Chapter 6

Introducing the Next Generation of Ecosystem Research in Europe: LTER-Europe's Multi-Functional and Multi-Scale Approach

Michael Mirtl

Abstract LTER-Europe is the umbrella network for Long-Term Ecosystem Research (LTER) and Long-Term Socio-Ecological Research (LTSER) in Europe. It forms part of the global LTER network (ILTER). Comprising 18 formal national member networks and five emerging ones LTER-Europe represents more than 400 LTER sites and 23 LTSER platforms. Besides this in-situ component LTER-Europe stands for a network of scientists, disciplines, institutions, data and metadata, and research projects. The Network of Excellence ALTER-Net (FP6) provided the frame for meeting the objective to integrate the highly fragmented European infrastructure with LTER potential across national and disciplinary boarders. LTER-Europe has become the terrestrial and aquatic component in the network of networks, currently organised by the ESFRI preparatory project LifeWatch. The interdisciplinary expertise represented by the ALTER-Net consortium allowed further development of the LTSER concept. LTSER platforms have been developed as multi-scale and multi-level infrastructure for investigating interactions of human and natural systems on the regional or subregional level. These hot spots of interdisciplinary research (IDR) and data sets are now complementing the first pillar of LTER-Europe's network, the network of LTER sites. The character and functional niche of LTER-Europe is best described by four core characteristics, namely "in-situ, long-term, system and process": LTER-Europe's research is generating or using data gathered together with a maximum of other sources of knowledge at concrete locations in the long term. This allows for the detection and quantification of processes of ecosystems and socio-ecological systems, which determine the sustainable provision of ecosystem services. Summarising, LTER-Europe is a multi-functional network, but also a process structuring and optimising a distributed research infrastructure, catalysing the development of research projects meeting societal needs and helping to streamline and harmonise the entire sector on the institutional, national, European and global level.

Keywords LTER-Europe network · Socio-ecological research · LTSER · Research infrastructure · Mode 2 research · European Research Area

6.1 Introduction

This chapter aims to provide an overview of Long-Term Ecosystem Research in Europe (LTER-Europe) as an umbrella framework and a process shaping ecosystem research and infrastructure in the continent. It outlines the history of LTER and describes the environment into which LTER-Europe has been moulded. We also describe the structure and governance of LTER-Europe with emphasis on two kinds of in-situ components – LTER sites and LTSER platforms – and the role it has played in establishing and further developing the concepts for socio-ecological research. Beyond that, LTER-Europe advanced to the regional implementation of LTSER proposing and testing a novel design of multi-functional research platforms or "LTSER platforms". Given the uniqueness of this proof of concept LTSER is indeed given disproportional space, not insinuating minor importance of the

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traditional, site-based LTER, but anticipating that this component of LTER has broadly been accepted as state of the art. The representativeness of LTER-Europe's network for major environmental and socio-ecological zones will be illustrated.

An additional goal of this chapter is to highlight the multi-functional nature of LTER-Europe, which has started to serve a wide range of purposes across all levels from concrete research sites to institutions, national networks, the European Research Area, related sister networks and the global research environment. In that sense LTER-Europe can in parallel be perceived as

– A Network of LTER sites,
– A Network of LTSER platforms,
– A Network of national networks,
– A Network of institutions,
– A Network of scientists (a community),
– A Network of disciplines,
– A Network of data and metadata,
– Part of a network of European networks,
– A Network of site-based research and research projects,
– A process structuring and integrating all the above.

By creating a better understanding of the complex nature of LTER-Europe the chapter attempts to animate both the scientific community and those in charge of establishing a framework for environmental research. We highlight the wide range of added values of LTER-Europe that support a new generation of environmental science thereby contributing to a knowledge base about major ecosystem services at stake.

6.2 Definition, Terminology and History of LTER

The US National Science Foundation (NSF) established the US-LTER program in 1980 to support research on long-term ecological phenomena in the United States. The 26 US-LTER sites represent diverse ecosystems and research emphases (http://www.lternet.edu/). Supported by the powerful US-LTER and through the initiating efforts of NSF in the 1990s, 28 countries worldwide had established national LTER networks and were formally accepted as members of the global LTER network (International Long-Term Ecosystem Research, ILTER) by the end of the 20th century. "ILTER consists of networks of scientists engaged in long-term, site-based ecological and socioeconomic research. Our mission is to improve understanding of global ecosystems and inform solutions to current and future environmental problems" (http://www.ilternet.edu/about-ilter/mission). ILTER consists of continental or sub-continental regional groups. In 2001, the European Environment Agency (EEA) was formally represented at the global ILTER conference in London, advocating that Europe needed a powerful and unified continental research and monitoring network to cope with the complex challenge to better manage European ecosystems according to the "Late lessons from early warnings" report of the EEA (Gee, 2001). This report especially underpins the demand for a better link between ecosystem research and Long-Term Ecosystem Monitoring (LTEM). It openly addressed the inefficient fragmentation of European ecosystem research, including deficiencies in the analysis and synthesis of principally available information and the communication of results to better inform decision making and policy. To support the initiation of such a European LTER network, the EEA acted as a key stakeholder for the first European LTER conference, held in January 2003 in Copenhagen. Amongst other strategic efforts, the first call of the EU's 6th Framework Programme (FP6) considered LTER in combination with biodiversity as a potential Network of Excellence.

Concurrently US-LTER came under scrutiny. A review of two decades of LTER identified major challenges (http://intranet.lternet.edu/archives/documents/reports/20_yr_review/). The reviewers elaborated a list of 27 recommendations, including the necessity of efforts to establish proper interdisciplinary and cross-site projects and comparisons, focus on synthesis science, setting up a standardised and quality-assured monitoring and experimentation component, establishing informatics and cutting edge information management as core functions as well as starting to include the human dimension in LTER. Concerned with the restructuring of the US-LTER and the establishment of the high-tech sensor component NEON, the US National Science Foundation as key mentor targeted on making the global LTER network, ILTER, independent of continuous US support with American scientists holding key offices in the network. As a first step ILTER elaborated formal by-laws in 2004 (http://www.ilternet.edu/about-ilter/ILTER-bylaws-10-01-2004.pdf/view). International consultants and organisational developers were engaged in 2005 to develop a strategic and operational plan for ILTER, formally adopted by the ILTER Co-ordinating Committee in 2006 in Namibia (http://www.lter-europe.net/Structure/key-documents). ILTER had passed the first phase of establishing a permanent and globally acting institution representing the most powerful in-situ network of ecosystem research facilities. In 2007 ILTER became a legal body, registered as an international scientific association in Costa Rica. Responsibilities in the governing structures of ILTER are now evenly spread across the continental regional groups of ILTER. By the end of 2008 ILTER comprised 40 national member networks.

In the context of these positive international developments, LTER-Europe accelerated its efforts from 2004, mainly due to the activities in the Network of Excellence "ALTER-Net" funded by the European Union. Developing the concept for LTER-Europe required institutional integration and IT solutions alongside the biodiversity issue as a thematic trigger. ALTER-Net facilitated the creation of a database of 1,800 facilities with "LTER potential" across Europe. The extensive metadata collated for these facilities underpin the heterogeneity and fragmentation anticipated by earlier enquiries and reports (e.g. GTOS-TEMS). Moreover, the uneven distribution (across habitat types and environmental zones) of locations where long-term research and monitoring is carried out became apparent. Supported by the request of the European Commission for institutional integration the partner institutions of ALTER-Net started to act as stakeholders for the LTER processes in their respective countries. In parallel, ALTER-Net expanded its efforts beyond the ALTER-Net institutional consortium, succeeding in including most European countries into the LTER-Europe process. As a milestone, the former western and eastern LTER networks were merged in the course of the formal foundation of "LTER-Europe" in June 2007 in Balatonfüred, Hungary. LTER-Europe has become the most powerful regional group worldwide, since August 2008 consisting of 18 national networks (Fig. 6.1). In Europe LTER focuses on terrestrial and aquatic ecosystems. Besides being an umbrella term for activities in the field of ecosystem and environmental research, it is also the name for formal LTER networks of research sites and scientists on national and continental levels composing the global LTER Network (ILTER).

6.3 Multi-Functionality and Key Characteristics of LTER-Europe

Contrary to the setup of LTER in the United States of America a top-down approach for the infrastructural component of LTER-Europe was not feasible due to the diverse funding mechanisms of the European research area. Secondly, a research frame programme continuously supporting ecosystem and socio-ecological research projects at LTER sites and LTSER platforms cannot to be accomplished in the mid term. In contrast, US-LTER benefits from the NSF as key stakeholder and funding body securely providing resources for both, infrastructure and scientific LTER projects, for a network of 26 LTER master sites and with a time horizon of decades. Consequently, the design of LTER-Europe, its infrastructure, governance and related research projects had to take extremely heterogeneous framework conditions into account, including varying initial situations across countries in terms of involved stakeholder institutions, national research programmes and divergent possibilities in former East and West European countries. Another challenge consisted of the conceptual expansion of LTER to LTSER, dealing with entire socio-ecological systems and inducing a transformation of the scientific community and interest groups that had so far been involved in and carrying the traditional LTER. We discuss this later in more detail.

