ExpeER
Distributed Infrastructure for EXPErimentation in Ecosystem Research

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Individual local research sites have been and will continue to be funded primarily by local and national funds. However belonging to European recognized distributed infrastructures facilitates getting these local/national funds. Large efforts have then been deployed to successfully set-up distributed pan-European infrastructures both for experimental sites (AnaEE) and for observational sites (eLTER).

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Contributors: [Jacques ROY, Michael MIRTL]

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1. Executive summary

Individual local research sites have been and will continue to be funded primarily by local and national funds. However belonging to European recognized distributed infrastructures facilitates getting these local/national funds. Experimental and observational research sites are needed for ecosystem science understand and predict how anthropogenic and environmental changes will affect ecosystem services to society. Large efforts have then been deployed to successfully set-up distributed pan-European infrastructures both for experimental sites (AnaEE) and for observational sites (eLTER). The vision and structure of these two infrastructures are presented and a larger integration picture is given.

2. National and European funding: search for synergies

Most ecosystem research sites (platforms) have been initiated by local researchers and funded by local or national institutions. Besides specific, three to four years research projects involving one or a few research platforms, there is, to our knowledge, no European funding mechanism enabling directly a long term sustainability of the research platforms. Integrated Infrastructure Initiatives (I3) programs, although very valuable, do not fund the maintenance or development of the participating sites: they only reimburse the functioning cost of receiving foreign researchers.

Most of the functioning, maintenance, development and personnel costs have then to come from the local and national institutions. These local/national sites funding, especially in times of limited research budgets, are under threat and the selection of local sites to constitute building blocks of distributed pan-European infrastructures is becoming a major criteria for these local/national funding.

Major ExpeER WP4 efforts were then directed towards establishing long pan-European distributed infrastructures that would, indirectly, secure the funding of a large number of individual research sites.

3. Complementarity of Observational and Experimental Research Infrastructures

There is a need for infrastructures covering observational and experimental ecosystem research. The non-invasive comparative approach consists in observations and monitoring of a large number of ecosystem types and sites in order to capture and analyse the diversity along gradients through statistical analysis and modelling. The experimental approach deals with the manipulation of relevant forcing variables within a more restricted number of ecosystem types and sites in order to analyse the cascade of responses at process level and their interactions for understanding the modification of ecosystem structures and functions by these variables. The comparative approach provides contextual information over large geographical, anthropogenic and ecosystem gradients that allows to come to generalization and extrapolation of results provided by experimental approach, and also a way for validation and calibration of models. The experimental approach allows the identification of

causal relationships. It allows then the prediction of ecosystem development under different scenarios of environmental changes, and also the elaboration of relevant actions for mitigation or remediation.

4. Successful progress towards ESFRI infrastructures

In view of this needed complementarity, ExpeER has catalysed the development and formalization of both approaches at the European scale and contributed to integration efforts. The coupling between the experimental and comparative approach will be facilitated by the further development of commonly relevant standards and services in the field of standardization and harmonization of parameters and methods, information management, field methods and ecosystem modelling.

Regarding the development of pan-European infrastructures for ecosystem research, substantial progress was made since 2010:

i) The ESFRI preparatory project AnaEE (2013-2016) conceptualizes and implements the experimental approach (See annex A). This European project already catalyzed large national funding for local research sites in France (AnaEE-France 11 M€ for 10 years) as well as in Belgium (AnaEE-Flanders, 5 M€ so far, more expected) and other countries.

ii) LTER-Europe streamlined its network and tested cross-site analyses in the Horizon 2020 project "eLTER". Subsequently, an eLTER ESFRI proposal was submitted in March 2015. (See annex B).Body text

5. Conclusion / Larger integration

Both AnaEE and eLTER are involved in the Horizon2020 environmental research infrastructures cluster project ENVRIplus, which will provide the major framework for developing the "ecosystem and biodiversity domain" in the European research infrastructures landscape. This will be done in close interaction with related infrastructures both in term of collocation of the research infrastructure components (sites, platforms) and in term of setting-up research programs across these infrastructures, providing a consistent infrastructure picture for stakeholders, both nationally and at the European scale.Body text

