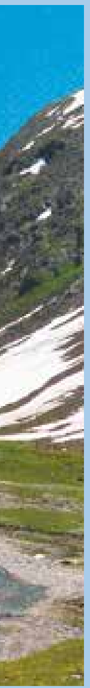

RESEARCH FOR
THE FUTURE

LTER-AUSTRIA WHITE PAPER 2015

Austrian Society for Long-term Ecological Research

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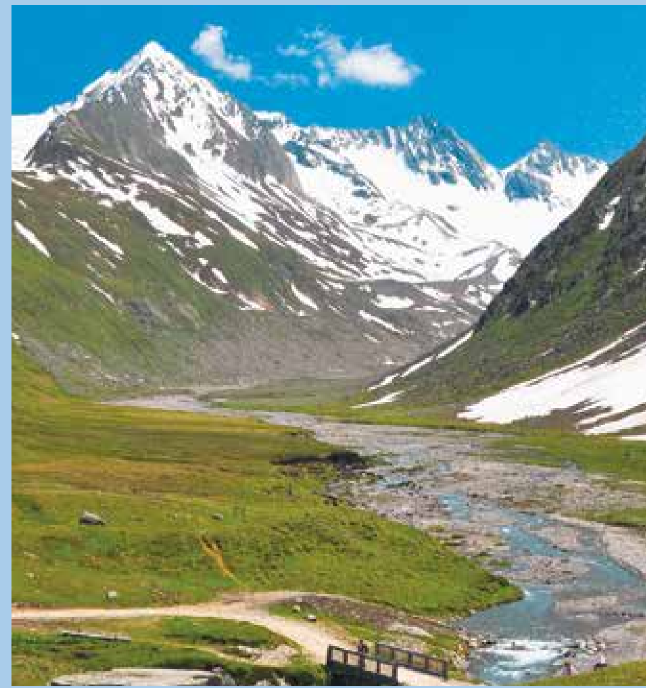
LTER Austria
Austrian Long-Term Ecosystem Research Network



ON THE STATUS AND ORIENTATION OF PROCESS ORIENTED ECOSYSTEM RESEARCH, BIODIVERSITY AND CONSERVATION RESEARCH AND SOCIO-ECOLOGICAL RESEARCH IN AUSTRIA

RESEARCH FOR
THE FUTURE

LTER-AUSTRIA WHITE PAPER 2015

Austrian Society for Long-term Ecological Research

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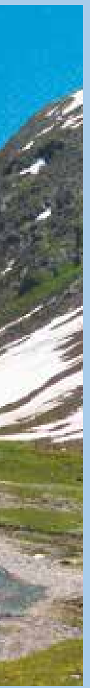

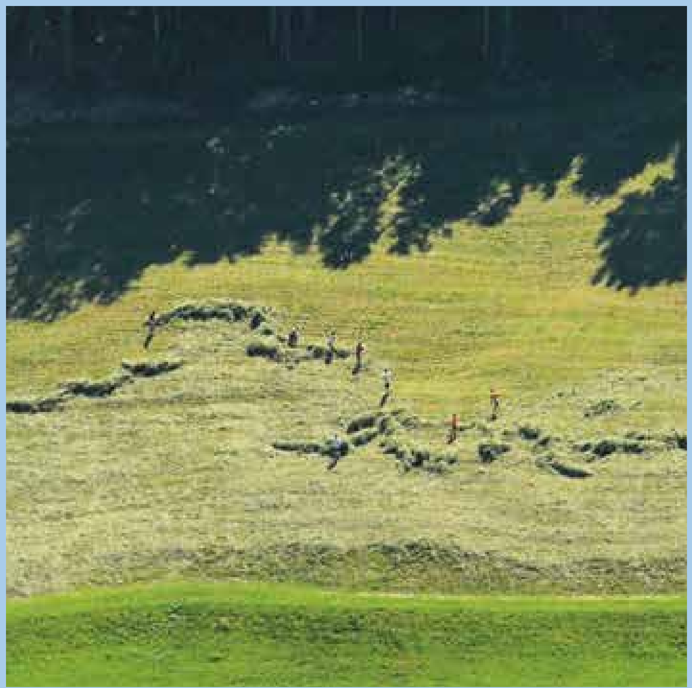

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SUMMARY

"Long-Term Ecosystem Research" (LTER) constitutes a network in Europe of approximately 400 research sites, 100 institutions and numerous research projects in 24 national networks. LTER-Europe conducts research across a broad spectrum of European ecosystems from the arctic and alpine to mediterranean sites.

How do ecosystems react over the long term to very different influencing factors? In more precise terms: How do they react at different scales (local, regional, continental, global) over decades and centuries to climate change, invasive species, material deposits/inputs or human utilization, etc? What characteristics enable them to adapt to stress? How are disturbances managed? What are the thresholds beyond which irreversible changes or degradation occur?

These are central questions addressed in long-term ecosystem research and LTER represents one of the few research networks worldwide whose projects also consider the organizational aspects of the long-term character of most processes: In short-term projects with a duration of 2-3 years, long-term ecological changes are hard or impossible to identify or to interpret correctly.

Only when they are "functioning" can our ecosystems provide a basis for life. Conversely, from a human perspective, 'ecosystem services' are strongly dependent on the particular form of social utilization (and ecosystem management) being practised. The **sustainable protection of essential ecosystem services and biodiversity under conditions of global change** is a core responsibility of society as a whole. Ecosystem research as a supplier of knowledge in respect of this task requires an integrated inter- and transdisciplinary approach, which records the multiplicity of interactions between human activities and ecosystems.

The long-term character and **complexity of both research issues and new technologies** renders **a new approach in terms of content, organization and structural aspects** to LTER necessary, both globally and within Europe (the European Research Area, ERA). These take account of key processes and projects of the European Commission (ESFRI, ENVRI, ExpeER, H2020 Infraia Infrastructure call). In this respect, the following apply: **Infrastructures and support schemes** must in future be **organised nationally** such that they constitute an adequate response to European framework programmes and make optimal use of their central services.

Interdisciplinary and integrated approaches require the **broadening of specialisms** within LTER to encompass the humanities, cultural and social studies (LTSER, Long-Term Socio-Ecological Research), as an integral component of LTER. Thus in the context of the White Paper, the **term "ecosystem research" includes** implicitly **process-oriented ecosystem research, biodiversity and nature conservation research as well as socio-ecological research.** The distinctive feature here lies with its focused engagement in researching the long-term ecological and socio-ecological transformation in the "critical zone" (see below) at concrete locations (LTER Sites, LTSER regions and beyond).

The framework conditions for ecosystem research in Austria have dramatically worsened in recent years (education, sites, project financing), whereas in countries such as Germany, innovative large-scale investment schemes are taking place in this field of science (e.g. TERENO, Biodiversity Exploratories). **If Austria wishes to play a significant role in European ecosystem research** through the involvement of its research sites, then the **field of science must be brought into line with international developments.** Only thus can excellent research be guaranteed at appropriately equipped sites and the priority research concerns for Austria be adequately addressed.

