects its composition, structure, and functions [7, 9]. Society as a whole, but in particular local communities, are strongly dependent and linked to a given ecosystem [9, 24, 33, 38], because they affect and are affected by the ecosystems they inhabit. Ecosystems also shape and modify human behaviour and, as such, our culture and social organization [4, 34].

In Chile, the last few decades have seen increasing pressure on the environment, causing damage to natural ecosystems, as well as a high dependence on external markets and an increase in economic and social inequality [16]. Population growth, economic growth and increased consumption together exert major pressures on the environment. The situation of the main Chilean productive sectors can be described as [16]: First, mining has somewhat improved its approach, especially in the large-scale mining sector, which abides by international standards. However, increasing pressure on the environmental costs of extraction and transport, the

environmental liabilities posed by abandoned tailings facilities and disused mines, together with the volume of water extracted from aquifers, have significant effects on ecosystems and inhabitants of mining areas. Second, agricultural and forestry systems continue to face the same problems as in the past: the fragility of ecosystems coupled with unsustainable management practices, shaped by patterns of land ownership, as well as a high demand for water. Third, marine resources continue to be over-exploited. Many fisheries have collapsed and salmon farming (which is continually expanding) is considered to be the cause of degradation of lakes, fiords and canals. Fourth, the natural resource based industrial sector continues to cause environmental problems.

The conceptual framework of socio-ecological systems [31] assists in our understanding of those links between human and ecological systems considering their dynamics and complexities, which can only be assessed if we identify key interactions between and beyond them [7, 31]. Such framework not only allows the organization of the attributes of an ecological system that is a source of resources (e.g. forest), the types of goods generated by that system (e.g. wood, fiber, food, water), the users and stakeholders (e.g. neighboring communities) and the social system that governs them (e.g. Local Government); but also, enables the analysis of how these attributes affect and are affected by interactions between and among attributes [31]. This analysis provides us with an understanding of feedback from the system at a given time and in each place in the context of global change. We have yet to fully appreciate the value of long-term ecological and social studies, in providing quantitative information about the changes that we are experiencing and informing actions to mitigate the impact or adapting to the new conditions [23, 33, 20]. People's capacity to make environmentally sustainable decisions depends on the scale of experience, awareness, disposition, and capacity to act, according to temporal and spatial scales that are usually considered important when investigating ecological processes [13].

Long-term research (spanning 10 or more years, [37]) is a vital element in the quest for meaningful progress in our knowledge of socio-ecological systems, in particular those terrestrial and marine ecosystems that sustain human life [18, 24, 33]. Human generations are brief by comparison with the rhythm of ecosystem change, and this often compromises our capacity to understand and manage complex long-term changes [13, 33]. The results of ecosystem studies conducted over short periods can be influenced by short-term effects or special conditions relating to the environmental variability or local disturbances, which generate temporarily unstable or transient conditions [1, 18, 22, 23]. By contrast, long-term studies can provide time-series of processes that can only be recorded in longer periods, and may account for biological, environmental, and climatic variables that permit comparison across larger scales [19, 22]. The synthesis of these time series promote the integration of conceptual and predictive models that serve to generalize ecological processes [18, 19, 22, 33]. An absence of the temporal context afforded by long-term research can lead to severe errors of judgment as we strive both to understand and predict change in the world around us and to manage our surroundings [1, 17, 18, 22, 33]. These kind of partial or erroneous understanding can also be the motive of conservation effort failures or inconvenient management decision from a long-term perspective [33], and can have incalculable effects over the ecosystems and the species conservation.

Contemporary society demands that the information used as the basis of public policy be knowledge-based, meaning that productive, social, and environmental decision-making must consider the relevant and specific scientific data for each particular region of the country [18, 19, 33]. Indeed, there is growing consensus on the need for transdisciplinary networks to generate knowledge and achieve the best possible understanding of interrelated socio-ecological dynamics that enable the assessment of the social and political consequences of complex environmental problems [5, 33]. These networks will predict change, but we also need direct measures of what is changing, how it is changing, and how rapid are these changes [19, 33]. This monitoring helps to trace current trajectories of change against previous predictions, and to inform future projections, thus improving society's capacity to adapt, innovate and avoid the occurrence of the worst foreseen scenarios [18–20, 23].