LTER-Europe was developed into an intricate landscape of European and national environmental monitoring schemes and nature conservation measures such as the UNECE International Co-operative Programmes, the UNESCO Biosphere Reserves and Natura2000 concerning their site networks, databases, responsible institutions and overlaps with environmental research. It has become a key element in the restructuring of the European research area in the field of life sciences (see below).

Consequently, LTER-Europe could not exclusively focus on single research topics, disciplines, administrational and economic levels, funding schemes, stakeholders, processes, or on infrastructure or research projects alone. It needed to serve multiple purposes

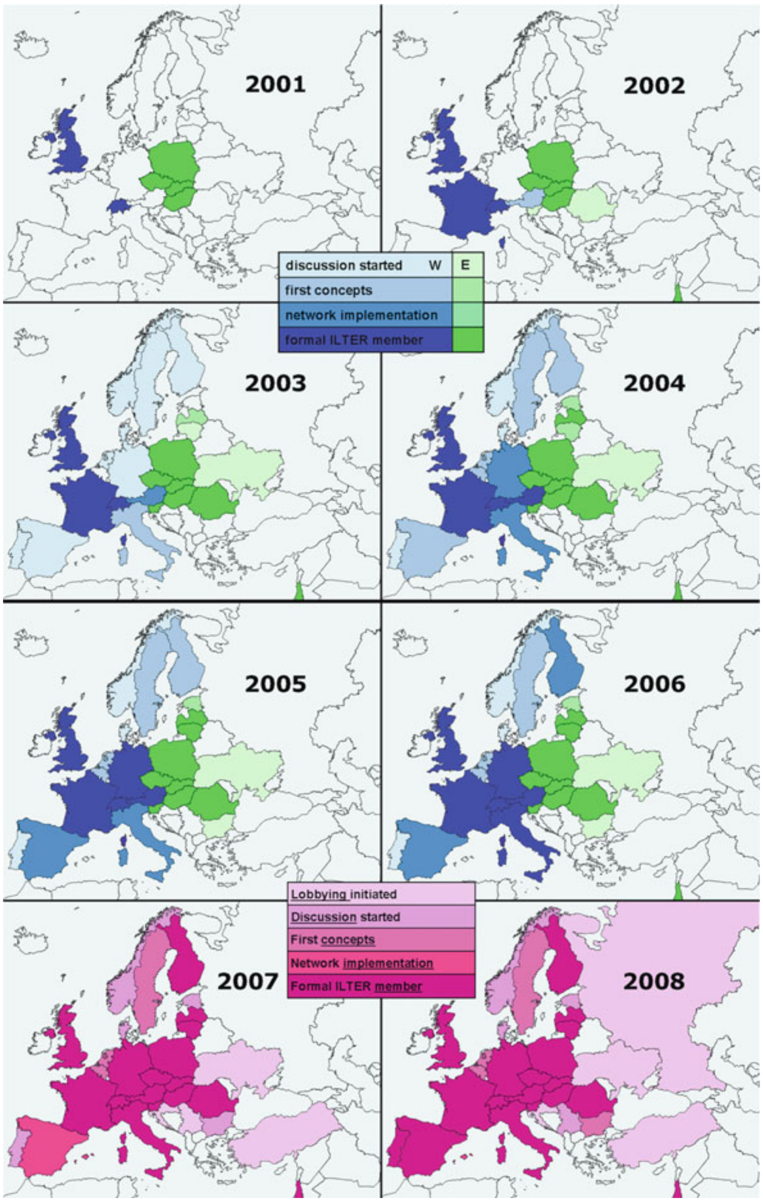

Fig. 6.1 Development of LTER-Europe 2001–2008; depths of colours indicate the level of formalisation with darkest colours for formal membership in the global LTER; in 2007 the former Eastern and Western networks were merged at the formal foundation of LTER-Europe (graph: M. Mirtl: http://www.lter-europe.net/Structure/key-documents)

and support a wide range of issues related to environmental research. Because of the general nature of a research infrastructure and research network like LTER-Europe, it was indispensable for LTER-Europe to identify the core characteristics and identity, thereby differentiating LTER-Europe from other networks. The identity of LTER-Europe is thus based on four characteristics:

In situ: LTER-Europe generates field data at different scales (up to the regional scale) and across ecosystem compartments. LTER projects make use of these interdisciplinary data hot spots, enhancing them with their own findings, but must not all necessarily gather raw data themselves.

Long-term: LTER-Europe dedicates itself to the provisioning, documentation and continuous use of long-term information and consistent data on ecosystems. The time horizon is decades in order to enable detection of trends. The long-term criterion accounts for the interdependency of LTER with the Long-Term Ecosystem Monitoring (LTEM), which is regarded as one of the most important but also most challenging aspects in establishing and securing sustainable LTER. It also requires complex information management to enable multiple and efficient use of data.

System: LTER-Europe contributes to a better understanding of the complexity of natural ecosystems and coupled socio-ecological systems, covering – as a network - the natural sphere of causation as well as the cultural sphere of causation (Fischer-Kowalski & Weisz, 1999). The typology of facilities of LTER-Europe (LTER sites and LTSER platforms) complies with the required disciplinary components, spatial and timescales.

Process: LTER-Europe's research aims at the identification, quantification and interaction of processes of ecosystems driven by internal and external drivers. The focal question is how these processes determine ecosystem services. This implies a scientifically sound combination of long-term monitoring (dynamics of state variables), research based on long-term data and short-term experimentation, covering all abiotic and biotic components of habitats and ecosystems across Europe's environmental and socio-ecological gradients.

As shown in Fig. 6.2 themes can be identified that benefit from being studied using a long-term process approach in an in-situ system (e.g. ecosystem services, climate and land use changes, biodiversity).

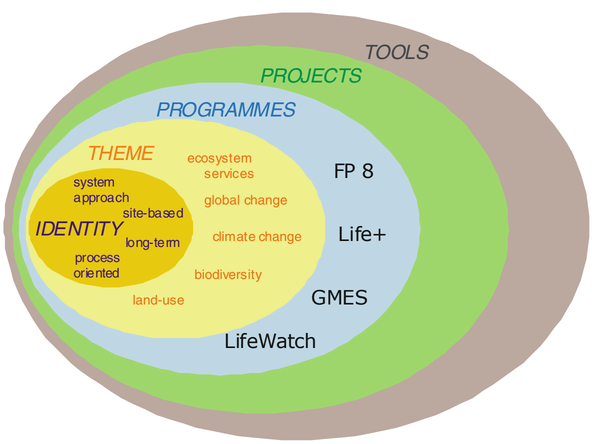

Fig. 6.2 The cascade spanning from the core characteristics of LTER-Europe to concrete projects at LTER sites and LTSER platforms and tools (graph: E. Groner: http://www.lter-europe.net/Structure/key-documents, modified with permission)

Specific programmes and projects on the continental (and global) scale, assigned to those themes and using a wide range of tools, have access to synergies enabled by LTER-Europe (comprising access to data, infrastructure in the field, laboratories and local teams of researchers etc).

6.4 The Integrated Network of LTER Sites and LTSER Platforms

LTER-Europe comprises two types of in-situ facilities, LTER sites and LTSER platforms, the primary difference being their spatial extension and structural complexity (Mirtl & Krauze, 2007). *LTER sites* extend over hundreds of hectares whereas *LTSER platforms* represent landscapes of thousands of square kilometres where natural, social and economic processes are intrinsically coupled. Therefore, LTER sites can be dominated by only one habitat type (e.g. grassland, forest) but the regions of LTSER platforms contain all elements of the landscape pattern, within the respective socio-environmental zone. Many of the LTER-sites were delineated to represent orographic and ideally also hydrological micro-catchments to allow for research related to matter and energy balances and hydrology; LTSER platform regions are or contain hydrological meso-catchments. As facilities for integrated system research both LTER sites and LTSER platforms represent a physical, logistical and research component, all of them being much more complex in the case of LTSER platforms (see below: The Design of LTSER Platforms). Activities at LTER sites concentrate on small-scale ecosystem processes and structures with core topics in the field of primary production, population ecology of selected taxonomic groups, biogeochemical cycles, organic matter dynamics, disturbances and – implicitly – biodiversity. LTSER platforms allow for investigating complex socio-ecological phenomena such as biodiversity conservation in the landscape context, including the influence of people's perception of biodiversity on decision making and the overall effects of biodiversity conservation measures in and outside protected areas. In Europe LTER has up to now focused on terrestrial and aquatic ecosystems. *LTER-facilities* are the umbrella term for wherever LTER might take place (location) and whatever might