Annex I Vision and structure of AnaEE

ADDED VALUE

AnaEE is a **world-class infrastructure** with a unique focus on experimentation that puts it at the heart of pressing global challenges. **Users and site managers will have access to the best sites and platforms in Europe**, centralised service facilities, high-level techniques and skills, increased visibility and leadership within Horizon 2020 and other international funding streams and projects, and a place at the center of the ecosystem science community.
AnaEE aims to be **a tool for capacity building** *via* state of the art facilities and structuring tools for the research community. AnaEE aims at economies of scale, greater interoperability and a widening of the user community.

ACCESS TO PLATFORMS AND DATA

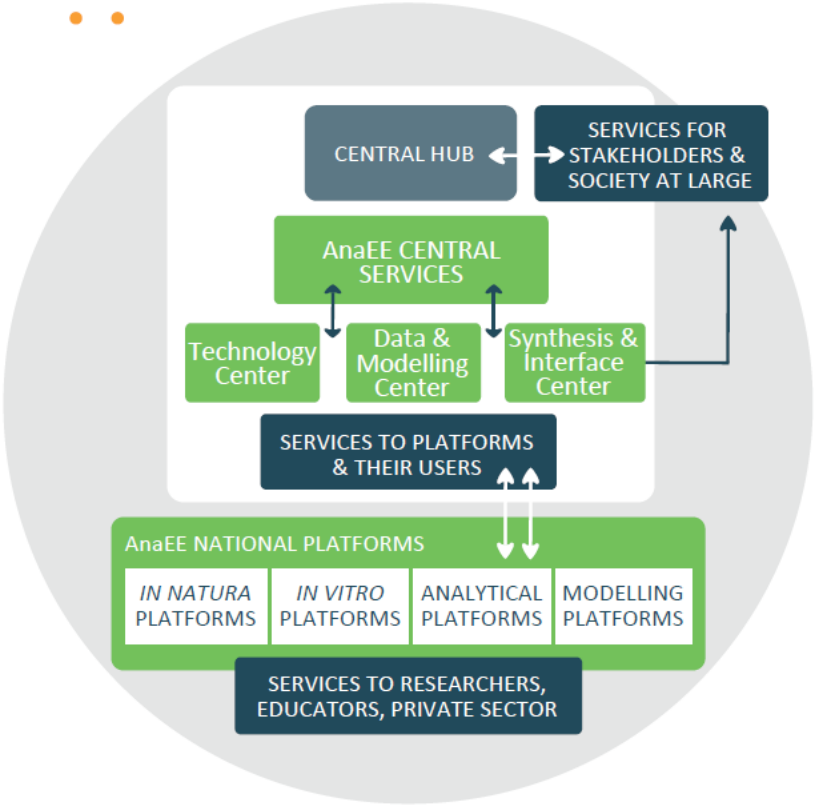
AnaEE aims to **open access to wide audiences** in both the public and private sector and be a one-stopshop for experimental ecosystem study. This will be based on a shared data and intellectual property frameworks and a single AnaEE access portal managed by our Central Hub. Our access policy work is also feeding into the development of ENVRI^{PLUS} and other upcoming projects.

INNOVATION

> In addition to obvious services to public sector researchers, AnaEE also aims to work **hand in hand with industry**. Industrial users are welcome to request access to use AnaEE's sites for pilot studies and other experiments. AnaEE also aims to build a strong innovation element build around new technologies (sensors, tools) and techniques through our dedicated technology transfer operations.

FUTURE GOVERNANCE

> AnaEE will be based on a **strong common governance structured in the form of a European Research Infrastructure Consortium (ERIC), whose members will be EU Member-States and Associated Countries**. The ERIC will be coordinated by a Director-General and a Central Hub (coordinating management, budgetary and strategic development issues, as well as the AnaEE Portal), which will oversee three Service Centres: a Data and Modelling Centre; a Technology Centre (covering technical development but also technology transfer and innovation) and a Synthesis and Interface Centre. These centres will ensure international access, improved measurements and data harmonisation, technology development, links between data and models, open access to raw data and syntheses. They will also allow researchers to network and provide an interface with key stakeholders.