The White Paper considers itself as making a contribution to the reorganization of the LTER field of science in Austria. It attempts to answer the following questions:

- What are the priority **research themes?**
- Where are the greatest **potentials?**
- What **framework conditions** are required in order to realise these potentials?
- What is Austria's best course of action within the **international context?**

KEY MESSAGES

The White Paper addresses the following **key messages** to stakeholders and infrastructure managers within the scientific field of "ecosystem research" in Austria. These messages are presented in detail in Chapter 7 , which derives concrete suggestions for reorganization from these. An editorial team drawn from across a broad range of disciplines has produced this White Paper with the involvement of more than 100 experts from different panels and workshops, taking account of key European framework processes.

(A) Creating framework conditions from an integrative, interdisciplinary perspective
- ➡ The scientific field of "ecosystem research" comprises three thematic areas, which address complex research issues: process-oriented ecosystem research, biodiversity and nature conservation research and socio-ecological research.

(B) The diverse research projects addressing ecological and socio-ecological research issues require appropriate funding support
- ➡ Research framework programmes or appropriately adapted awarding criteria for existing programmes.

(C) Core financing for necessary infrastructure (incl. IT-related infrastructure)
- ➡ Core financing in line with international models is a prerequisite for maintaining and further developing the necessary infrastructure for long-term environmental research and monitoring at the respective sites.

(D) Pooling permanent sites for multiple utilization in national research strands and contributing to the European Research Area (ERA)
- ➡ Creating a pool of priority sites with a model for their long-term trusteeship. This should enable Austria to contribute in a cost-efficient way to diverse European and international programmes and to ensure an appropriate reflux of funds.

(E) Operational Headquarters as a hub connecting national and international activities
- ➡ The coordination and documentation of LTER Sites in Austria will consolidate the stakeholder network, comprising research, practice, decision making and politics, and strengthen networking at international level. The integration of the sites' databases ensures the multiple utilization of high value information.

Chapter 7.2 provides a breakdown of these five key messages in relation to current circumstances (page 51) and leads from these into the recommendations for solutions made in Chapter 7.3 (page 52 onwards).

LTER-Austria intends through this White Paper to present the national strategic challenges, which appear as "Grand Challenges" in the 2020 FTI Strategy from the Federal Ministry for Transport, Innovation and Technology:
"… In this context, questions of ecological changes are as much the focus as those regarding health and food security. This involves technological as well as systemic or social research, supported by analyses, impact studies, scenario- and model-based studies, space-based and terrestrial environmental monitoring, etc. … This presents society not only with technological demands but also with the need to adapt the use of land and space appropriately. Securing the sustainable production of biogenous raw materials and energy sources … and their distribution … requires a comprehensive, regionally differentiated knowledge of environmental, ecological, economic and social conditions, which must be obtained through interdisciplinary, targeted basic research." (Austrian Federal Government, 2011).

The Austrian Society for Long-Term Ecological Research is grateful for the awarding of science funding made by the Federal Ministry for Science, Research and Economy and the international programme "Global Change" of the Austrian Academy of Sciences.

1 CONTEXT AND FRAMEWORK

1.1 AIM AND BACKGROUND OF THE WHITE PAPER: KEY MESSAGES

➡ **What knowledge is required to sustain the foundations of human life?**
➡ **What framework conditions are required for the research?**

European projects concerned with research strategy have addressed these questions in recent years and have initiated a reorganization of ecological research (FP6, FP7, H2020, ESFRI, see Chapter 6, page 45 ff.). This reorganization takes account of the infrastructural and logistic requirements for researching complex phenomena and their long-term dynamics (distributed research facilities, information technology). The Austrian Society for Long-Term Ecological Research (LTER-Austria) intends that the "LTER-Austria White Paper" should provide fresh impetus for the national repositioning of a field of science that has been confronted by massive changes in terms of content, social perception and funding conditions over the last 10 years.

The White Paper outlines current and emerging issues. It aims to contribute to the strategic orientation of long-term ecological and socio-ecological research in Austria. It provides an opportunity for research teams and organizations to position themselves in the Austrian and European research landscape. It provides an overview and future perspectives in the context of both the European Research Area and global challenges for those reponsible for Austrian research strategies and research funding mechanisms (Ministerial research departments, the Austrian Science Fund (FWF), the Austrian Academy of Sciences, etc.).

In structural terms, it aims to support the organizational development of institutions for the benefit of ecological and socio-ecological themes through a division of work at both national and European levels and to raise awareness of the importance of Austrian expertise and research facilities.

The White Paper aims to answer the following questions:
- What are the priority **research themes?**
- Where are the greatest Austrian **potentials?**
- What **framework conditions** are necessary to put these potentials into practice?
- What is Austria's best course of action in the **international context?**

The White Paper addresses ecosystem research via three thematic areas:
1. Process-oriented ecosystem research
2. Biodiversity and nature conservation research, and
3. Long-term socio-ecological research (LTSER).

The **term "ecosystem research" thus implicitly addresses all three thematic areas,** unless otherwise specified. Ecosystem research as it is understood in the LTER-Austria White Paper also covers the **"Critical Zone",** that is, the layer of the globe between the stratosphere and the deeper geosphere, within which solar energy-powered life exists. This understanding is reflected in the most recent developments in Europe, China and Australia, according to which Critical Zone Research will make use of the infrastructures of LTER. In this context, there is an increasing focus upon (1) vertical interactions, particularly with the geosphere, and (2) very long-term processes, such as soil formation.

PRODUCTION METHODOLOGY OF THE WHITE PAPER
Teams of experts associated with the Society for Long-Term Ecological Research worked on each of the thematic areas listed above. They conducted interviews with leading research institutions and those who use and apply the results of such research, and then organised small-scale workshops to develop specific chapters for each thematic area.

Chapters 3 to 5 follow a harmonized structure, which aims to facilitate analysis and synthesis across all the thematic areas. Analysis should filter commonalities and explicit differences with the following objectives:
1. To avoid unproductive overlapping and make use of synergies
2. To create framework conditions for research excellence in the individual thematic areas by identifying any specific aspects that prevent "ecosystem research" from being addressed and supported as an undifferentiated whole.

Nationalpark Gesäuse: © Archiv Nationalpark Gesäuse

The second objective is closely coupled with the above-mentioned European efforts to ensure that the European Research Area is also more competitive in terms of ecological research, closely related to the creation of a stable financial basis for the infrastructures of ecosystem research (ESFRI, national ESFRI Roadmaps). In 2008 and 2009, LTER-Austria produced the first version of the White Paper. This phase also involved contact with the Austrian Platform for Biodiversity Research (BDFA). To avoid overlapping and inconsistencies and to make use of synergies where possible, the chapter addressing the thematic area of "Biodiversity and nature conservation research" was produced in close cooperation with this organization. Following an international review, the first LTER-Austria White Paper was completed in 2010 and presented in collaboration with the Network of Excellence ALTER-Net at an international conference in Vienna in November 2010. The current, comprehensively updated third edition of the White Paper was developed through a renewed joint untertaking and consultation process during the autumn of 2013 and summer of 2014. Following an international review process, the White Paper will be presented at an international LTER conference in February 2015 in Vienna in the context of European and global research concepts.