Informing the current trajectories and future projections of ecosystems implies interacting with different social groups, in order to strengthen sustainability at a territorial scale. In Chile, this means interacting with the State at the regional, provincial and communal levels, but also with those who own the land and water, in the territories where productive activities that have effects on ecological systems and local social well-being are carried out. This requires the active participation of research networks that strengthen research based on sites, where universities, institutes and research centers can contribute decisively, with financial support from the State and private companies, carrying out strategic planning to generate socio-ecological knowledge in areas with socio-ecological problems. In this joint work, state development and control agencies (i.e. the National Forestry Corporation-CONAF, Agricultural and Livestock Service-SAG, Water Agency-DGA, Fisheries and Aquaculture Agency-SUBPESCA, National Geology and Mining Service-SERNAGEOMIN, etc.) are essential, since

they are the direct link between the productive activity, mainly private, and the State, but they are also the ones who receive the new knowledge generated and execute regulations and public policies.

In this context, it is essential that the State has a national agency, with regional/territorial offices, that coordinates the different public agencies. The future Biodiversity and Protected Areas Service (SBAP), under the Ministry of the Environment, could assume this coordination function and interact closely with the Ministry of Science and Technology to decide, together with the private sector and civil society, the co-financing of research focused on solving socio-ecological problems on a local scale.

Socio-ecological long term studies in Chile

The ecosystems of Chile are unique due to its biogeographic history and variability along a wide latitudinal range. Over 5,000 km of Pacific coastline and mountainous geography stretches the length of the country to create abrupt variations in altitude and deepness. and an archipelagic zone in the southern extreme, featuring bioclimatic transitions that shape zones of endemic biodiversity, with globally unique biogeographic characteristics.

In 2008 the Chilean Long-Term Socio-Ecological Research Network (LTSER-Chile) was created with three sites that conducted research in terrestrial ecosystems [3, 14]. Since its foundation in 2008, the LTSER-Chile has completed several of its developmental phases (Fig. 1), beginning with three long-term study sites (sites 2, 6 and 9 in Fig. 2a) and the formal creation of the network, and has conducted management proceedings alongside entities in both the public (e.g., the Ministry of the Environment; CONAF; public universities) and private sectors (e.g., foundations, scientific centers, private universities, and international networks). Since 2018, the LTSER-Chile has been a Foundation and now comprises nine study sites funded by a variety of private (eight) and public (four) institutions. The Network does not account for all of the long-term research conducted in Chile, but it constitutes an attempt to combine efforts and grant visibility and a formal capacity to this line of research in Chile.

The main funds for the operation of the LTSER-Chile Network to date have been public from programs of scientific excellence, such as the Millennium Science Initiative (Ministry of Planning and Cooperation-MIDEPLAN) and Basal Centers (Associative Research Program-PIA/ANID). Each study site, for its part, is financed by a