INTERNATIONALTIES AND SYNERGIES

> AnaEE will work alongside, and provide synergies with, ICOS (long-term observations of the global carbon cycle and greenhouse gas emissions), as well as other European environmental infrastructures, notably through ENVRIPLUS.
> AnaEE has also signed or is negotiating cooperation agreements with NEON (National Ecological Observatory Network, USA) and TERN (Terrestrial Ecosystem Research Network, Australia).

ABOUT AnaEE

> AnaEE is a key European infrastructure that aims to help us better understand, respond to and anticipate processes such as climate change and land use changes that affect food security, natural and managed ecosystems and biodiversity across the European continent and around the world.
> AnaEE will bring together highly instrumented experimental, modelling and analytical platforms to support scientists in their analysis, assessment and forecasting of the impact of global changes.
> As of 2015, AnaEE involves 11 countries in its Preparatory Phase, and four more countries that have submitted platform proposals and may potentially join AnaEE. Our proposed platforms cover a wide range of ecosystem types and pressures.

Annex II Vision and structure of eLTER

LTER is an acronym for Long Term Ecosystem Research, and constitutes a large global network of field stations conducting long-term environmental research and monitoring. It also stands for the related long-term ecosystem research per se and the involved research community. The foundation of the network is the individual member field stations. These are organised in national LTER networks, which in turn are members of continent based mother organisations. At the highest level in the hierarchy, all LTER sites and networks are collected in the worldwide International LTER network, ILTER.

LTER-Europe is the European regional group of ILTER, consisting of 25 acknowledged national networks and 2 emerging networks (www.lter-europe.net) with LTER Sites and LTSER Platforms. LTER-Europe is permanently operated since 2007, based on formal by-laws and democratic procedures, and has been involved in numerous European projects.

eLTER H2020: The H2020 cooperation project between LTER-Europe and the European critical zone research, developing network level RI services alongside a set of exemplary analyses of data originating from 162 sites across Europe. These sites are recruited from the basic pool of LTER infrastructure organized in formal national networks and CZ projects.

eLTER ESFRI: The proposal and initiative to formalize a eLTER ESFRI research infrastructure component for multiple use by user groups such as the LTER, the Critical Zone or Macrosystems Ecology research community. ESFRI is one option for LTER in Europe, specifically at the interface with other RIs and in the field of joint service development.

The main objectives of LTER Europe are:

- to identify drivers of ecosystem change across European environmental and economic gradients;
- to explore relations between these drivers, responses and developmental challenges under the framework of a common research agenda;
- to promote the development of harmonised parameters and methods;
- to develop criteria for LTER Sites and LTSER Platforms to support cutting edge science with a unique in-situ infrastructure;
- to improve co-operation and synergy between different actors, interest groups, networks, etc.;
- to coordinate quality assured archiving and access of data.

Besides supporting scientific research in a wide range of ecosystem types (terrestrial, inland waters, transitional waters) and domains (hydrology, soil science, biodiversity, climate etc.), LTER-Europe features a strong and growing socio-ecological research component. As focal regions for research on the Human-Environment-System interactions, the LTSER Platforms provide the infrastructure for research on sustainability and ecosystem services (carbon sequestration, food security, sustainable agriculture and forestry, water supply), and inter- and transdisciplinary research facilitating close interactions with stakeholders at multiple levels (local to regional, national and continental).

eLTER H2020 and eLTER ESFRI build on and further structure the **LTER distributed in-situ infrastructure of the network LTER-Europe**, comprising about 400 formally acknowledged ecosystem research sites (65% terrestrial, 26% aquatic and 9% transitional waters LTER Sites; see Figure 1 for more details) and 35 LTSER Platforms for socio-ecological research at the regional scale.