1.2 LTER AS A GLOBAL AND EUROPEAN FRAMEWORK

LTER has a 40-year history upon which to draw. Since the 1970s, humanity has encountered complex and supra-regional environmental problems, such as soil acidification and forest dieback. In this period, LTER was primarily focused upon the natural science components of long-term ecological research, which aim to improve the understanding, analysis and documentation of ecosystem processes, patterns and phenomena.

It was recognised that (1) the temporal dimension of the emergence, development and transformation of such patterns and processes extended far beyond the usual duration of research projects (3-5 years), (2) the spatial dimension of processes could not be captured at individual sites, and (3) comparable methods and approaches were a prerequisite for upscaling research results. In other words, **long-term studies** were required and research questions needed to be addressed through a **network of sites.** Moreover, the **investigation of entire ecosystems** (water and material balances), as opposed to the investigation of individual aspects, was seen as increasingly important. A more recent term, which makes reference to integrative approaches to the portion of the Earth in which life exists, is **"Critical Zone Research"** (NRC 2001).

To **implement** this understanding, the US National Science Foundation (NSF) developed the first national LTER network, which enabled the gathering of long-term data series on the most significant ecosystem processes, using the same methodology at different sites, and making these available for cross-site comparisons. The concept was so successful in the USA that it became the nucleus of a global network (see Info-Box 1).

Because of the high population density and long history of human utilization of large areas of land to a more or less intensive degree in Europe, while natural and near-natural ecosystems can now only be found on a small portion of the land area, it made sense to accord the aspect of human utilization greater prominence when transferring the LTER concept to the European context (Mirtl 2010). This led to the development of the LTSER concept (Long-Term Socio-Ecological Research), in which Europe and Austria play a leading role in global terms (see Chapter 1.3). A reference work was published in 2013, in which Austria took the lead (Singh et al., 2013). The FP6 Network of Excellence "ALTER-Net" tested the implementation of the LTSER concept in European pilot regions (see Info-Box 1). This addressed the challenge of producing scientific foundations for a more sustainable management of ecosystems and thus also for the goal of more sustainable development.

45 national networks for long-term ecological research (**LTER:** Long Term Ecosystem/Ecological Research) have joined together to form the **International Long-Term Ecological Research** Network (IlTER). This global association of research sites encompasses the most diverse types of ecosystem (forest, grassland, cities, etc.) across all climate zones and forms a unique long-term data system
➡ **www.lter-europe.net**

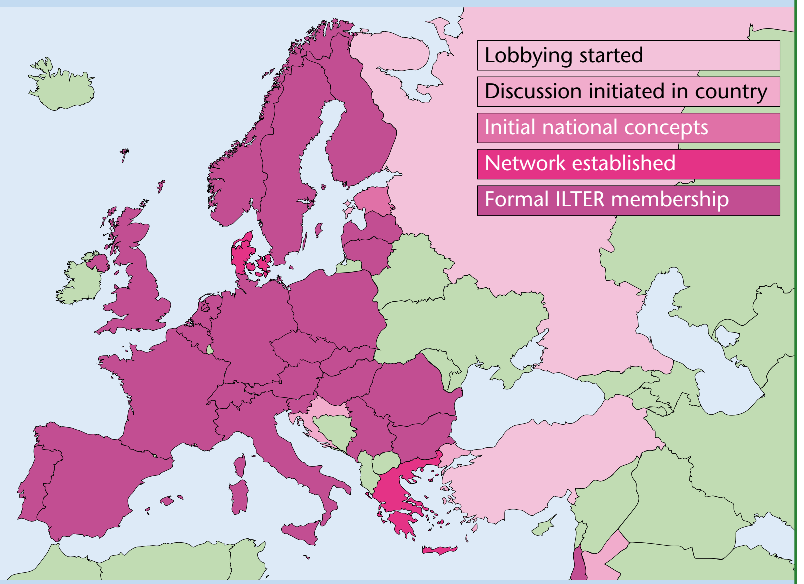
The global **ILTER** network is organized into regional groups, e.g. "North America", "Pacific Region", etc. The Network of Excellence **ALTER-Net** (FP6, http://ec.europa.eu/research/fp6) established the conceptual basis for a pan-European regional group from 2004. **LTER-Europe** (European Long-Term Ecosystem Research Network) was formally established by partners from Western and Eastern Europe in 2007, and by 2014 had expanded to include 24 member States.
➡ **www.alternet-info.net**

LTER-Europe, a network of…

- Researchers ("Community")
- LTER Sites
- LTSER platforms
- Data and metadata
- National networks
- Institutions
- Disciplines
- In-situ research

And a…

- Part of the network of networks
- Research strategy process



The **in-situ network** of LTER-Europe includes c. **35 LTSER Platforms** (see Chapter 1.3), i.e. complex research infrastructures for socio-ecological research, in which the most important natural areas in Europe are the subject of exemplary research. The second infrastructure type consists of the c. **400 traditional LTER Sites.**

LTER-Europe has become a **key component of the European Research Area** (a network of networks). LTER-Europe cooperates with diverse ESFRI and infrastructure projects, such as the IT-based infrastructure LifeWatch, for which it functions as a complementary in-situ component, ICOS or ExpeER (integration with experimental approaches). Along with this comes the definition of synergies and interfaces with key programmes, networks and institutions, such as UNESCO/Biosphere Reserves, UNECE/ICPs, the European Environment Agency, GEO-BON/EUBON, Copernicus, Natura2000, ENVRI, EUDAT, etc.

LTER-Europe is related to a central **reference document,** which sets out the design, type of site, scientific strategy, geopolitical distribution, administrative structures, services and interfaces to other relevant networks and processes (Mirtl et al. 2009). A substantial next step towards data integration is the Horizon2020 Projekt "eLTER", which was accepted in January 2015 (co-operation with the Critical Zone research community, 15 out of 15 review points). In 2014 LTER-Europe was placed within the environmental sector of the "ESFRI Landscape". An ESFRI proposal is being prepared for March 2015.

Info-Box 1: The European and global context of LTER-Austria (Mirtl et al. 2013)

LTER has developed into a major component of European ecosystem and environment research infrastructure. LTER-Europe is working to define the interfaces to other European networks in this area and in environmental monitoring (UNECE ICP Integrated Monitoring, UNECE ICP Forests, UNESCO Biosphere Reserves, EEA, etc.). Environmental monitoring plays a significant role in the provision of long-term basic data, an indispensable component of long-term research (see Chapter 1.4). All these activities have direct significance for Austria and LTER-Austria, because of the need to progress the integration of infrastructures, networks and data stocks for reasons of efficiency. This is reflected in the Austrian consortium of LTER institutions, which includes the organizations that fund environmental monitoring (e.g. the Environment Agency Austria, Austrian Research Centre for Forests - BFW) and academic institutions.