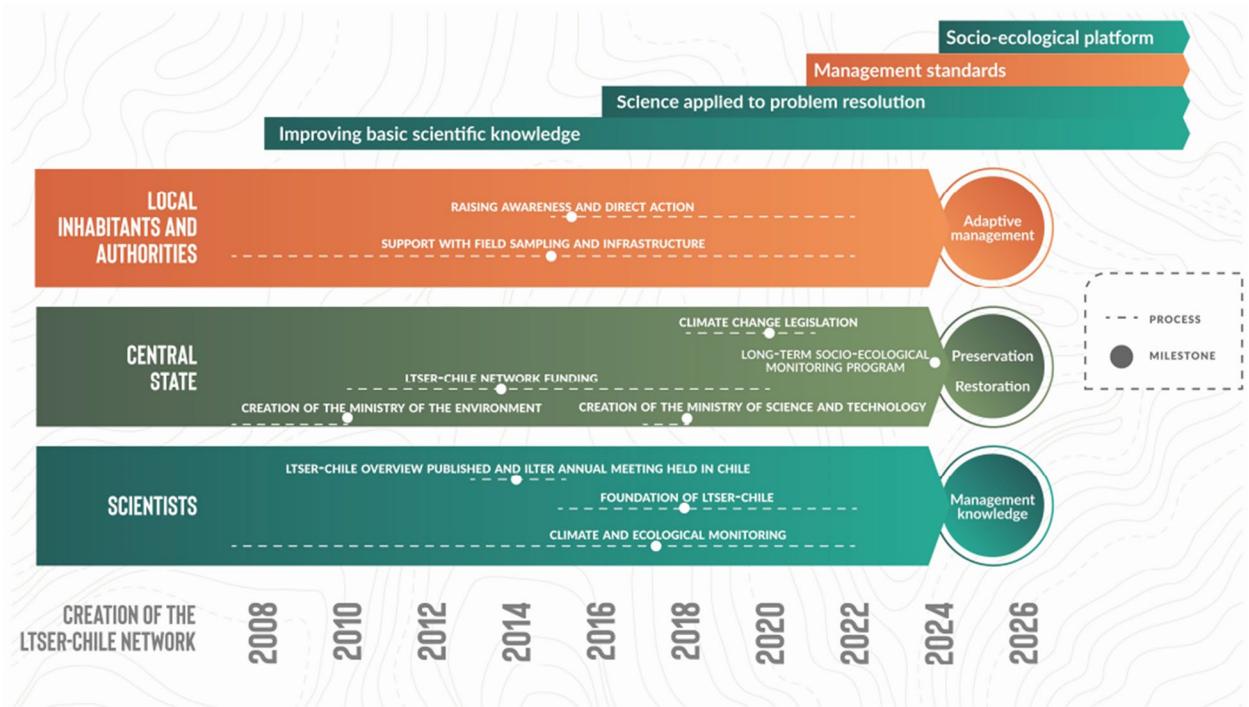
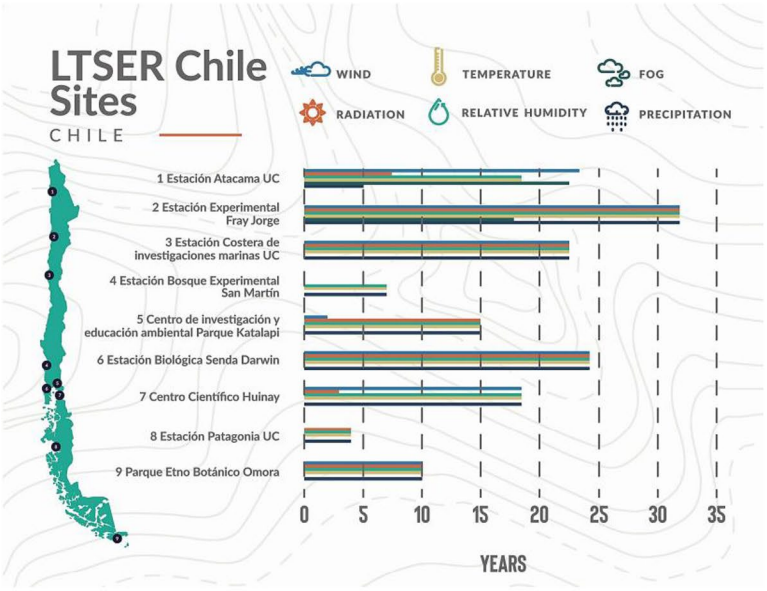
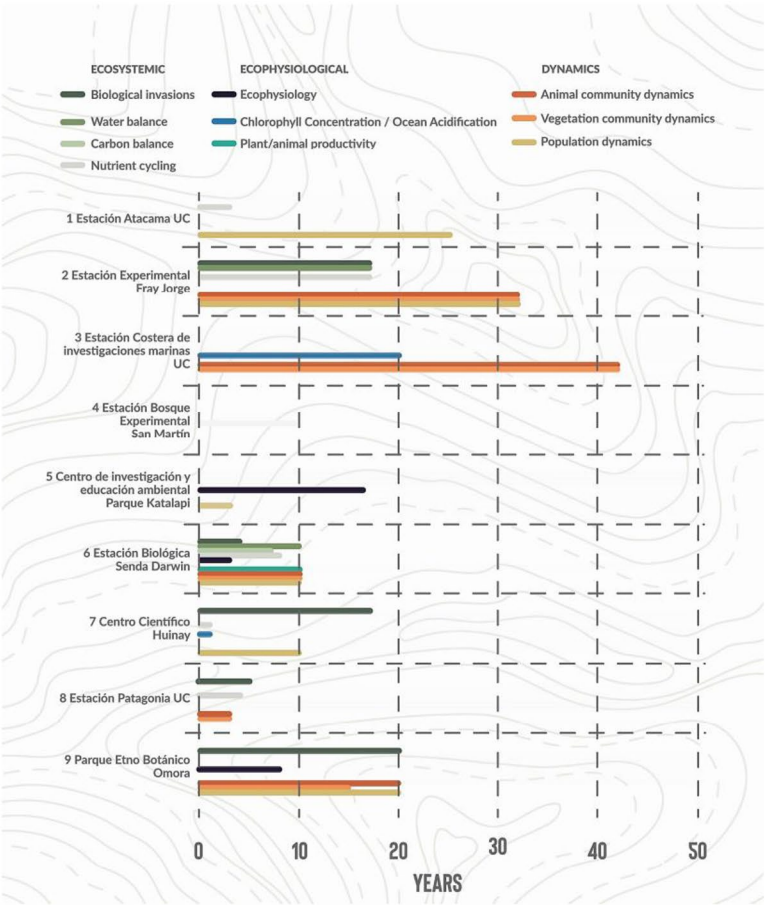