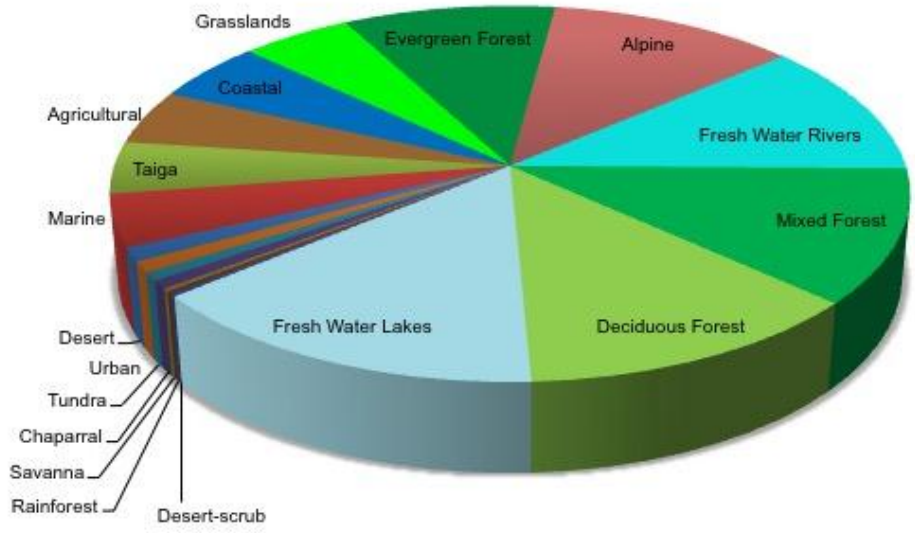


Figure 1: Overview on the biomes covered by the formally acknowledged LTER sites (excluding marine).

The infrastructures are operated by around 100 institutions. LTER-Europe has condensed research sites originally set up in varying contexts (projects and networks driven by national/institutional strategies and domain specific requirements), which focus on investigating entire ecosystems and comply with the five pillars of LTER (see above). The network is the result of a 15 years de-fragmentation and integration process of ecosystem research infrastructures in 30 countries, which resulted in formal LTER networks in 24 countries. One more country (Denmark) will formally apply for membership in 2015. All sites and national networks comply with a refined site classification (see following sections for details) reaching from highly instrumented master sites (21%), to regular LTER sites (48%), extensive/satellite (26%) and emerging sites (5%) (see Figure 2). The internal complexity of sites and level of organisation between neighbouring sites is reflected in the site types: 4% are single plots, 57% are simple sites, 40% complex sites and 9% are organized in LTSER Platforms.

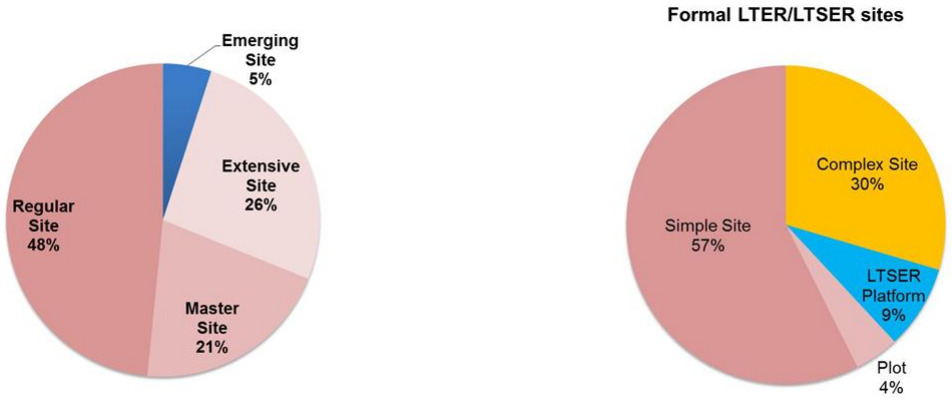


Figure 2: Overview on the distribution of site categories and site complexity of the formally acknowledged LTER sites (excluding marine).