The figure below (Fig. 1) provides an overview of how LTER-Europe is embedded in the infrastructure landscape. The purpose of the figure is to group together the elements of this landscape (e.g. in-situ infrastructures). LTER maintains multiple and diverse relationships and cooperation activities (partly formalized in MoUs), which cannot be described in detail in the scope of this White Paper. In many cases, this European (and global) context and relationships between these elements are reflected in the national organization. This is also the declared aim of LTER-Austria. Chapter 7 presents options for how such a national organization might look in the case of Austria.

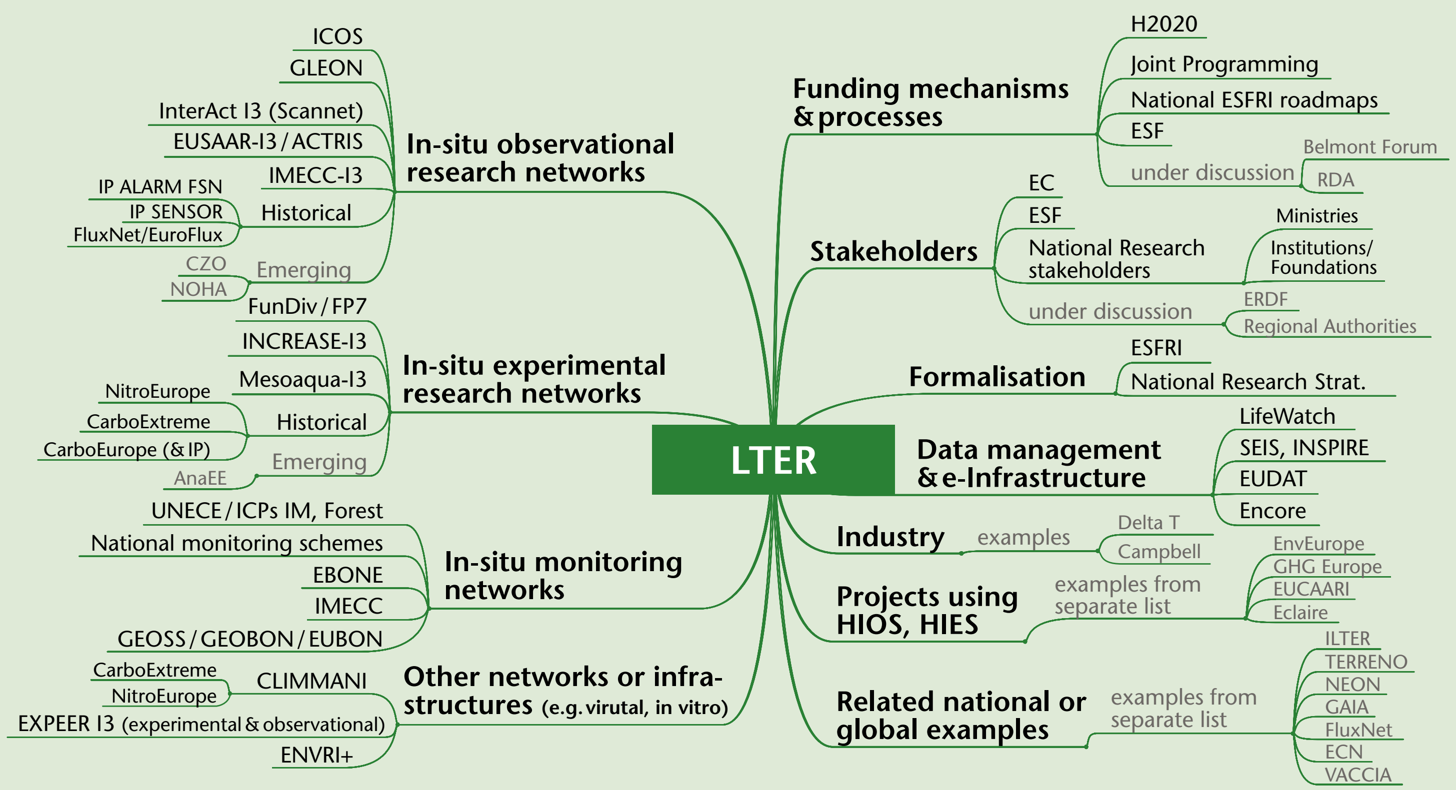


Fig. 1: "Landscape" of ecosystem research in Europe: The main branches in the diagram refer to sectors such as (above left) observational or experimental infrastructures. On the left, are the branches for in-situ infrastructures (networks of sites), and on the right are other relevant elements, such as e.g. e-infrastructure for data management.

1.3 "NEXT GENERATION LTER"

Since ecosystems interact closely with human activities, the LTER system was expanded around the turn of the millennium, to enable it to record processes of interaction between society and nature. This led to the emergence of the LTSER (Long-Term Socio-Ecological Research) concept: This focuses on long-term changes in the interplay between global change and the interaction of socioeconomic and ecological systems. In this way, LTSER contributes to an integrated form of sustainability research. In Europe, LTSER is an integral part of LTER-Europe.

Under Austrian leadership, the current reference work on LTSER was published in 2013 by Springer (Singh et al. 2013). Its special role and implementation in Europe is elucidated by Mirtl et al. (2013) in this document. LTSER takes entire landscapes with their diverse interactions between society and nature as the subject for research. LTSER combines social and economic aspects and the history of human utilization with classical long-term ecological research. This facilitates research into phenomena that are characterized by social processes, such as hunting and wildlife management, the creation of conservation areas and their interaction with the surrounding environment, or the effects of changes in production and consumption upon resource use, land use and ecosystems. LTER-Europe encompasses both LTSER and "classical" LTER. The expansion of this concept also increases the benefits to human society of process-oriented ecosystem research at traditional LTER Sites, because it enables their results to be placed within a context that is meaningful for society.

LTSER in part focuses on regions, which form entities that have their own character in terms of the natural pace, culture and history of human utilization, such as e.g. "Eisenwurzen" in the Austrian core region or the "Tyrolean Alps". LTSER thus requires a different research infrastructure, the so-called **LTSER Platforms.** These are **regional clusters of research and observational sites/projects,** which are effectively coordinated internally, and integrated to a high degree within international networks. They function equally as platforms for cooperation between the most diverse specialist areas (interdisciplinarity), and also between research representatives and users (transdisciplinarity). Research questions with regional relevance are investigated in cooperation with others and the results are also utilized on a regional basis (participation, education).

The **CONCEPT** of the LTSER PLATFORMS TAKES ACCOUNT OF THREE FUNCTIONAL LEVELS:

- Physical infrastructure: measurement equipment, institutions, data (demography, settlement patterns, land use, economy, natural areas, etc.)
- Communication space, concepts, networking: common language, development of thematic foci, methods and models, participation, transdisciplinarity, national and international networks
- Concrete projects, which, via the use of LTSER services and LTSER infrastructure, should deliver products that could not be produced in any other context – excellent and innovative research.