Fig. 1 LTSER-Chile Network timeline and projection. The color bands indicate the various social actors involved. The grey dots indicate the relevant milestones of these actors, and the segmented black lines indicate the time frame of each milestone. The projections concern how best to configure a long-term monitoring program in Chile for the current decade to address the principal impacts of global change (adapted from [29])



(a)



(b)

Fig. 2 Time series of **a** geophysical and **b** ecologicalvariables studied at the LTSER-Chile study sites

sponsoring institution (mainly private Universities and Foundations), who determine the research and teaching focuses, as well as the infrastructure and scientific equipment within each study site.

The LTSER-Chile is currently in a phase of institutional consolidation, for which it must comply with certain standards [10, 17, 18, 26] to achieve its objective of alignment with international agreements (top-down approach) and to fulfil the need for self-definition for research platforms (bottom-up approach; [10]). Long-term socio-ecological studies should be representative of the diversity of territories and biomes and address at least the following objectives: (1) to study ecosystem functioning, (2) to assess the impact of human development on the environment, (3) to contribute to a national public network monitoring long-term ecological and social changes, and (4) to provide support for the development of sustainable ecosystem management/administration policies [6, 12] at the local, regional, national and global scales [8, 10, 22, 26, 35]. The scope of various national and international initiatives, combined with site-based studies and long-term commitment to research, means that the LTSER-Chile Network has the potential for analyzing how Chilean socio-ecological systems evolve and respond to political and economic interventions [19]. Specifically, its activity can be directed towards identifying and monitoring changes in collaboration with interested parties involved in the provision of ecosystem services and the components of well-being [12, 19, 38].

LTSER-Chile can also contribute to achieve global challenges, as the understanding of local ecosystems provides insights to manage global change effects and accomplish climate change international commitments. New global efforts -as the Climate Green Fund and others from the new agreements of COP27- developed to support the adaptation and restoration of natural and social systems needs the understanding and the assessment of long-term studies to be effective and precise to support the different countries and its territories. In a local scale, the recent Climate Change Law (milestone of Climate Change Legislation in Fig. 1) in Chile needs this kind of studies to inform the climate action plans to be developed for municipalities, regional governments, and the national plan level.

LTSER-Chile key questions

Fundamental to the execution of a successful long-term study is the formulation of key research questions regarding basic knowledge concerning local ecosystems (e.g. species list, classification of communities/ecosystems, interaction dynamics; [22]) and the human groups that inhabit them (e.g. human demographics and cultural practices). It is also important that monitoring should extend to those users of the territory (e.g., private corporations, public organisms) who conduct or promote productive activities and thus affect the functions of local ecosystems and the social dynamics of their inhabitants [12, 33].