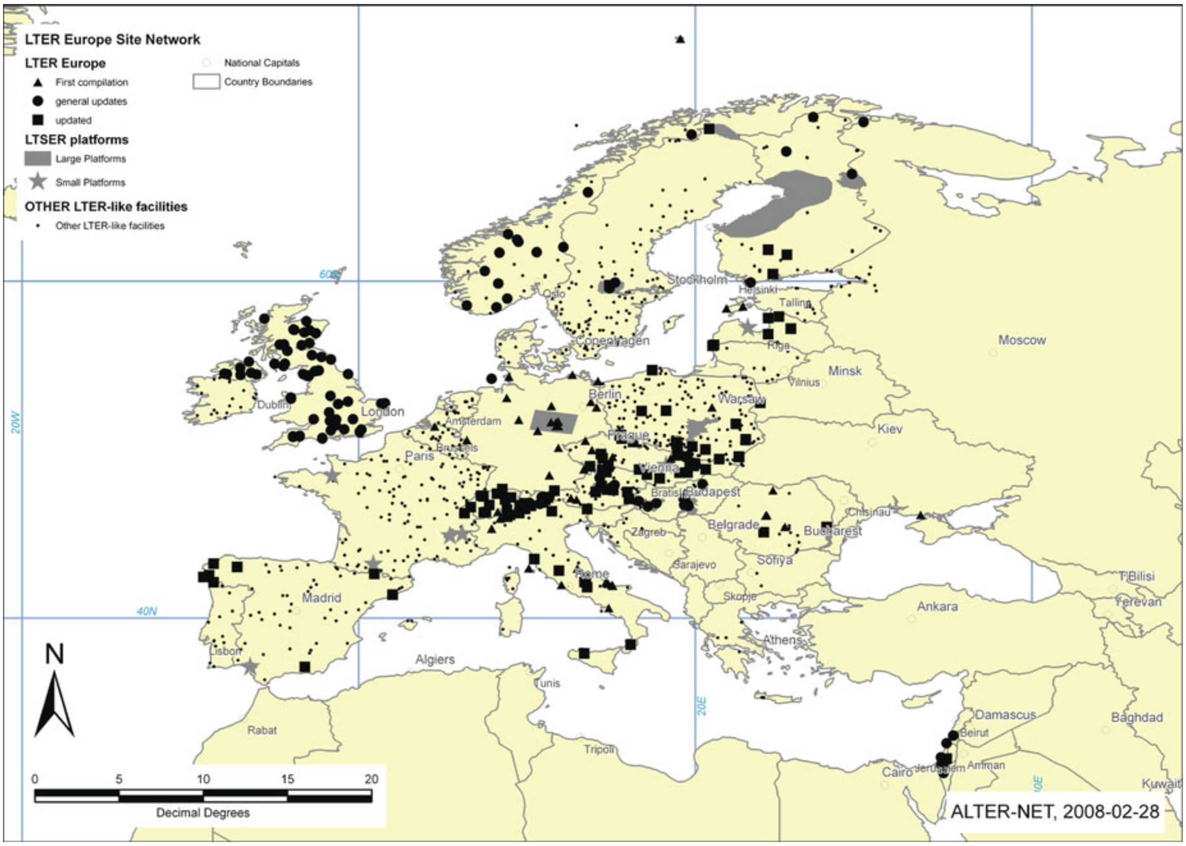

Fig. 6.3 Location of 406 LTER sites and 23 LTSER Platforms in Europe (graph: J. Peterseil: http://www.lter-europe.net/Structure/key-documents)

facilitate LTER-activities (e.g. logistics, laboratories, on-site supporting institutions). Figure 6.3 shows the location of 406 LTER sites and 23 LTSER Platforms in Europe.

6.4.1 Introducing the LTSER Component

Since the beginning of the 21st century existing national and continental networks for Long-term Ecosystem Research (LTER) underwent major reviews in a direction that emphasised more focus on their relevance for society, the efficiency of knowledge dissemination and adequacy of current designs to tackle urgent political questions many of which are related to the sustainable use of ecosystem services and the effects imposed on them by Global Change (Hobbie, Carpenter, Grimm, Gosz, & Seastedt, 2003).

The concept of LTSER platforms evolved in response to that demand implying the expansion of the traditional LTER approach. Important drivers and pressures and their impacts cannot be comprehensively investigated on the spatial scale of hundreds of hectares, even if a network of hundreds of sites of that scale covering Europe's environmental zones is available (e.g. the effects of agricultural subsidies on management practices and biodiversity on the landscape level). Moreover, to support fundamental research on ecosystem processes in the long-term the selection of locations for traditional LTER sites was biased in favour of natural or semi-natural ecosystems (Metzger et al., 2008). Thus, the characteristics of the LTER-facilities as well as the disciplines involved in research do not suffice to appropriately investigate socio-ecological systems (Redman, Grove, & Kuby, 2004). This has become a bromide since first stated in the course of evaluating and restructuring ecosystem research and ecosystem research infrastructure in the late 1990s (e.g. US-LTER review; http://intranet.lternet.edu/archives/documents/reports/

20_yr_review/). Since then even in studies designed to address complex interactions between society and natural resources mismatches between the observed spatial units and the related spatial scale of management as well as the level of political actions were detected (Dirnböck et al., 2008). This resulted in the request for a new-generation of LTER considering the human dimension in a scale- and level-explicit design and thus signalling the transition towards Long-Term Socio-Ecological Research or LTSER (Haberl et al., 2006; Chapter 26).

But *developing the framework for LTSER* needs to take a wide range of components into account, ranging from the underlying concepts to the challenge of developing the common language indispensable for proper interdisciplinary research (Kaljonen, Primmer, De Blust, Nijnik, & Külvik, 2007). Identifying appropriate regions and physically implementing LTSER has been revealed to be a major long-term effort, which strongly requires a shared vision and division of tasks on the European scale. The Network of Excellence ALTER-Net (FP 6) provided a frame for meeting the addressed challenges and integrates the strengths of the existing, but extremely fragmented LTER infrastructure on the site level. The interdisciplinary expertise represented by the ALTER-Net consortium allows further development of the main pillars of LTER-Europe's network, the now integrated networks of LTER sites and LTSER platforms.

At the network level the *strategic research intention of the LTSER component* is to establish a tool for building socio-ecological research capacity across Europe. The major socio-ecological systems of the continent shall be represented by at least one LTSER platform each, where exemplary research can efficiently take place, including the participation in assessments and forecasts of changes in structure, functions and dynamics of ecosystems and their services, and defining the socio-economic and socio-ecological implications of those changes. LTSER platforms are also to define and address key management issues according to complex local and regional settings – cultural and social values and expectations, economic conditions and constraints, inherent biophysical capacities, and impacts of internal and external factors. Finally, LTSER platforms will test and further develop tools and mechanisms for the communication and dissemination of knowledge across cultural and societal gradients.

LTSER is context-driven, problem-focused and interdisciplinary. It involves multi-disciplinary teams brought together for short periods of time to work on specific problems in the real world. Gibbons et al. (1994) labelled this *mode 2* knowledge production as opposed to traditional research (*mode 1*), which is academic, investigator-initiated and discipline-based knowledge production. So mode 1 knowledge production is investigator-initiated and discipline-based while mode 2 is problem-focused and interdisciplinary. *LTER-Europe provides an integrated framework for both types of knowledge production*.

6.4.2 The Design of LTSER Platforms

The required elements of LTSER platforms are firstly derived from the need to represent functionally and structurally relevant scales and levels. Secondly, the choice of elements of LTSER platforms depends on the characteristics of individual regions with regard to their landscape, occurring ecosystem types and administrational structures as well as economic, social and natural gradients within the target region. Nevertheless, the design of LTSER platforms in principle distinguishes *three functional layers* to which all elements can be assigned: (i) physical infrastructure comprising in-situ research sites, technical infrastructure like power supply and sensors, laboratories, sites of sectoral monitoring networks, collections, museums, visitor centres; (ii) research itself in the sense of research projects and a pro-active involvement of the research communities on the regional, national and international level and (iii) integrative management serving as the interface between all the above elements and providing services to enable efficient research and dissemination of results (Fig. 6.4).

Regarding the *physical infrastructure* LTSER platforms represent clusters of facilities supporting LTER activities and providing data. Ideally, we propose to distinguish between (i) site-level activities representing in-depth ecological research in quantitatively relevant habitat types, containing specific sampling plots, (ii) intermediate-scale elements such as national parks, biosphere reserves or investigated meso-catchments and finally (iii) the region as such (Fig. 6.5). Nested designs from the site- to the landscape levels and cascadedly harmonised sampling and parameter sets