A set of about 130 metadata attributes (installations at the sites, covered research topics, data policy etc.) in the DEIMS site documentation of LTER (see chapter **Erreur ! Source du renvoi introuvable.**) allows for the fast and objective selection of sub-sets of sites, which are suited for specific project involvements. 24 nationally LTER co-ordinating institutions are partners in different consortia, which are (1) contributing a wide range of practical experiences in infrastructure building and operation under strongly varying conditions across countries, and will (2) support the implementation of top down strategies, components and processes (e.g. by involving in national ecosystem RIs integration platforms).

i. Categories of facilities

As said, LTER site categories were introduced in 2009 and have been consistently applied to about 450 facilities. Shaping the eLTER ESFRI RI focusses on (1) the fine tuning of a modular design, which is applicable across Europe, (2) construction by drawing from extensive and documented resources in 24 countries, and (3) the identification of geographic and topical gaps, where appropriate existing sites need to be identified or new sites have to be established.

The eLTER RI will complete the coverage the socio-environmental space of Europe in a respresentative way (Metzger et al. 2010). The integrated eLTER RI features a hierarchical design with an increasing number of facilities towards the bottom of the hierarchy:

(1) Regional multi-scale and interdisciplinary case study areas (**eLTSER Platforms**), comprising multiple smaller scale elements in a spatially nested design
(2) Smaller scale ecosystem research sites (**eLTER Sites**)
    a. Fully instrumented **eLTER Master Sites** as hot spots for instrument-intensive research, ideally suited for co-location with more specific RIs, e.g. small scale experiments or specialized monitoring programmes
    b. **eLTER Regular Sites** covering major ecosystem processes to allow analyses and assessments of overall ecosystem functioning (the level of instrumentation and equipment depending on the ecosystem type and specific ecological profile of the site)
    c. Well-connected **eLTER Satellite Sites** for specific purposes (might be less equipped or extensive, but serving special purposes such as increasing coverage, enabling upscaling or monitoring larger scale processes)

(3) Design-link with large scale, representative environmental monitoring schemes.

The eLTER RI facilities will be assembled across Europe (1) in close interaction with related RIs, (2) according to regional specificities and the resulting observational/experimental design required to investigate ecosystems contained in the region of interest (see Figure 3).

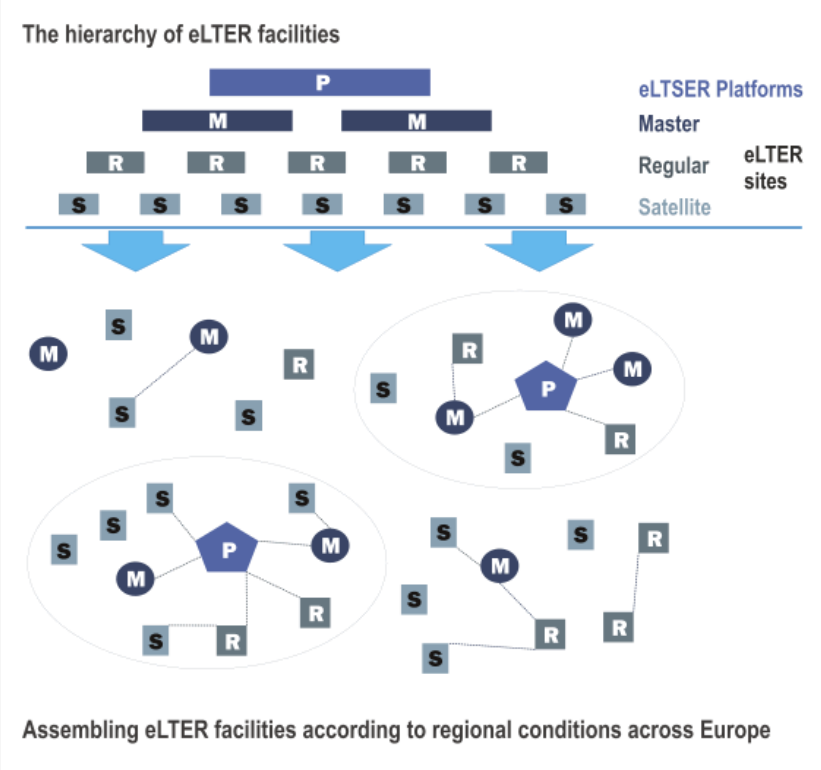


Figure 3: The spatial construction of the eLTER RI assembles elements (eLTSER Platforms, eLTER Sites (Satellite, Regular, Master) according to (1) research needs and (2) national possibilities. Overall, socio-ecological regions will be covered across Europe.