As the basis of its research, the LTSER-Chile seeks to respond to several general questions. Serving as a framework for the research, the broadest asks: How does global change affect biodiversity (composition, structure, and functions)? The responses and applications vary according to more specific questions, such as:

(1) How are the components, structure, and functioning of biodiversity affected by habitat loss and overexploitation in productive and lesser impacted areas of Chile?
(2) Which human actions affect the provision of goods and services for human populations in rural and urban territories?
(3) Which and how human actions affect the proper functioning of ecosystems in different parts of the country?
(4) What can be done to identify and mitigate the impacts of global change and restore the functions and processes of ecosystems that have been degraded by human action? (adapted from Núñez-Ávila et al. 2014).

The socio-ecological approach yields questions and challenges to which responses can only be provided by long-term monitoring, as they require the assessment of trajectories of change, for instance: How can we associate climate trends over time with biodiversity trajectories and the management of threats in support of conservation? How can this knowledge be integrated with current climate variability? These are key questions to be asked as we strive to adapt to today's unprecedented changes and global change dynamics.

Environmental variables (Fig. 2) and socio-cultural variables currently monitored by the LTSER-Chile are highly diverse and depend on the location of and approach taken at each study site. There are terrestrial and marine-coastal study sites that serve to enrich the national frame of reference to answer the research questions (i.e. [28]). Terrestrial sites represent a diversity of ecosystems, including the Atacama Desert, cloud forests and Mediterranean xerophytic formations, deciduous and evergreen temperate rainforests, and sub-Antarctic forests in the far south of the country. The coastal sites, for their part, represent the central Chilean coast and the beginning (fjords) and end (islands) of the archipelagic zone of southern Chile. The climatic variables are the most relevant and best represented, along with

variables associated with the quantification and characterization of biodiversity (Fig. 2). By contrast, the social variables are under-represented within LTSER-Chile due to research bias, primarily in the field of biology and ecology, along with the limited development of interdisciplinary research, which is a persistent issue in Chile.

On the other hand, the databases are not standardized or available on a public platform. This is partly due to the Chilean scientific culture, which is based on individual research, where researchers apply to the National Fund for Scientific and Technological Development (FONDECYT) to carry out short-term studies (2–3 years) and, where the State until recently did not require the publication of the data. This, added to a logic of intra- and inter-university competition and an orientation towards the publication of scientific articles as the main metric of a researcher's success, make it difficult to create an open data platform. Therefore, in most cases, the databases of long-term ecological variables belong to individual researchers and their accessibility is given by the publication of scientific articles or the will of each person. An exception is climate data, which is mainly found on open data platforms.

Challenges and projections

Challenges facing the LTSER-Chile Network

The main challenge currently facing the LTSER-Chile is to persuade public and private decision-makers of the important role of long-term study sites in solving socio-ecological problems at the local and national levels. The critical challenges and key objectives for long-term science of excellence are diverse [21], but long-term research must be directed toward developing solutions to current socio-ecological problems [17, 23]. Throughout its history, development in Chile involved economic growth based on the exploitation of natural resources and natural heritage [15], and this has led to a multitude of socio-ecological problems of which the most significant drivers are: (1) land-use change and landscape homogenization, (2) soil erosion and desertification, (3) overexploitation and lack of integrated management of freshwater and marine ecosystems, and (4) pollution generated by industries and cities whose growth is not subject to planning [15, 16, 25, 27]. In addition, the fact that the land with the highest added value is in coastal areas influenced political decision makers to distribute protected areas in mountain areas, far from biodiversity hotspots [2]. Then, a transdisciplinary approach must be taken to tackle the problems at their roots, and this should involve local communities and public and private academic institutions at the local, regional and national levels.

For the Chilean reality, this implies a reorganization of the institutions, which requires a close coordination of the State between its Ministries and the definition of an organism, like the future SBAP, that coordinates and informs the other public services (CONAF, SAG, DGA, SERNAGEOMIN, etc.). On the other hand, an open data platform is required, managed and funded by the future SBAP, which allows the delivery of territorial information to improve decision-making in the private sector and provide tools for auditing. In this organizational context, the LTSER-Chile network can be a fundamental contribution through long-term monitoring of socio-ecological variables.