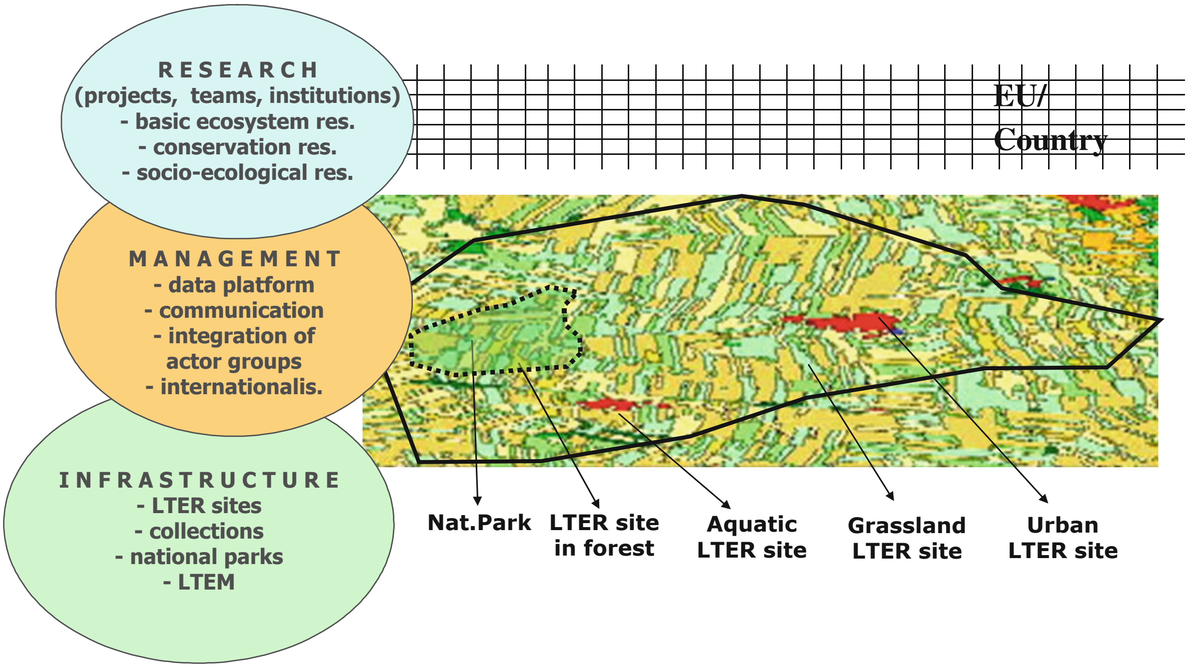

Fig. 6.4 The functional layers of LTSER platforms (*left*) and exemplary infrastructural elements according to landscape composition (graph: M. Mirtl: http://www.lter-europe.net/Structure/key-documents) (Mirtl et al., 2009)

enable the systematic assessment of the representativeness of individual elements for their vicinity. Elements belonging to bigger scale activities, including national and international monitoring schemes, are functionally linked for further up- and downscaling and crosswise validation (e.g. biodiversity indicators).

By means of land cover statistics, habitat and landscape type distributions and environmental parameter gradients the adequacy of existing research infrastructure is assessed (e.g. dominating land use sectors like agriculture ought to be covered by research on the effects of current and alternative management practices).

LTSER platform management: In order to achieve a scale and level explicit design the levels of administration, decision making and management impacting

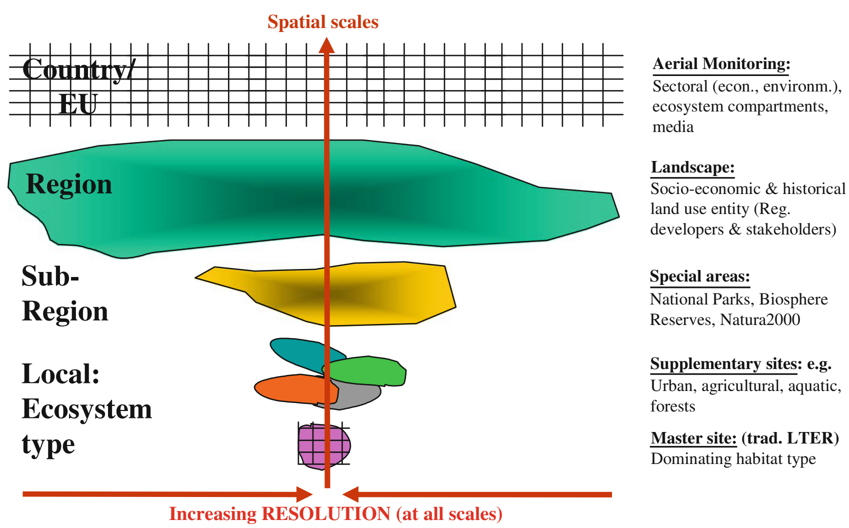

Fig. 6.5 Infrastructural elements of LTSER platforms across spatial scales within a LTSER platform region (graph: M. Mirtl: http://www.lter-europe.net/Structure/key-documents) (Mirtl et al., 2009)

the area at different scales are identified, differentiating between internal and external drivers. Socio-ecological profiling reveals key ecosystem services, environmental and economic compartments and societal factors driving the system. An actor analysis identifies the corresponding interest groups engaged in regional and local decision making, management, administration, regional development, education, monitoring and research itself, as well as stakeholders of dominating economic and land use sectors. Only interactive involvement of these key groups allows for the identification of research demands as regionally perceived. One of the processes LTSER platforms support is reconciling national and international top-down research strategies with bottom-up necessities of nature protection, regional development, environmental reporting, and the assessment of abatement strategies.

LTSER and LTSER projects in the proper sense mediate between strategies and requirements. Non-scientists should be involved in the definition phase of projects and the re-translation of scientific findings into guidelines for administration and management. Transdisciplinary and participatory approaches play an important role in the dissemination of knowledge and educational efforts to change behaviour where scientific findings recommend so. Accessory re-translation and implementation projects have access to other funding sources than research itself (e.g. LEADER, LIFE+, Interreg). All the above implies the necessity of establishing a multi-dimensional communication space considering a wide range of idioms spoken across actor groups of the same mother tongue. The same is true for science when it comes to the required data access and data flows. Without central facilitation the efforts for provisioning required data for complex LTSER projects alone would exhaust projects, even if these data were freely available.

It is obvious and has broadly been accepted that LTSER requires a *platform management* secured in the long term and providing a wide range of services deducible from the outlined work and communication flows. Amongst these services are:

– Conceptual work
– Project development
– Networking across interest groups, disciplines and stake holders
– Communication (inter- and transdisciplinary communication space, WEB site etc.)
– Data integration and policy
– IT-Tools
– Representation (nationally, internationally)
– Public relations
– Lobbying
– Fund raising

The management cares for an open communication space including the implementation of trans-disciplinary and participatory approaches necessary to adopt research agendas to regional and local needs and for achieving access to and involvement of the regional population, key stakeholders and decision makers, all of whom can be seen as beneficiaries of the knowledge produced. Moreover, the management stands for a modern data policy and quick data exchange based on cutting-edge IT solutions for data integration (ontologies, tools for semantic mediation, disperse data sources). The research component of LTSER platforms has been described with the concept above.

6.4.3 Representativeness and Coverage

LTER projects scrutinise ecosystems in an exemplary way, assuming comparability of basic mechanisms in similar environments. The functional integration of LTER and sectoral monitoring schemes (water, air, biodiversity) set up with the ambition of probabilistic sampling in order to achieve reliable trend information, allows for empirical estimates of what LTER sites and LTSER platforms represent. Even though Long-Term Ecosystem Monitoring (LTEM) on the site- and platform level indispensably complements LTER-Europe's ecosystem research projects, the mission of LTER-Europe does not comprise providing representative information on ecosystem trends with full aerial coverage on the continental scale.

Hence, all European environmental zones must be represented by LTER sites covering the natural gradients within these zones. But the distribution of LTSER platforms needs to reflect the variation induced by humans, for example through land management, pollution and other disturbances. The extent and the ways in which humans influence the environment differ greatly, as do their impacts on ecosystems (Reid et al., 2005). Redman et al. (2004) give a list of socio-economic patterns and processes that influence ecosystems. Economic power and human population pressure form the basis of the majority of environmental pressures (Ehrlich & Holdren, 1971; Dietz & Rosa, 1994) whereas several stratifications of the European biogeophysical environment have been provided (Metzger, Bunce, Jongman, Mücher, & Watkins, 2005; Metzger, Leemans, & Schröter, 2005), LTER-Europe required a complementary stratification of socio-ecological regions of the continent in order to support the construction of its network of LTSER platforms. The ALTER-Net project elaborated the LTER Socio-ecological regions (LTER-SER) of Europe with a 1 km^2 resolution, delineating 48 European socio-ecological strata (Metzger & Mirtl, 2008). The data set is based on the Environmental Stratification of Europe (EnS) (Metzger, Bunce, et al., 2005; Jongman et al., 2006), a biogeophysical stratification developed using multi-variate clustering of largely climatic variables.

The EnS was combined with a newly developed socio-economic stratification based on an economic density indicator in order to overcome both the limitations in data availability at the 1 km^2 resolution across Europe and in distortions caused by using administrative regions (termed Nomenclature d′Unités Territoriales Statistiques (NUTS) regions). The economic density indicator, defined as the income generated per square kilometre (€ km^{-1}), can be mapped at a 1-km^2 spatial resolution. Economic density forms an integrative indicator that is based on the two key drivers that were identified above: economic power and human population pressure (Metzger, Bunce, van Eupen, & Mirtl, 2009). The indicator, which has been used to rank countries by their level of development (Gallup, Scach, & Mellinger, 1999; Sachs, Mellinger, & Gallup, 2001) can be considered a crude measure for impacts on the environment caused by economic activity (Radetzki, 2001).