The **LTER Sites within the research platforms** constitute important elements of a scale-explicit, nested LTSER design (see Fig. 2). In accordance with this, the LTER Sites represent important habitat types for the landscapes in an LTSER Platform. Ecosystem processes are investigated from the level of the smallest possible scale of sampling plot size, through small catchment areas to the landscape level. Special areas and conservation areas such as national parks, nature parks, biosphere parks, wilderness areas, etc., play an important role within "nested design", since through appropriately coupled inventory systems, the degree to which small-scale sites within these areas are representative of the area as a whole can be evaluated in empirical terms. This facilitates the transfer of local measurement data to the region and of regional measurements (e.g. air quality) to smaller-scale sites (upscaling, downscaling). Another important aspect concerns reference to administrative boundaries (e.g. municipality or district boundaries), since on one hand these may be used to establish relations with the political system, and on the other, because much socioeconomic and environmental data within official statistics, which are indispensable for LTSER (e.g. population figures, building, agriculture and forestry statistics, etc.), can only be found at the level of administrative entities such as cadastral municipalities, municipalities, districts or federal provinces.

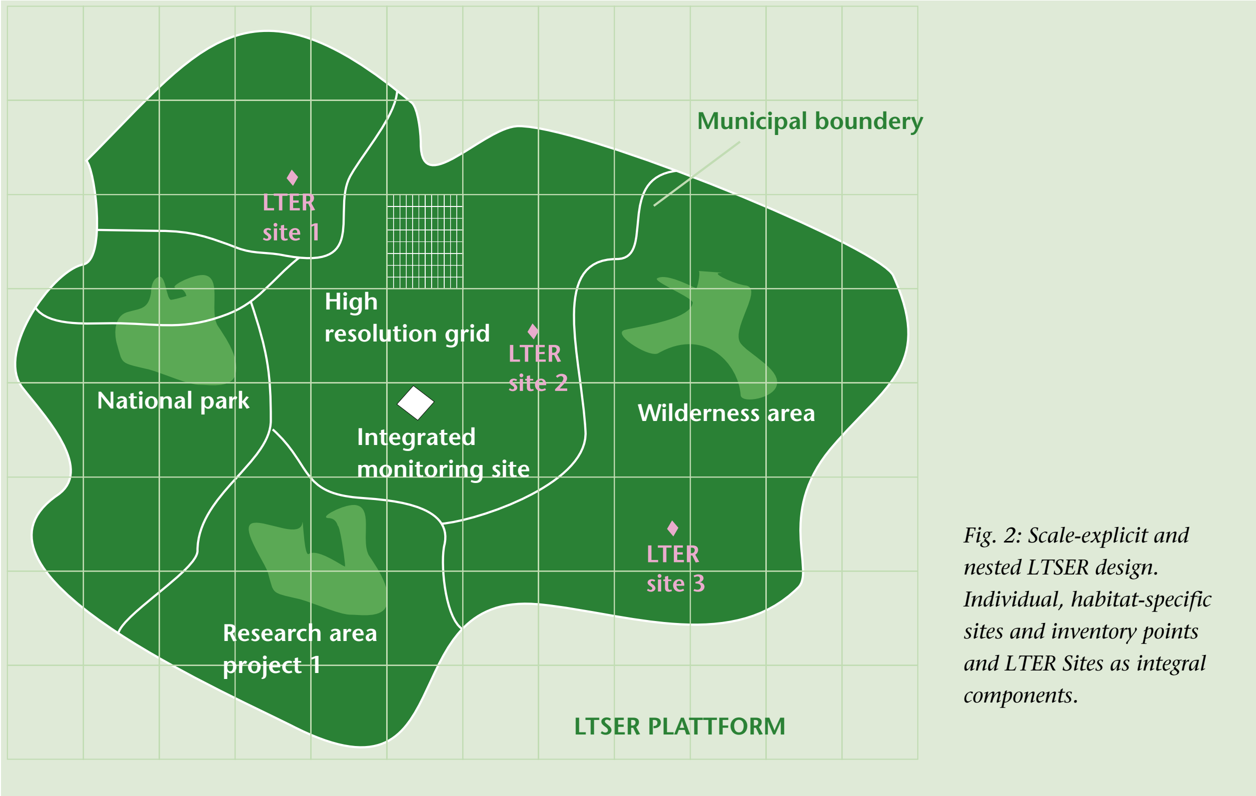


Fig. 2: Scale-explicit and nested LTSER design. Individual, habitat-specific sites and inventory points and LTER Sites as integral components.

The **added value** of research platforms lies primarily in the fact that they make it possible to address integrated socio-ecological questions (society-nature interaction), i.e. questions of sustainability research that simply cannot be asked at plot-level. As such, they form the basis for interdisciplinary cooperation, division of work and the opportunity for LTSER to deliver socially relevant results. This can be demonstrated using the example of air pollutants: laborious and expensive measurements of pollutant inputs are only undertaken at a few locations. However, there is a range of investigations into the impact of pollutants in diverse types of ecosystems. By using these measurement data together and taking a regional approach, the causes can be identified, the consequences for ecosystems can be represented and recommendations for improving the management of resources can be formulated.

LTSER DEMANDS **HIGH STANDARDS** REGARDING THE RESEARCH APPROACH AND THE REQUISITE FRAMEWORK CONDITIONS:

- A multi-scale approach in the context of observing small-scale processes and trends within individual ecosystem types, such as e.g. forest or grassland, up to and including the comprehensive analysis of entire regions. In this context, the results of each scale level should be of maximum use to other levels: "Regionalisation".
- An integrative and interdisciplinary investigation of the interactions between social, cultural, economic and ecological factors ("Society-nature interaction") in the regional context.
- Focusing and increasing efficiency of research activities and research potentials through the use of content-related synergies, existing data and infrastructures.
- Harmonization of regional and international research through the coupling of local, regional, national and international research projects. Inclusion of the research platforms within international projects with the aim of achieving an optimal division of work.
- Modelling and scenario development to facilitate and create the scientific basis for decision-making at local, regional and national levels – politically relevant information based on LTER databases and LTER know-how.

1.4 INTERACTION BETWEEN MONITORING AND RESEARCH IN LTER

A key attribute of LTER concerns the analysis of long-term trends across all elements of the system and the embedding of short-term projects within this information. Trends can, however only be identified by means of reliable monitoring data (standards regarding methods and instruments, quality assurance), which to some extent, despite regulatory guidelines, are still not always available in sufficient quantities.

➡ *EXAMPLE: The EU Water Framework Directive (WFD) obliges Member States to achieve a good ecological and chemical status for all natural water bodies by 22 December 2015. Because of its low testing frequency, the national water monitoring programme, regulated by the Water Quality Monitoring Regulation (WGEV) in accordance with the stipulations of the WFD, is not suited to adequately record the impacts of extreme events, such as the "100-year flood" in 2013, upon water quality. Furthermore, not only the aquatic areas themselves need to be documented but also the (semi-)terrestrial areas that are in direct proximity and exchange with the water bodies. The spatial and temporal changes in land use and land cover in the catchment area of a body of water or a lake have a significant impact upon water quality. The findings and recommendations based on detailed measurements from LTER Sites, and their incorporated observations with the catchment area thus represent services that are of national and EU-wide relevance.*

For LTER Sites, therefore, complementary long-term ecosystem monitoring (LTEM) represents a resource-intensive routine task, which, although it is closely linked to the research itself, differs significantly from research projects in terms of its activity profile and the requisite qualifications and funding mechanisms (stable core budget, long-term staff involvement, secure data management).