On the other hand, the permanent support of the State is required to achieve the sustained operation of the study sites in the long term and to strengthen the coordinating role of the LTSER-Chile Network. In this sense, it is essential that Congress appreciate the importance of this type of research and generate institutional mechanisms to permanently finance long-term research based on the study sites, in addition to adapting current regulations to incorporate scientific knowledge in decision-making on public policies and the management of terrestrial and marine ecosystems.

Representativeness and maintenance of LTSER-Chile

The LTSER-Chile consists of nine study sites and holds Foundation status. In the next phase, the focus will be on achieving greater ecosystem representation by integrating new long-term study sites at different latitudes and altitudes, with consideration given to regional diversity. Emphasis will be put on marine-coastal and terrestrial sites in central Chile (30–40°S), as this zone has the greatest concentration of biodiversity and human population. Activities relating to the productive matrix will also be conducted, and this will involve the formation of partnerships with institutions and researchers (e.g., regional universities) and productive sectors (e.g., wine and forestry), a complex task considering the many entities involved.

Furthermore, the lack of a stable funding source hinders the installation and operation of a long-term monitoring system, as this requires scientific equipment and the presence of a group of researchers and technicians at each study site.

In this context, it is vital to strengthen monitoring and research to answer relevant questions at the local or national level; to incorporate multi-disciplinary training and the long-term approach into undergraduate and postgraduate education; to improve science communication, particularly to decision-makers at the local, regional and national scale; to establish a direct connection between monitoring and the local community to develop management and governance models at the local level,

and to secure ongoing public funding to maintain the functioning of the long-term study sites (e.g., equipment, personnel and station operation). Its also important to seek financing from public-private alliances, as well as internationally, to strengthen and fill the shortcomings detected so far in the network and its operation.

LTSER-Chile: emphasis on data analysis, replicability, training and collaboration

Two issues are of considerable relevance to the long-term monitoring of socio-ecological variables: access to information and integrated data analysis. Regarding the former, a data platform is needed for the assembly and analysis of data generated at each study site. The platform should be publicly and freely accessible and should provide processed data from biological and ecological monitoring, as well as ways to collaborate and integrate information from other sites similar or close to those of the network. This is not currently available in Chile but is fundamental to improving decision-making regarding the implementation of productive activities in the various territories. These issues require the formulation of protocols to homogenize monitoring at various sites and a data sharing policy.

Regarding integrated data analysis, it is important to combine geospatial analysis tools with monitoring at each of the study sites. Current technology permits the analysis of satellite images, which can provide relevant information at different spatial and temporal scales, such as estimation of primary terrestrial and marine productivity, biomass, and soil moisture, and this can be complemented with specific information generated at the study sites, such as plant and insect phenology and climate data. Together, this combination of multiple spatial and temporal information scales allows us to better understand the dynamics of each ecosystem, the processes operating within them, and their patterns of change. To integrate information collected at different spatial scales, research protocols are needed to allow homogenization of the monitoring of key variables and the implementation of common studies and/or experiments of the study sites. This enables comparison of results from all study sites and improved modelling of the interactions and future functionality of Chilean socio-ecological systems.

International cooperation and engagement should continue through participation in international research networks such as ILTER and FLUXNet, fostering the exchange of experiences between national and international researchers, and funding of academic associations. This will allow the LTSER-Chile to contribute knowledge and remain engaged with problems on a global scale, such as climate change.

We must also foster training at several levels, in partnership with universities and science centers, in the form of specific courses and workshops for each territory, combining multiple disciplines and applied to a range of social actors, including public officials, private company boards, and residents of each of the territories. Support for undergraduates and postgraduates is also crucial, as well as encouragement to conduct their theses in the study site territories and to address specific socio-ecological issues. The role of the academic institutions and research centers are key to join effort and design new path of cooperation and research effectiveness in LTSER-Chile.