As LTSER platforms are still scarce, each national decision on a new platform can close major gaps in the network (Fig. 6.6). In order to promote decisions in favour of an optimised division of tasks within the

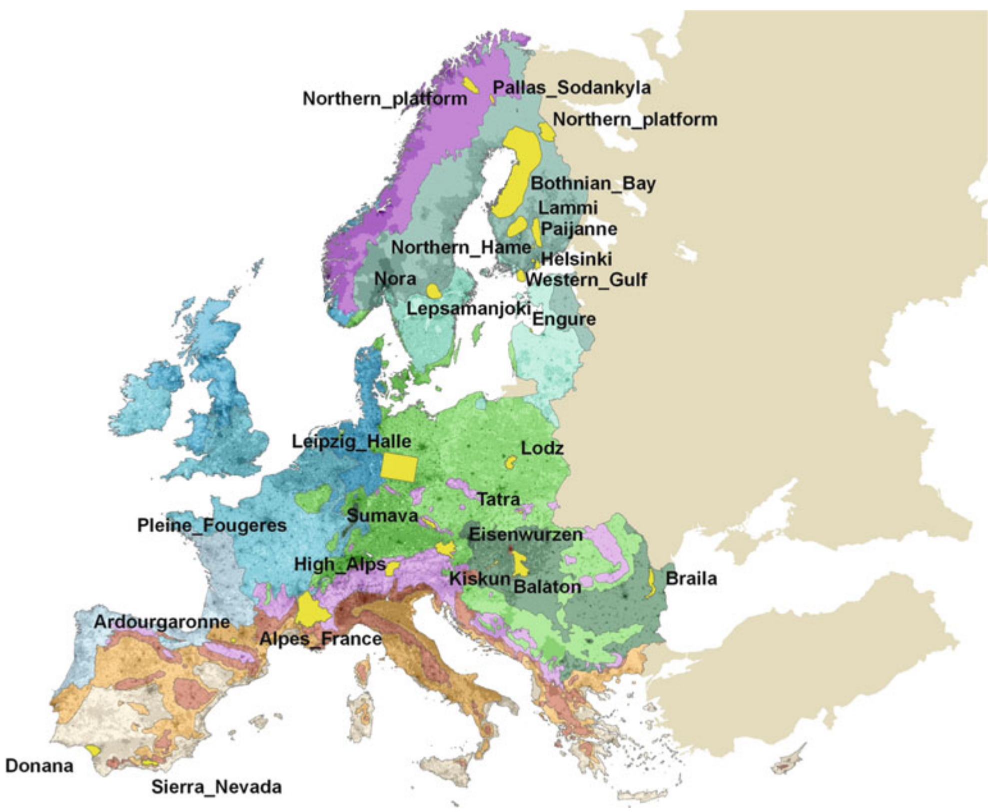

Fig. 6.6 The detailed pattern of 48 LTER Socio-Ecological Regions of Europe with 23 LTSER platforms, including five preliminary platforms (Metzger et al., 2009; ALTER-Net; with permission)

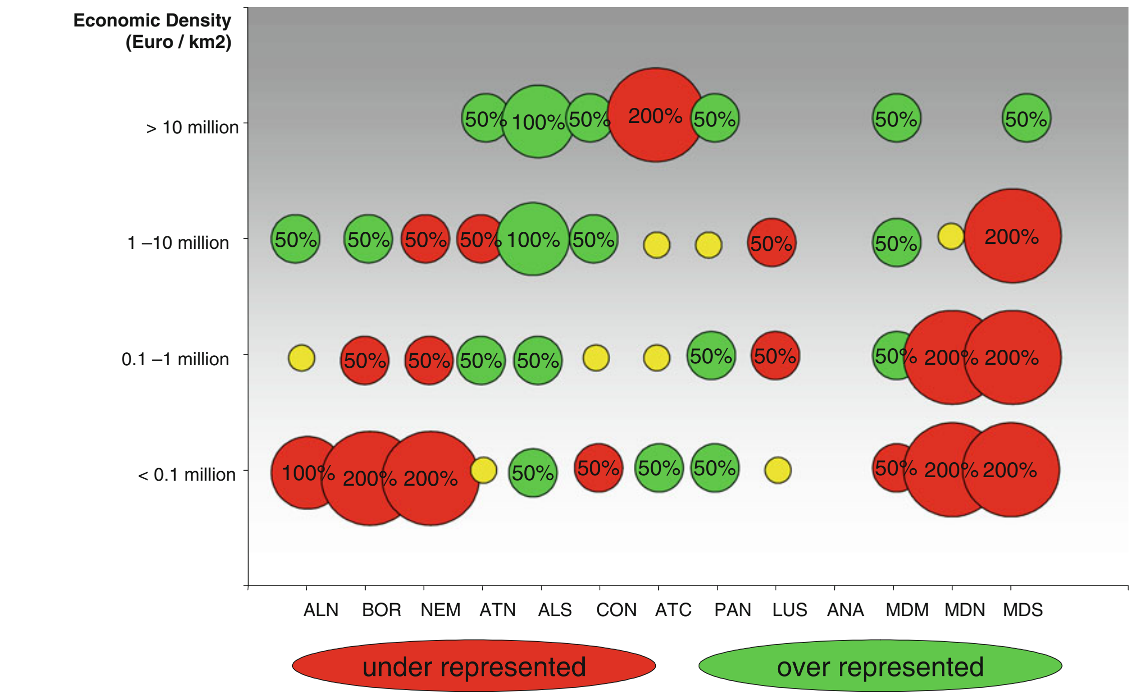

Fig. 6.7 Representativity analysis of Europe LTER facilities with European environmental zones (EnS) on the *x*-axis, from Atlantic north (*left*) to Mediterranean south (*right*); *dark/red* = under-represented; *light/green* = over-represented; *yellow/dots* = proportionally represented (Metzger & Mirtl, 2008; ALTER-Net; with permission)

European Research Area, a representativeness analysis was conducted disclosing environmental and socio-ecological zones over-, under- and proportionally represented by LTER facilities (Fig. 6.7).

The analysis shows two strong biases in the present LTER effort. Firstly, urban and disturbed regions, where humans interact most directly with nature, are consistently underrepresented, illustrating a bias for traditional ecological research away from human activity. Secondly, the Mediterranean, for which some of the most extreme global change impacts are projected, is receiving comparatively little attention. Both findings can help guide future investment in the European LTER network – and especially its LTSER component - to provide a more balanced coverage.

6.4.4 Implementing LTSER Platforms

The process outlined below has been developed and tested at a small number of LTSER platforms which were proposed by the FP 6 NoE ALTER-Net in 2006, especially the Austrian LTSER Eisenwurzen, the Finnish LTSER platforms, LTSER Donana in Spain and LTSER Braila Island in Romania. LTSER Eisenwurzen, where the implementation started in 2004, served as exemplar and basis for the training of LTSER platform managers.

According to the rules and governance of LTER-Europe the national LTER networks are responsible for choosing their LTER sites and LTSER platforms in the respective countries. LTER-Europe provides a framework to assist in national network building and decision making. Under the auspices of ALTER-Net a set of criteria for LTER networks, LTER sites and LTSER platforms have been developed since 2005 and was formally adopted in 2008 (Technical report on LTER-Europe Criteria: http://www.lter-europe.net/Structure/key-documents).

LTSER platforms contain clusters of LTER facilities located in the defined LTSER platform regions. The development of LTER-Europe was, on the request of the European Commission, to be based on existing infrastructure wherever possible. The first step in deciding potential areas for LTSER thus capitalises on inventories of existing infrastructure on the national level such as LTER sites, well-equipped sites of ecosystem monitoring schemes, protected areas, National Parks, Biosphere Reserves etc. Once, existing hot spots have been identified further decisions ought to consider (i) the LTER-Europe criteria for LTSER platforms (comprising aspects of infrastructure, data and data availability, access to key actor groups and streamlined activities), (ii) the scientific interests and strengths of the national research communities and (iii) the importance of the environmental zone the area represents (economy, ecosystem services). From the European perspective national networks are expected to help improve the coverage of the network as well as possible. All environmental zones (EnS) and socio-ecological regions (LTER-SER, see above) should be represented by LTER sites and LTSER platforms and the LTER facilities would ideally be evenly distributed over these zones. As mentioned, LTSER platforms are still scarce. Therefore, each national decision on a new platform can close major gaps in the network. The coverage of European LTER facilities across 48 socio-ecological strata was tested. LTER-Europe also provides country-specific analyses and maps to promote decisions in favour of an optimised division of tasks within the European Research Area.

Following the decision on the location of a new LTSER platform a range of analyses are done as a basis for further steps, aiming at the identification of

- dominant habitat and land use types to be dealt with by research facilities in the LTSER region,
- levels of decision making, administration and management affecting the region (provincial governments),
- actor groups to be considered in the LTSER platform consortium,
- existing data and other information on the region (environment, economy, administration, demography etc.),
- existing communication structures within the region, especially with respect to regional development and knowledge dissemination,
- prevailing human-caused pressures on ecosystems and conflicts on the use of natural resources,
- prevalent ecosystem services and their link with regional economy,
- environmental, economic and demographic gradients within the region.