Monitoring also requires a range of "hard" infrastructure, which needs to be permanently available, if it is to be truly state-of-the-art, e.g. powerful and reliable electricity supply for thermostatic stabilization, stable data transfer, year-round vehicular access, snow clearance, and measurement towers. At the same time, many research issues have attained such a high level of complexity that they can now only be addressed by using highly sophisticated equipment and experimental approaches. Good examples of this are measurements of greenhouse gas balances in ecosystems with a combination of atmospheric measurements and vertical profiles of soil, vegetation and the free atmosphere (see ICOS in Chapter 6 on p. 43) as well as facilities for analysing nitrogen balances in soils.

Measuring point at Zöbelboden: © Michael Mirtl

This is one of the reasons for the European discussion and the trend towards concentrating research activities at "super-sites" or, in the terminology of LTER – "LTER Master Sites".

At the same time, the European Environment Agency (EEA) initiated expert discussions on the reorganization of European monitoring systems. A related project, "Monitoring 2015", has also been ready to begin in Austria for some years already. The central question involves the extent to which parameters and measurement networks that are generally sectorally monitored are suited to finding answers to emerging research questions or to serving in the context of integrated ecological assessment. This represents a thematic link to LTER, where the design of LTER Sites has for decades focused on the integration of media-related monitoring (soil, water, air, vegetation, etc.) and one that evaluates trends and interactions across media. From the aspect of multiple utilization of monitoring data, LTER Sites regularly become central docking points for numerous monitoring systems. This allows opportunities for the development and validation of methods and indicators, which has especial relevance for the connection with legal regulations, such as the WFD mentioned above.

Addressing research questions in many instances requires basic monitoring that goes far beyond the standard programme of sectoral monitoring systems (temporal and spatial density, measurement accuracy) and must be coordinated at a Europe-wide level. This opens up possibilities for transdisciplinary research approaches that not only aim at an holistic-integrative monitoring approach for individual disciplines but also include the concerns, knowledge and experiences of local populations (e.g. agricultural and forestry workers, tourist officials, local community representatives). Only thus can an environmentally friendly, sustainable development be supported by economically viable means, taking account of socio-cultural contexts.

In many areas, therefore, the "operation" of LTER Sites is synonymous with basic measurements and the provision of quality-assured data. **The costs and routine activities that this entails comprise one of the reasons as to why universities in Austria are hardly in a position to secure the long-term operation of LTER Sites. The need for a division of tasks and seamless bringing together of basic operations, trend analyses, short- and long-term research projects, as well as the efficient use of the infrastructures that are required for both, require a well-organized partnership (see Fig. 3), for which LTER offers a framework** (suggested structure for a LTER-Austria research cluster in Fig. 14 in Chapter 7.3.1)

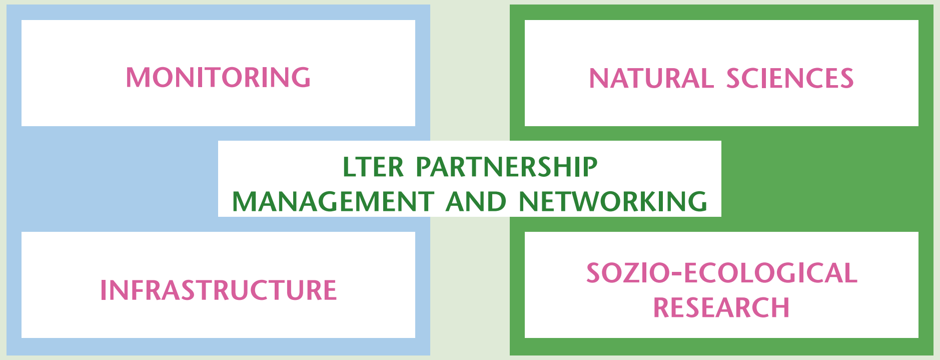


Fig. 3: Integration of long-term monitoring (and long-term ecosystem monitoring) and research (LTER)
(Figure: A. Richter)

The annex chapter 8.3 expands on the interactions between environmental monitoring and LTER from the European perspecive.

1.5 LTER-AUSTRIA

1.5.1 PROFILE AND PROCESS

The Austrian Society for Long-Term Ecological Research, LTER-Austria, was founded in 2002. Since then, Austria has made a significant contribution to the international LTER process (ALTER-Net, ILTERN), although structured long-term funding and institutional consolidation are not yet in place. Austria currently chairs the European LTER network.

LTER-Austria sees itself as representing the interests of long-term ecological and socio-ecological research and also to some extent covers the research focus of the Critical Zone concept. All the key relevant institutions and infrastructure organisations are represented in LTER-Austria.

With reference to the international concept, the LTER-Austria network sees itself as:

- A network of in-situ components (LTSER Platforms, LTER Sites)
- A community of scientists and scientific institutions, sharing an underlying consensus in content terms (LTER-Austria White Paper)
- A "transmission belt" to stakeholders (decision makers and practitioners) to ensure the development of infrastructure and competitive ecosystem research in Austria.

The LTER process in Austria is presented in Fig. 4.