Summing up, the long-term socio-ecological monitoring programs should evolve and adapt in response to the latest information generated by the studies, or adopt new questions arising from the research results. Finally, the network's long-term socio-ecological research should report how human systems (e.g., policy, urbanization, built environment, and behaviors) regulate the resilience of ecosystems that, in turn, feedback into the human system in the form of ecosystem services [7, 9, 13, 20].

The false dilemma: "Basic" and "Applied" science

This fictitious dilemma pervaded the scientific development of many societies [18, 19, 33], and was not absent in Chile. The divorce between "basic" and "applied" scientists generated different languages, for instance, between ecologists ("basic" scientists), conservationists ("applied" scientists in ecology) and environmental policy makers (politicians deciding about conservation objects).

Addressing the challenge of unifying conservation efforts with long-term ecological research will require an initial increase in state investment in R&D from the current 0.3% of GDP to 1.2% over 5 years and a subsequent increase to at least 2%, according with international experience [11, 30]. This will constitute State science funding capable of generating new knowledge and addressing the country's current and future socio-ecological problems. There is no other way to sustain long-term research, meaning that our knowledge of our ecosystems and the social interactions that occur within them will remain only partial.

The COVID pandemic may empower humanity to adopt a mentality that will enable us to become more resilient in the face of global change and help us to identify how our collective actions can lead to a more sustainable future for our planet [13]. A consistent focus should combine an understanding of ecological systems, achieved through long-term monitoring at study sites that are representative of Chilean ecosystems, with territorial planning that covers responsible ecosystem management through socially acceptable interventions that

can be selected and evaluated by the local inhabitants and actors within a territory.

This long-term socio-ecological research strategy should simultaneously strengthen modes of subsistence at the local level using coherent changes and the application of sustainable management practices, integrating the need for policy change at the local, regional and national levels [18]. In this context, local knowledge must be complemented by scientific knowledge, as the former comes from practical experience within the territory and has enabled inhabitants to respond and adapt to historical changes in climate and landscape [4, 6, 8, 12]. The values and beliefs of the local community should be integrated into the system of knowledge and practices for progress to be made toward a system of biocultural ethics that allows responsible administration of our ecosystems in the long term [34]. In other words, discoveries made by long-term network-based science have implications for decision-making in the form of scales, disciplines, and governance, and seek to generate resilient and sustainable socio-ecological systems stretching from the community to the global level [10, 13, 33].

Projections for LTSER-Chile

The generation of scientific knowledge involves a range of skills, and long-term socio-ecological monitoring enables consolidation of the process [22]. It applies a diversity of knowledge and motivates constant development based on the discovery of unforeseen opportunities and needs, such as the installation of new infrastructures, the application of technologies, or the formulation of territorial management plans [12, 21]. It requires the assembly of transdisciplinary teams to complement the knowledge present in each territory. In democratic spaces, it permits the generation of proposals and the achievement of socially accepted results [5]. Furthermore, it brings together diverse creative assemblages capable of innovating in our forms of inhabiting ecosystems to make and produce knowledge-based societies and respect the cultures and ecosystems of each territory [34].

Conclusion

Addressing the challenges of the LTSER-Chile will require a political commitment on the part of the State and the private sector through regional and local planning and involving an ongoing public (and private-public effort) funding arrangement, for long-term research at representative sites, all based on a program whose objective is to address socio-ecological problems. As such, we propose a program of long-term socio-ecological monitoring (Fig. 1) involving at least four lines of work: generation of knowledge relating to ecosystem management; direct action to preserve ecosystems considered key to the well-being of territories; restoration of degraded territories and ecosystems; and the implementation of adaptive management in a joint effort alongside local inhabitants, researchers, private corporations, and the State.

We have a unique opportunity to use our long-term effort to develop a more sustainable future, the LTSER-Chile is full available to work on and to promote this new path to the biodiversity conservation in Chile.

Authors' contributions

CF conceived and designed the commentary, analyzed data and wrote the manuscript, JA conceived and designed the commentary, RN edited the manuscript, AG edited the manuscript, SN edited the manuscript, MT edited the manuscript, AM edited the manuscript, LC edited the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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