In many of the LTSER platforms, consortia of those who control the major regional monitoring and research infrastructure form the core group promoting and implementing LTSER platforms. As their mission usually stretches over decades they offer ideal settings for hosting the LTSER platform management. Ideally the platform management is funded by the main beneficiaries of its services, namely the generation of better knowledge for local decision making and management (territorial authorities) and a unique framework for socio-ecological science (research funding agencies). Through promotion campaigns, workshops and bilateral information the LTSER concept and plans for its implementation in a new area are advertised in all relevant communities in order to build the LTSER platform consortium committed to by a Memorandum of Understanding (MoU), which should address the scientific and practical goals, governance structure and data policy of the platform. According to the respective MoU the LTSER platform management sets up services listed in the section above on LTSER platform design.

An alternative approach to the management of the research of a LTSER platform is to start from the bottom in a project-oriented way. Here various institutions develop the strategy for the research and plan the research activities jointly and – if possible – build the monitoring necessary for the research raised in the strategy. This approach is beneficial especially in the context of LTSER where innovations in carrying out research are required. The risk involved in the top-down approach is that the old traditions around ecological research will dominate the framing of the research which does not open space and build motivation for other disciplines to enter the LTSER research arena.

A crucial step in building LTSER platforms consists of the spatial delineation of the LTSER region. As empirical socio-ecological research capitalises on data and information from different realms these data need to refer to the same spatial units. In most cases the best available economic and census data are provided with a resolution on the level of municipalities. Municipal boundaries are self-evident borderlines for LTSER platform regions. Problems arise when ecological and social borders do not match. Preferably, the platforms provide a buffer zone to exclude this problem.

The LTSER platforms established so far vary considerably in composition, size and targets. Whereas some follow an integrated regional approach considering the entire policy cycle from user-oriented knowledge generation to management and political measures, others still are rather clusters of site-based research concentrated in a specific area. But there is clear evidence of a trend towards integrated approaches. As pointed out earlier, only structured access to key groups in the regions allows for the identification of research demands as regionally perceived and the dissemination and putting into practice of research findings.

6.5 Network of National LTER Networks

LTER-Europe consists of 18 national LTER networks in Austria, Czech Republic, Finland, France, Germany, Hungary, Israel, Italy, Latvia, Lithuania, Poland, Portugal, Rumania, Slovenia, Slovakia, Spain, Switzerland and the United Kingdom. In about eight more countries LTER networks are under development, ranging from the establishment of key contacts or stakeholders for a national LTER process to current final steps toward formal recognition. The current coverage of LTER-Europe is given in Fig. 6.8.

Each adopted national network has been established according to the national peculiarities regarding organisation and funding of research projects, institutions and infrastructure. Nonetheless LTER-Europe achieved comparable overviews of the respective national organisation in the form of "National LTER Mind Maps", mapping key network elements (stakeholders, institutions, LTSER platforms, LTER sites) and their relations (www.lter-europe.net). The mind maps contain references to the contact persons of each element. LTSER platforms and LTER sites are also linked with the LTER-Europe InfoBase. Key data on national LTER networks are annually reported through a LTER National Standard Report. The contents of these reports are mirrored in WEB pages interlinking the LTER-Europe WEB site with national LTER WEB sites, providing a comparable overview.

LTER-Europe and the national LTER processes have been key to issues of ecosystem research and related infrastructural requirements in almost all European countries. Since forest dieback research lost importance in the mid-1990s and environmental monitoring faced extensive economies hand-in-hand with declining public concern about environmental issues the strategic effort of the European institutions was to reorganise and integrate the distributed and fragmented LTER support avoiding an irrevocable loss of infrastructure, expertise and data.

6.6 Governance of LTER-Europe

A major goal of ALTER-Net was to create a permanent LTER network in Europe. This was achieved by establishing LTER-Europe as a regional group of the global LTER and adopting a governance structure in the LTER-Europe bylaws (http://www.lter-europe.net/Structure/key-documents). Each formal national LTER network is represented in the LTER-Europe Co-ordinating Committee (CC) as the central decision-making body. To actively include countries with LTER networks under development the National Networks Representatives Conference (NNRC) was set up as a platform for all countries with LTER.

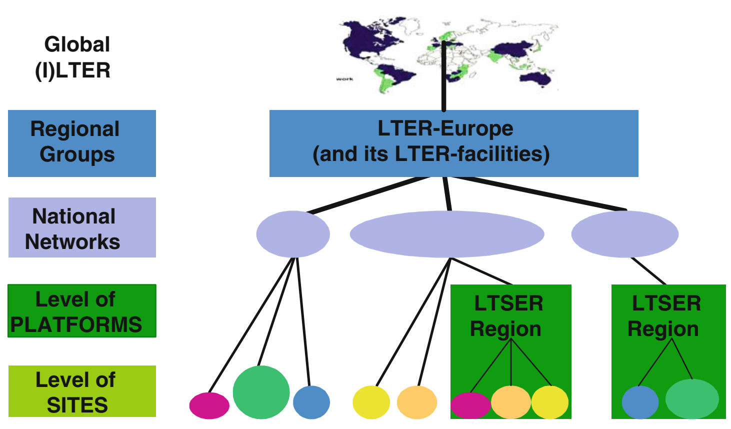

Fig. 6.8 Hierarchical organisation of LTER through national LTER networks. Not all national networks feature both LTER sites and LTSER platforms (graph: M. Mirtl: http://www.lter-europe.net/Structure/key-documents)

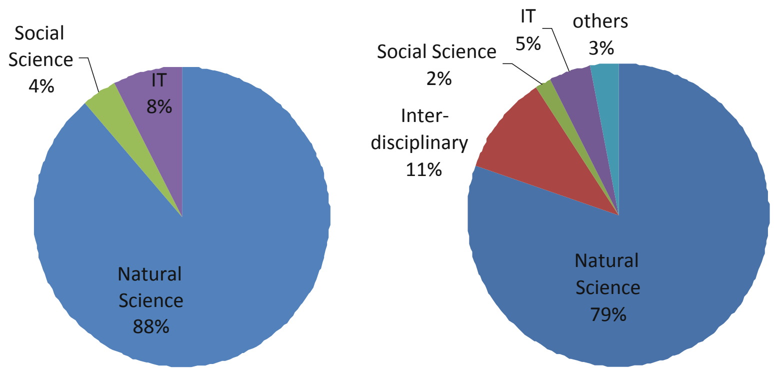

Fig. 6.9 Disciplinary background of LTER experts participating in the annual LTER conferences 2007 (*left*) and 2008 (*right*) (graph: M. Mirtl: http://www.lter-europe.net/Structure/key-documents) (Mirtl et al., 2009)

The continuity of LTER-Europe strongly depends on the group of experts co-ordinating LTER sites and managing LTSER platforms across the continent. This community is organised as the Scientific Site Coordinators Conference (SSCC). Annual LTER-Europe conferences are held to bring all bodies together. To secure key services and cover major scientific and technical aspects of the network, LTER-Europe Expert Panels (EP) were set up, comprising science strategy, communication, standardisation and harmonisation, technology, information management, LTSER and IDR as well as site management.

6.7 Network of Scientists and Disciplines

The modified scope of LTER implied changes in the composition of the involved scientific communities. In the initial phase of LTER-Europe only natural scientists carried the process. Because of the early agreement on improving information management and efforts to structure and collect metadata on LTER facilities and data IT experts joined the community. Despite a broad consensus on the necessity of a strong LTSER component in LTER-Europe it took several years until the disciplinary background of LTER experts started to reflect this fact. Figure 6.9 gives the share of disciplines of participants of major LTER conferences in 2007 and 2008.

6.8 A Network of Data and Metadata

The overarching goal “LTER” of the FP 6 NoE ALTER-Net has given information management high priority. The functionalities required to support the integrated and interdisciplinary approach outlined above were conceptualised and key elements were implemented (Fig. 6.10), comprising (i) a pilot version of an object-relational information system holding semantically structured data (MORIS), (ii) a core ontology for ecological and socio-ecological observations (SERONTO) and (iii) a metadata collection and entry system (LTER InfoBase).