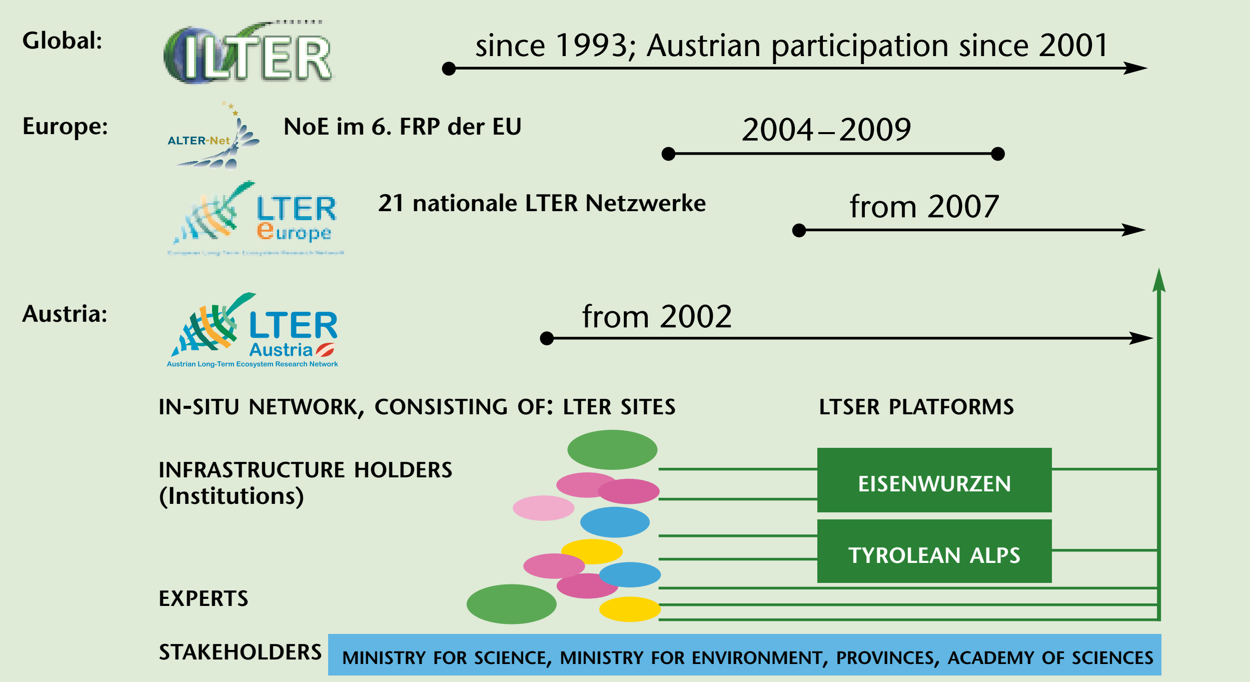


*Fig. 4: **The LTER process in Austria: Top:** The arrows (above) mark the temporal sequence of significant framework processes: Austria has been involved in the global LTER network **(ILTER)** since 2001. In 2002, the Austrian Society for Long-Term Ecological Research **(LTER-Austria)** was founded, with its experts participating in the FP6 Network of Excellence **ALTER-Net.** A key product of ALTER-Net was **LTER-Europe,** founded in 2007. **Center:** The LTER-Austria society recruits members from the experts working at LTER sites and in LTER projects, who participate in ALTER-Net. In accordance with LTER-Europe standards, Austrian sites are selected and LTSER platforms developed. These form the Austrian contribution to the European LTER network. For a professional organization, the long-term commitment of stakeholders and infrastructure providers is essential, especially for this area of research. Below: Stakeholders in Austria*

The comparative representation of the organisation and the embedding of national LTER "communities" and their Sites across all the Member States in the so-called "LTER National Mind Maps" is a particular achievement of LTER-Europe. The Austrian Mind Map is shown in in Fig. 5.

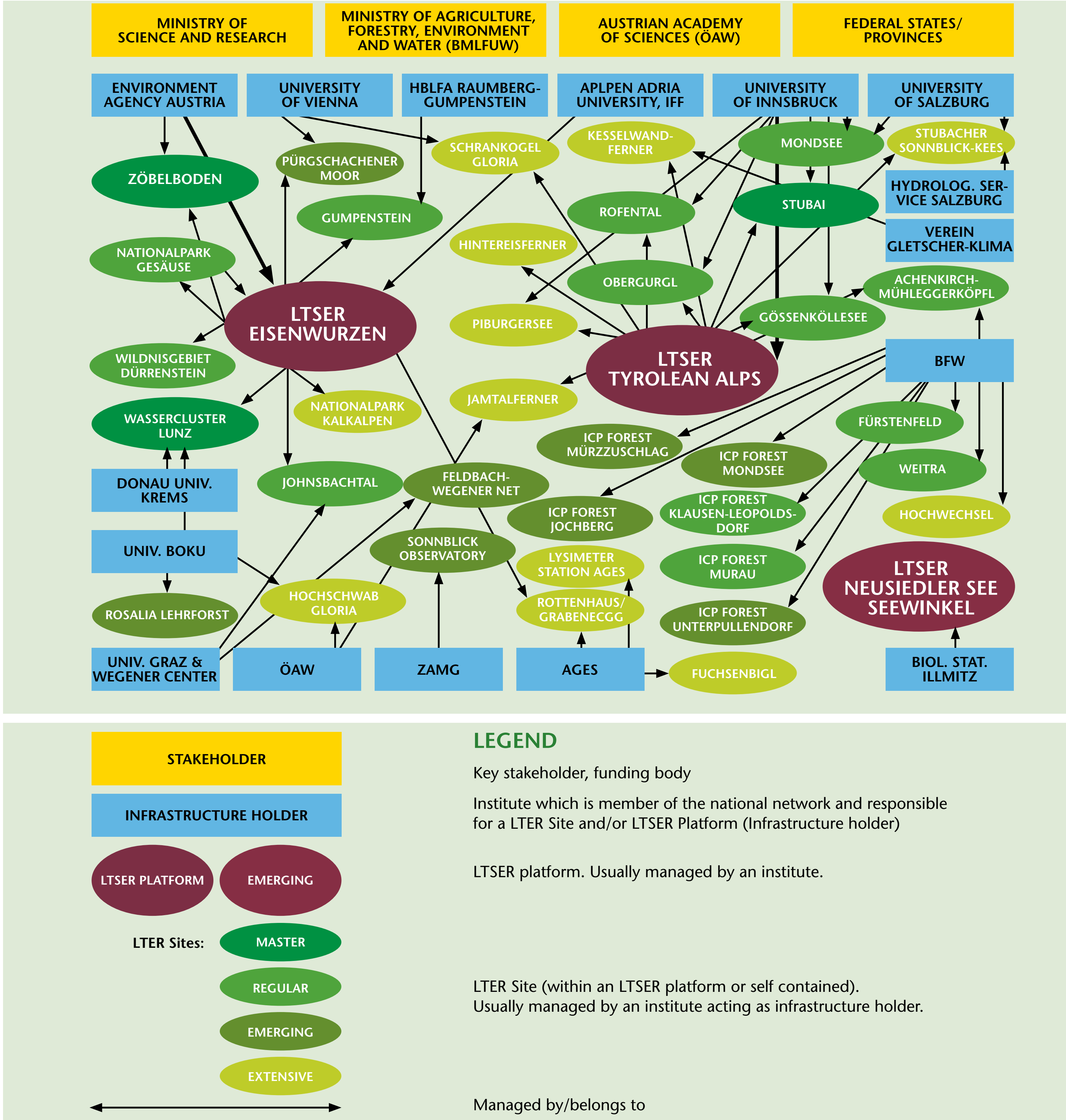


Fig. 5: "Mind Map" for LTER in Austria, showing the network of stakeholders (YELLOW), host institutions (BLUE), LTSER Platforms (DARK RED) and LTER Sites (LIGHT GREEN). Some sites are potential sites, whose classification and documentation are awaiting confirmation.

1.5.2 THE IN-SITU NETWORK OF LTER-AUSTRIA

The development of Austrian long-term ecological research (LTER) originally built upon the nationwide research activities of the Austrian Network for Environmental Research (ÖNUF) to develop projects and institutions for ecosystem research.

Two areas with a high existing concentration of such infrastructures (LTER Sites) and active research teams appeared suitable for the development of so-called LTSER Platforms:

- LTSER "Eisenwurzen" (northeastern Limestone Alps, including the pre-Alpine regions of Upper Austria, Lower Austria and Styria)
- LTSER "Tyrolean Alps" (Ötztal and Stubai Alps, Tirol)

The Eisenwurzen research platform is already largely implemented and the development of the Tyrolean Alps research platform ongoing. A further recommended platform in the Pannonian region of eastern Austria known as the "Seewinkel" has been included in the preparatory planning of the revised management plan for the biosphere reserve, and most recently was registered as the "emerging LTSER Platform Neusiedler See-Seewinkel". The complex "Mondsee" site has also acquired some of the aspects of an LTSER Platform in recent years.