Specifically eLTSER Platforms and fully instrumented Master Sites will be further developed as integrated nodes between related or more specific research infrastructures (functional interfaces and co-location with ICOS, AnaEE) to link them up with the long-term data legacy of LTER. The *in-situ* LTER-Europe network is already complementary to e-infrastructures such as LifeWatch and EUDAT (existing MoUs about interrelations and the division of tasks). This complementarity will be detailed in the eLTER RI.

1. eLTSER Platforms: Regional multi-scale and interdisciplinary case study areas on grand societal challenges

Best examples of proof-tested approaches for multi-functional ecosystem research infrastructures supporting both natural scientific and socio-ecological research include the most advanced LTER-Europe LTSER Platforms, German TERENO sites, the French “Zones ateliers” and regional Critical Zone research approaches.

The next generation “eLTSER Platforms” of the eLTER ESFRI infrastructure will integrate these approaches.

Regionalising ecosystem, critical zone and socio-ecological research in a new kind of integrated RI, “**eLTSER Platforms**”, signifies a paradigm shift regarding the methods and goals of research. This shift is not on the level of individual research projects, but refers to

the cooperative and collective goal of developing a detailed and holistic understanding of how spatially explicit socio-ecological systems work by integrating many projects across disciplines and over long time periods. This, of course, includes the investigation of socio-economic components of the system and their interaction with the environment. The knowledge that the research aims to generate pertains to 1) sustainable use of resources and 2) development of adaptive policies for study regions whose systems are changing due to anthropogenic local and global environmental change (e.g. climate change adaptation).

The quest for this knowledge leads to one of the fundamental components of LTSER besides excellent basic disciplinary and interdisciplinary research: the two-directional flow of information between actors in the region (stakeholders) and researchers (scientists). The actors are any members of the regional population, or those who are not from the region but have a distinct interest in the region's ecosystem services. They include any individuals or groups who have a vested interest in the area under research – whether that is economic, political, or social. The role of such stakeholders in LTSER is threefold: Firstly, the subjectively perceived knowledge gaps regarding sustainable use of ecosystem services have to be collected across actor groups (which is a scientific challenge in itself) and distinguishes the two major approaches of LTSER implementation in Europe. Secondly, stakeholders assist in defining the key research questions, such that these questions are not solely generated from the scientific point of view of individual disciplines, but in the framework of an agreed interdisciplinary and stakeholder-informed research agenda. Thirdly, in order to identify realistic options and limitations for dealing with global changes (e.g. climate change) at the regional/local level, the region's social and economic environment must be identified and analysed (threshold interactions across scales and sectors, see below). This final step responds to the apparently contradictory requests for regionalisation on the one hand and internationalisation on the other, both on the continental European scale and internationally.

Developing ILTER or critical zone research global comparisons are attracting increasing interest as the LTSER approach is adopted and implemented by a growing range of networks (national LTERs and other LTER regional groups, Global Land Project). This is partly happening under different terms such as Socio-Ecological Observatories (SEO, Mountain Research Initiative) or the "Place-Based Long-Term Social-Ecological Research" advocated for by the PECS group of ICSU.

Functional components of LTSER Platforms

Analysing the challenges outlined above, key components in the design of eLTSER Platforms are: physical infrastructure, actors and stakeholders, research activities and co-ordination/management (see ***Figure 4***).