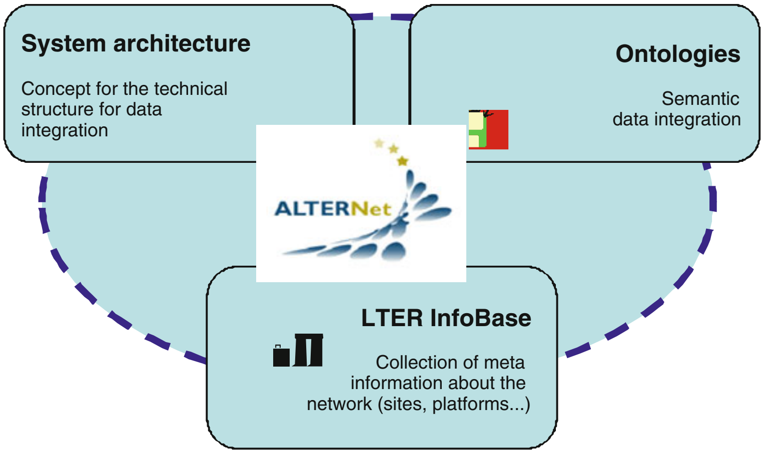

Fig. 6.10 Main pillars of LTER-Europe’s information management (modified original of J. Peterseil, with permission: http://www.lter-europe.net/info_manage)

A major challenge for a network like LTER-Europe consists of the distributed nature of its infrastructure and data. Because of this heterogeneity and operational aspects it was decided to integrate data and databases through an ontology covering any kind of object investigated by LTER and all measured properties of these objects (parameters) across domains. Ontology formally represents a set of concepts within a domain and the relationships between those concepts. According to Gruber (1995) ontology is a formal specification of a shared conceptualisation of a domain of interest. Shared means a common understanding of the knowledge to be formalised as a basis for the domain experts, to which own specific views can be mapped. This opinion is supported also by Davenport (1997): "People can't share knowledge if they don't speak a common language". As LTER covers a wide range of domains core ontology was needed, determining in principle how observations are described. ALTER-Net set up a discussion and decision-making process to achieve agreement on the Socio-Ecological Research and Observation oNTOlogy (SERONTO; van der Werf et al., 2008). The mid-term goal of LTER-Europe is to achieve a seamless drill-down to primary data through metadata. As a first step a hierarchically structured metadata system was established to describe the distributed network of LTER sites and LTSER platforms (LTER Infobase based on eMORIS; http://www.lter-europe.net/sites-platforms). Information ranges from basic descriptors to comprehensive lists of measured parameters across domains, infrastructural and administrational data. The key purpose of the LTER Infobase is achieving an overview of ecosystem research facilities in the continent and enabling the search for LTER sites or LTSER platforms according to given criteria, for example grassland sites within a certain elevation range where temperature and nitrogen deposition have been measured.

6.9 Part of a Network of Networks

LTER-Europe was developed into an intricate landscape of European research networks and multi-site research projects (e.g. FP 6 IP ALARM, FP 6 IP SENSOR), national environmental monitoring schemes such as the UNECE International Co-operative Programmes and nature conservation measures like the UNESCO Biosphere Reserves (EuroMAB) and Natura2000. Even long-term research projects setting up networks of sites like the Field Site Network (FSN) of the IP ALARM cannot secure the maintenance of these networks beyond their runtime in the range of 3–5 years. On the other hand networks set up primarily for ecosystem monitoring purposes would benefit from a complementary research component which they cannot provide themselves (e.g. UNECE ICP Integrated Monitoring). Most of the site infrastructure both of European and country networks is funded on the national level. Nevertheless examples of efforts to systematically integrate different in-situ networks are scarce. Because of the necessity to build on existing infrastructure the process of establishing national LTER networks has initiated such network integration in many of the LTER-Europe member countries (e.g. Finland, Italy, Austria, Germany), where LTER sites and LTSER platforms tend to serve two or more purposes in other research, monitoring or nature conservation schemes (e.g. LTSER platforms containing National Parks, Biosphere Reserves, Nature2000 sites, sites of UNECE ICP Forests, UNECE EMEP stations etc.).

On the European level other sectors like the marine research communities, taxonomic collections and experimental ecology have launched networks and projects (MARBEF, EDIT, ANAEE). Each, again, with topical or infrastructural overlaps and a wide range of potential synergies from the point of view of a visionary restructuring of the European research area in the field of life sciences. As part of the effort to formalise this process across individual initiatives, the LifeWatch preparatory project (LifeWatch, 2007) was accepted in the ESFRI roadmap (ESFRI, 2006). Currently LifeWatch foresees the integration of in-situ networks on the European level with LTER-Europe as the terrestrial and aquatic component (Fig. 6.11). Information management, legal and financial aspects shall be covered as centralised services of LifeWatch across the topical networks.

6.10 Key Potential and Strengths of LTER

Nowak, Bowen and Cabot (2006) gave excellence evidence of the unique strength of LTER and LTSER. They found that land use and management had significantly changed in big parts of the Lake Mendota watershed, without prompting a decrease in phosphorous loads to the lake – with a resulting stagnation

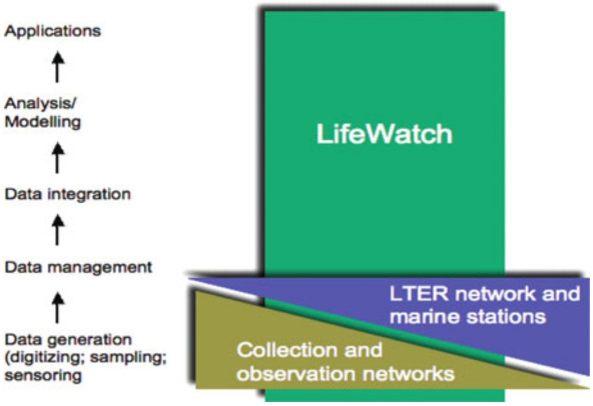

Fig. 6.11 LTER-Europe as the terrestrial and aquatic in-situ component of LifeWatch (from LifeWatch co-ordinator W. Los, with permission)

or even further decline of biodiversity. So, an interdisciplinary team of sociologists, agronomists and ecologists started searching for the reason for the detected phenomenon, applying the concept of disproportionality on the case. It is based on the fact that fundamental biological and social processes are characterised by positively skewed normal or even log-normal probability distributions. If, for example, the distribution between appropriate and inappropriate conservation behaviour of people in a specific watershed unfavourably overlap with the distribution of resilient and vulnerable parts of this watershed, easily overlooked malpractice may cause severe environmental impact. In the studied case dumping of manure by a few big farms in the Lake Mendota watershed had created hot spots of phosphorous in the landscape. These consequences of inappropriate social behaviour were frequently located close to farms or settlements and were thus unproportionally prone to erosion events (wind, storms). "Fast variables" such as (1) construction processes and (2) changes of vegetation cover influence such sensitivity, increasing or creating vulnerable environmental conditions. The consequence of a cross-wise overlap of two uneven probability distributions had disproportional influence on the overall system, because they accounted for a significant part of the overall P-load to the lake. As the P-Pools in the landscape are a so-called "slow variable" it will last decades before P-discharge into Lake Mendota will significantly decline in order to allow biodiversity to recover.

The lake Mendota study underpins key strengths and added values of LTER as a unique frame work for investigating the interaction of

- fast variables vs. slow variables (the long-term),
- processes at different spatial and timescales,
- processes in different realms (nature – society).

Alongside such examples the recommendations from the Millennium Ecosystem Assessment can be seen as a general framework towards policy-relevant ecosystem and biodiversity research. Carpenter et al. (2006) ask for tools capable of evaluating the success of human interventions in ecosystems, as well as the used indicators for monitoring biological, physical and social changes.

Within such a framework and the strong focus on in-situ research and monitoring, LTER and especially LTSER support or offer:

- *Evaluation and mechanic insight into main drivers* of ecosystem change, for example do the main drivers of biodiversity according to the Millennium Assessment (climate, N-input, land use change), have the expected effects in concrete regions and at concrete sites across Europe?
- Development and evaluation of *indicators of* the social and natural system across spatial and timescales.
- Research, monitoring and indicator development towards the assessment of the state and trend of *Ecosystem Services*.
- Possibility to *validate the applicability of socio-economic concepts and system-theories* in concrete human–natural systems.
- Evaluation of applicability of *socio-economic methods* to characterise systems, for example Socio-Economic Metabolism concept (Fischer-Kowalski & Haberl, 1997, 2007) and Human Appropriation of Net Primary Production (Haberl et al., 2002, 2004).
- Evaluating and monitoring interventions in socio-ecological systems (e.g. conservation measures).
- Recommendation of *measures for halting biodiversity loss* (e.g. Lake Mendota example).
- Application, validation and further development of *Integrated Assessments (IA)* on the regional scale.

Very importantly, LTER also represents an enormous potential for serendipitous science. Serendipity is the effect by which one accidentally discovers something fortunate, especially while looking for something else entirely (http://en.wikipedia.org/wiki/Serendipity) Firstly, sagacity is required to be able to link together apparently innocuous facts to come to a valuable conclusion. But – evenly important – one needs access to the facts to apply sagacity. Translated into environmental science and LTER, processes, cause–effect relationships and mechanisms eventually driving our socio-ecological systems and significantly affecting ecosystem services can only be identified on the basis of well documented long-term data and information. Creating such databases for a representative network of locations and securing the sustainable use of costly gathered legacy information belongs to the core of LTER-Europe's mission. Thus, while some scientists and inventors are reluctant about reporting accidental discoveries, others openly admit its role; in fact serendipity is a major component of scientific discoveries and inventions. According to Stoskopf (2005) it should be recognised that serendipitous discoveries are of significant value in the advancement of science and often present the foundation for important intellectual leaps of understanding. Bearing the importance of LTER's precautionary principle the 20 years review of US-LTER underpinned the importance of serendipitous science exploiting unexpected events as opposed to synthesis science looking forward and being hypothesis and theory driven.

Regarding biodiversity indicators LTER can deal with *two main questions*: (i) what are reliable indicators for biodiversity (what do they stand for in the context of the entire system) and (ii) biodiversity itself as an indicator for specific drivers (biotic, abiotic and anthropogenic), including the question of susceptibility and specificy, more specifically:

- Testing of biodiversity monitoring schemes and methods aiming at an integrated assessment across levels of biodiversity (e.g. in the frame of the FP 7 project EBONE, http://www.ebone.wur.nl);
- Comparison of identical indicators applied at different scales (e.g. bird inventories);
- Response time of indicators (e.g. eutrophication effects on ground-layer vegetation in forests);
- How do different indicators react to drivers relative to each other in time and space? How does the reliability, susceptibility and specific reaction (to drivers) vary across biogeographical regions?