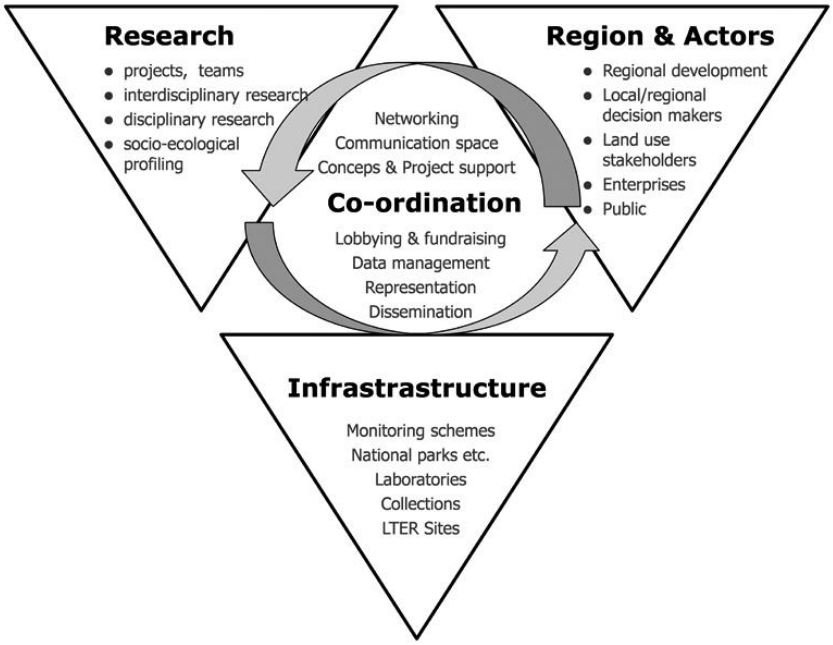


Figure 4: The functional components of LTSER Platforms

In a nutshell, eLTSER Platforms are regional hot spots of data and expertise, where infrastructure and monitoring, multiple research projects and regional stakeholders work together in order to i) increase knowledge of socio-ecological interactions relevant to sustainable use of environmental resources and ii) feed this knowledge into local and regional decision making and management in the pursuit of long-term sustainability. This implies a high level of co-ordination, embedding individual projects in a research framework and supporting them with data and relevant contacts.

The required components of eLTSER Platforms are defined according to broad research demands to represent functionally and structurally relevant scales and levels on the one hand, and characteristics specific to the region on the other. Specifically, defining the components depends on an individual region's landscape, habitat types and administrative structures, as well as economic, social and natural gradients.

The designs of eLTSER Platforms that have been established so far, (in principle) combine elements of these four functional components with varying priorities described in several chapters of part II and part III in the reference textbook on LTSER, published by Springer (Singh et al. 2013).

Physical infrastructure & spatial design

Regarding physical infrastructure, eLTSER Platforms represent clusters of facilities supporting ecosystem, socio-ecological systems and critical zone research activities and providing data. In much previous socio-ecological research, studies designed to address interactions between society and natural resources suffered from a mismatch between the observed spatial units and the related spatial scale of management and political response (Dirnböck et al. 2013). eLTSER Platforms seek to avoid these flaws by developing nested,

scale- and level-explicit designs according to comprehensive socio-ecological profiles (example below).

With respect to infrastructure, the eLTSER Platform design distinguishes between (i) grid points of regional, national or international monitoring schemes, (ii) local infrastructure, such as research centres, museums or laboratories (iii) site-level activities (eLTER Master, Regular & Satellite Sites) representing in-depth ecological research and monitoring in the region's primary habitat types, containing specific sampling or experimental plots at finer spatial scales, (iv) intermediate-scale elements such as national parks, biosphere reserves or intermediate-scale catchments, and finally (v) landscapes (

Figure *5*). The hierarchical design from the site to the landscape level and cascaded, harmonised sampling and parameter sets, enable the representativeness of individual plots or sites to be assessed. Elements belonging to higher scale activities, including national and international monitoring schemes, are functionally linked, enabling further up- and downscaling and site-to-site validation (e.g. biodiversity indicators).

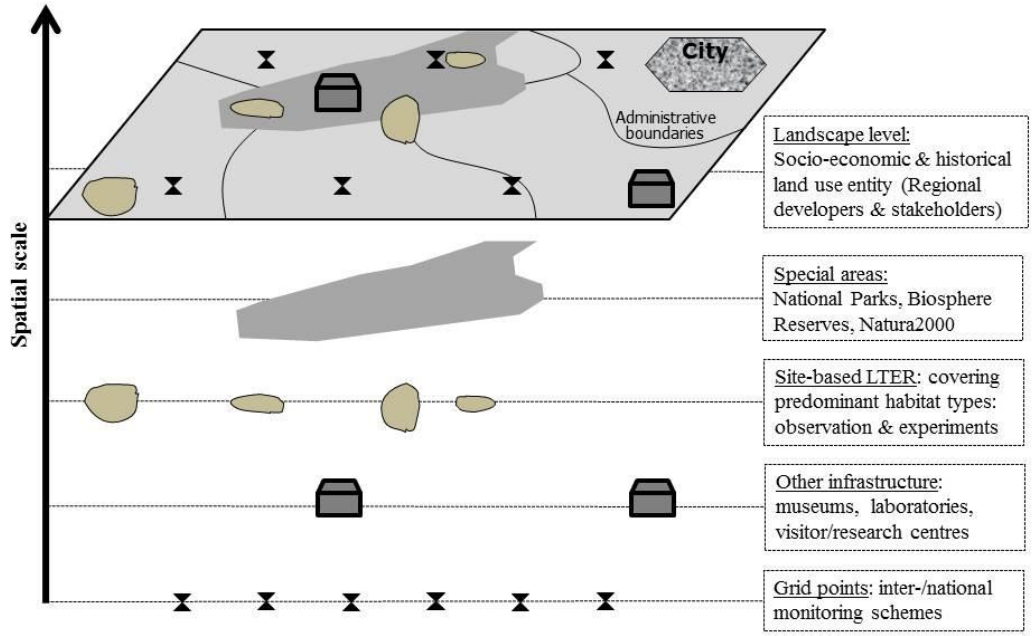


Figure 5: Infrastructural elements of eLTSER Platforms across spatial scales within a eLTSER Platform region.

The adequacy and appropriate composition of existing research infrastructures is assessed by means of land cover statistics, habitat and landscape type distributions. Environmental parameter gradients (e.g. predominant land use sectors like agriculture) should be covered by applied research on the effects of current and alternative management practices.

eLTER Sites

The main characteristics of eLTER Sites are listed below. Given the nested design, the eLTSER Platforms will host many of the eLTER Sites at the European scale. However, in order to achieve representatives of European ecosystems and geopolitical regions, the coverage of landscape scale processes and linkage to larger scale monitoring schemes, eLTER Sites will also be located outside eLTSER Platform regions.

eLTER Master Sites:

- full system approach (covering the entire ecological profile, decisive structures and functions for ecosystem processes);
- technical site designs customized according to the ecological profile, enabling integrated analyses across system strata (geosphere to atmosphere);
- covering the required spatial scales;
- time series of at least 10 years;
- permanently operated (regular/weekly sampling, continuous measurements etc.);
- inventories at appropriate intervals across ecosystem compartments;
- core basic infrastructure: permanent access, power supply, data transmission;
- highly instrumented;
- multi use: many other networks and/or related projects use the site;
- special role in the overall eLTER ESFRI context;
  - preferred nodes with other (more specific) ecosystem research RIs (e.g. ICOS),
  - experimental approaches existent, or the site design supports their co-location,
- synonyms: “top sites”, “super sites”, “LTER hubs”, “HIS=Highly Instrumented Sites”, “M-Site”.

eLTER Regular Sites:

- in principle complying with the description of LTER Master Sites (ecosystem approach);
- **they differ in the:**
  - level of instrumentation: some indicators might be measured with simpler methods,
  - multi-use and availability of long-term data across all ecosystem compartments and disciplines,
  - number of network memberships;
- special role in the overall eLTER ESFRI context,
  - increase network coverage,
  - enable countries with less available resources in the field of ecosystem research to contribute;
- synonyms: “regular LTER site”, “R-Site”, “Regular Sites”.

eLTER Satellite Sites:

- not following the full ecosystem approach (e.g. for reasons of limited spatial scale considered);
- specific scientific and/or monitoring foci;
- may emphasize the long-term monitoring (observation), but there must be an explicit research component;
- special role in the overall eLTER ESFRI context,
  - link to the landscape level,
  - RI for topics, which cannot be tackled at a small number small scale highly instrumented sites;
- synonyms: “extensive LTER site”, “E-Site”.