Because of the limited usability of averaged or aggregated measures of processes and properties (social and environmental) to explain trends at lower scales the in-situ generation and provision of high-quality data at different spatial and timescales is indispensable. LTER facilitates synergies between long-term environmental monitoring providing reliable trend information and short-term measuring campaigns and experimentation data, which in return help with optimising and adapting monitoring designs. In many cases only interdisciplinary research (IDR) allows for the detection of complex phenomena.

The communication structure and governance established by LTER-Europe enables the efficient planning and execution of cross-site experiments and comparisons. Projects capitalising on LTER sites and LTSER platforms benefit from earlier investments in infrastructure and data by far exceeding the respective project budget, moreover each project adds to the value of LTER facilities, contribution data, knowledge and expertise. Thus, comparably low investments into the networking and central services of LTER have a significant financial leverage in the sense of a well-structured European Research Area.

6.11 Outlook

The NoE ALTER-Net ended in March 2009. It has fostered the LTER process at multiple levels from institutional commitments to the broad recognition of a distributed research infrastructure by European stakeholders and related networks. LTER-Europe forms the biggest regional group in the global LTER network and has set up permanent governance structures. Major strategic challenges ahead are the establishment of stable infrastructure funding mechanisms (nationally and on the European scale e.g. through ESFRI/LifeWatch) and the development of complementary research frame programs for LTER and LTSER projects. Data and metadata of LTER infrastructure have to be regularly updated to enable efficient selections of facilities that could be used by any kind of projects requiring an in-situ component. LTSER platforms provide a perfect basis for Integrated Assessments (IA) as well as the testing and further development of IA methods. The need for quality-assured long-term data series requires the integration of LTER with long-term environmental monitoring (LTEM), both in-situ and conceptually.

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References

Carpenter, S. R., DeFries, R., Dietz, T., Mooney, H. A., Polasky, S., Reid, W. V., et al. (2006). Millenium ecosystem assessment: research needs. *Science, 314*, 257–258.

Davenport, T. (1997). *Knowledge management case study: Knowledge management at Microsoft.* From: http://www.itmweb.com/essay536.htm.

Dietz, T., & Rosa, E. A. (1994). Rethinking the environmental impacts of population, affluence and technology. *Human Ecology Review, 1,* 277–300.

Dirnböck, T., Bezák, P., Dullinger, S., Haberl, H., Lotze-Campen, H., Mirtl, M., et al. (2008). Scaling issues in long-term socio ecological biodiversity research. A review of European cases. Social Ecology Working Paper No. 100, Institute of Social Ecology, Vienna.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science, 171,* 1212–1217.

ESFRI. (2006). European roadmap for research infrastructures – Report 2006. Office for Official Publications of the European Communities, 84 pp. ISBN 92-79-02694-1.

Fischer-Kowalski, M., & Haberl, H. (1997). Tons, joules, and money: Modes of production and their sustainability problems. *Society and Natural Resources*, *10,* 61–85.

Fischer-Kowalski, M., & Haberl, H. (2007). *Socioecological transitions and global change: Trajectories of social metabolism and land use.* Cheltenham, UK, Northampton, USA: Edward Elgar.

Fischer-Kowalski, M., & Weisz, H. (1999). Society as hybrid between material and symbolic realms. Toward a theoretical framework of society-nature interaction. *Advances in Human Ecology, 8*, 215–251.

Gallup, J. L., Scach, J. D., & Mellinger, A. D. (1999). Geography and economic development. *International Regional Science Review, 22*, 179–232.

Gee, D. (2001). *Late lessons in early warning.* Copenhagen: European Environment Agency.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies.* London: Sage.

Gruber, T. (1995). Toward principles for the design of ontologies used for knowledge sharing. *International Journal Human-Computer Studies,* 43, 907–928.

Haberl, H., Krausmann, F., Erb, K.-H., Schulz, N. B., Rojstaczer, S., Sterling, S. M., et al. (2002). Human appropriation of net primary production. *Science, 296*, 1968–1969.

Haberl, H., Schulz, N. B., Plutzar, C., Erb, K.-H., Krausmann, F., Loibl, W., et al. (2004). Human appropriation of net primary production and species diversity in agricultural landscapes. *Agriculture, Ecosystems & Environment, 102*, 213–218.

Haberl, H., Winiwarter, V., Andersson, K., Ayres, R., Boone, C., Castillo, A., et al. (2006). From LTER to LTSER: Conceptualizing the socio-economic dimension of long-term socio-ecological research. *Ecology and Society, 11,* 13.

Hobbie, J. E., Carpenter, S. R., Grimm, N. B., Gosz, J. R., & Seastedt, T. R. (2003). The US Long Term Ecological Research program. *Bioscience, 53*, 21–32.

Jongman, R. H. G., Bunce, R. G. H., Metzger, M. J., Mücher, C. A., Howard, D. C., & Mateus, V. L. (2006). Objectives and applications of a statistical environmental stratification of Europe. *Landscape Ecology, 21*, 409–419.

Kaljonen, M., Primmer, E., De Blust, G., Nijnik, M., & Külvik, M. (2007). Multifunctionality and biodiversity conservation – Institutional challenges. In: Chmielewski, T. J. (Ed.), *Nature conservation management – From idea to practical results* (pp. 53–69). Lublin-Lodz-Helsinki-Aarhus: ALTERnet.

LifeWatch (2007). LifeWatch Preparatory Phase, supported by the European Commission with FP7 Grant Agreement No 211372-LIFE. Available from: http://www.lifewatch.eu/index.php?option=com_content&view=article&id=63-122008updateprep&Itemid=4.

Metzger, M. J., & Mirtl, M. (2008). LTER Socio-Ecological Regions (LTER-SER) – Representativeness of European LTER facilities – Current state of affairs. *AlterNet Technical Paper,* p. 5. Available from: http://www.alter-net.info.

Metzger, M. J., Bunce, R. G. H., Jongman, R. H. G., Mücher, C. A., & Watkins, J. W. (2005). A climatic stratification of the environment of Europe. *Global Ecology and Biogeography, 14*, 549–563.

Metzger, M. J., Bunce, R. G. H., van Eupen, M., & Mirtl, M. (2009). An assessment of long term ecological research activities across European socio-ecological regions. Journal of Environmental Management (accepted).

Metzger, M. J., Leemans, R., & Schröter, D. S. (2005). A multidisciplinary multi-scale framework for assessing vulnerability to global change. *International Journal of Applied Geo-information and Earth Observation, 7*, 253–267.

Mirtl, M., & Krauze, K. (2007). Developing a new strategy for environmental research, monitoring and management: The European Long-Term Ecological Research Network's (LTER-Europe) role and perspectives. In: Chmielewski, T. J. (Ed.), *Nature conservation management – From idea to practical results* (pp. 36–52). Lublin-Lodz-Helsinki-Aarhus: ALTERnet.

Mirtl, M., Boamrane, M., Braat, L., Furman, E., Krauze, K., Frenzel, M., et al. (2009). LTER-Europe Design and Implementation Report–Enabling "Next Generation Ecological Science": Report on the design and implementation phase of LTER-Europe under ALTER-Net & management plan 2009/2010. Umweltbundesamt (Federal Environment Agency Austria). Vienna. 220 pages. ISBN 978-3-99004-031-7. In press.

National Research Council (NRC). (2004). *NEON, addressing the nations environmental challenges.* Washington, DC: The National Academy Press.

Nowak, P., Bowen, S., & Cabot, P. E. (2006). Disproportionality as a framework for linking social and biophysical systems. *Society and Natural Resources, 19*, 53–173.

Radetzki, M. (2001). *The green myth – Economic growth and the quality of the environment.* Multi-Science Publishing Co. Ltd.

Redman, C. L., Grove, J. M., & Kuby, L. H. (2004). Integrating social science into the Long-Term Ecological Research (LTER) Network: Social dimensions of ecological change and ecological dimensions of social change. *Ecosystems, 7*, 161–171.

Reid, W. V., Mooney, H. A., Cropper, A., Capistrano, D., Carpenter, S. R., Chopra, K., et al. (2005). *Millennium Ecosystem Assessment Synthesis report.* Washington, DC: Island Press.

Sachs, J. D., Mellinger, A. D., & Gallup, J. L. (2001). The geography of poverty and wealth. *Scientific American, 284*, 62–67.

Stoskopf, M. K. (2005). Observation and cogitation: How serendipity provides the building blocks of scientific discovery. *ILAR Journal, 46*, 332–337.

Van der Werf, B., Adamescu, M., Ayromlou, M., Bertrand, N., Borovec, J., Boussard, H., et al. (2008). SERONTO: A Socio-Ecological Research and observation oNTOlogy. In: Weitzman, A. L. & Belbin L. (Eds.), *Proceedings of TDWG.* Fremantle, Australia.