LTER Sites are a) integral components of LTSER Platforms and b) beyond these, complement the LTER network through the addition of important natural spaces and indicator sites for driving factors such as climate change. Table 1 provides an overview of the Austrian LTER Sites and LTSER Platforms. The structure of the table reflects the organisation of the national pool of ecosystem research infrastructure relating to LTER:

- LTSER Platform Eisenwurzen
  - o Platform sites in alphabetical order
- LTSER Platform Tyrolean Alps
  - o Platform sites in alphabetical order
- Other LTER Sites in alphabetical order

Fig. 5 in Chapter 1.5.1 shows the organisational structure of sites and platforms (relevant institutions, etc.) and Fig. 6 shows the location of LTER Sites and LTSER Platforms.

TABLE 1: The following Austrian LTER sites and LTSER platforms were reported to the european and global LTER database; appropriately documented and accredited by LTER-Europe.:

	SITE NAME	SITE-TYPE	BE-LONGS TO	CATE-GORY	HABI-TAT-TYPE*	INFRASTRUCTURE HOLDER	CONTACT E-MAIL & WEBSITE	SCIEN-TISTS **
	LTSER Platt-form Eisen-wurzen (EW) LTER_EU_AT_001	LTSER Platform		Regular	Forest	Umweltbundesamt GmbH	Andrea Stocker-Kiss andrea.stocker-kiss@umweltbundesamt.at www. plattform-eisenwurzen.at	25
	Feldbach – WegenerNet LTER_EU_AT_029_002	Simple Site	LTSER EW	Emerging	Agricul-tural	Wegener Center für Klima und Globalen Wandel, Universität Graz	Gottfried Kirchengast gottfried.kirchengast@unigraz.at	4
	HBLFA Raumberg-Gumpenstein LTER_EU_AT_006	Complex Site	LTSER EW	Regular	Grass-land	HBLFA Raumberg-Gumpenstein	Renate Mayer; renate.mayer@raumberg-gumpenstein.at; www.raumberg-gumpenstein.at	
	Hochschwab GLORIA LTER_EU_AT_007	Simple Site	LTSER EW	Extensive	Montane	Österr. Akademie der Wissenschaften/Institut für Interdisziplinäre Gebirgsforschung & BOKU/Zentrum für Globalen Wandel und Nachhaltigkeit	Harald Pauli harald.pauli@oeaw.ac.at http://www.gloria.ac.at	
	Johnsbachtal LTER_EU_AT_029_001	Simple Site	LTSER EW	Regular	Montane	Institut für Geographie und Regional-forschung, Universität Graz	Oliver Sass oliver.sass@uni-graz.at	10
	Nationalpark Gesäuse LTER_EU_AT_005	Complex Site	LTSER EW	Regular	Forest	Nationalpark Gesäuse GmbH	Daniel Kreiner daniel.kreiner@nationalpark.co.at www.nationalpark.co.at	60
	Nationalpark Kalkalpen LTER_EU_AT_008	Complex Site	LTSER EW	Extensive	Forest	Nationalpark OÖ Kalkal-pen GmbH	Hartmann Pölz hartmann.poelz@kalkalpen.at	
	Pürg-schachener Moor LTER_EU_AT_041	Simple Site	LTSER EW	Emerging	Peatland	Univ. Wien, Institut für Geographie und Regionalforschung	Stephan Glatzel stephan.glatzel@univie.ac.at Simon Drollinger simon.drollinger@univie.ac.at	5
	Rottenhaus/ Grabenegg LTER_EU_AT_038	Simple Site	LTSER EW	Extensive	Cropland	Österr. Agentur für Gesundheit u. Ernäh-rungssicherheit (AGES)	Heide Spiegel adelheid.spiegel@ages.at www.ages.at	5
	WasserCluster Lunz LTER_EU_AT_010	Simple Site	LTSER EW	Master	Fresh-water	Univ. Wien, Univ. für Bodenkultur Wien, Donau-Univ. Krems	WasserCluster Lunz office@wkl.ac.at www.wcl. ac.at	21
	Wildnisgebiet Dürrenstein LTER_EU_AT_004	Simple Site	LTSER EW	Regular	Forest	Schutzgebietsver-waltung Wildnisgebiet Dürrenstein	Christoph Leditznig christoph.leditznig@wildnisgebiet.at www.wildnisgebiet.at	5
	Zöbelboden LTER_EU_AT_003	Complex Site	LTSER EW	Master	Forest	Umweltbundesamt GmbH	Thomas Dirnböck thomas.dirnboeck@umweltbundesamt.at Johannes Kobler johannes.kobler@umweltbundesamt.at; Ika Djukic ika.djukic@umweltbundesamt.at; www.umweltbundesamt.at/im	25

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SITE NAME	SITE-TYPE	BE-LONGS TO	CATE-GORY	HABI-TAT-TYPE*	INFRASTRUCTURE HOLDER	CONTACT E-MAIL & WEBSITE	SCIEN-TISTS **
LTSER Platt-form Tyrolean Alps (TA) LTER_EU_AT_002	LTSER Platform		Regular	Montane	Institut für Ökologie, Universität Innsbruck	Ulrike Tappeiner ulrike.tappeiner@uibk.ac.at	
Achenkirch-Mühlegger-köpfl LTER_EU_AT_024	Complex Site	LTSER TA	Regular	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturge-fahren und Landschaft (BFW)	Robert Jandl robert.jandl@bfw.gv.at www.bfw.ac.at/rz/bfwcms.web?dok=4391	10
Gossenkölle-see LTER_EU_AT_012	Simple Site	LTSER TA	Regular	Montane	Institut für Ökologie, Universität Innsbruck	Birgit Sattler birgit.sattler@uibk.ac.at Ruben Sommaruga ruben.sommaruga@uibk.ac.at	20
Jamtalferner LTER_EU_AT_014	Simple Site	LTSER TA	Extensive	Montane	Institut für Interdiszipli-näre Gebirgsforschung, ÖAW	Andrea Fischer andrea.fischer@oeaw.ac.at www.mountainresearch.at	2
Kesselwand-ferner LTER_EU_AT_016	Simple Site	LTSER TA	Emerging	Montane	Verein Gletscher-Klima	Andrea Fischer: andrea.fischer@oeaw.ac.at www.gletscher-klima.at	6
Obergurgl LTER_EU_AT_018	Complex Site	LTSER TA	Regular	Montane	Alpine Forschungsstelle Obergurgl, Universität Innsbruck	Nikolaus Schallhart klaus.schallhart@uibk.ac.at http://www.uibk.ac.at/afo	35
Patscherkofel LTER_EU_AT_019	Simple Site	LTSER TA	Closed (1963-2008)	Montane	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Gerhard Wieser gerhard.wieser@uibk.ac.at Gilbert Neuner gilbert.neuner@uibk.ac.at	
Piburger See LTER_EU_AT_020	Simple Site	LTSER TA	Extensive	Fresh-water	Institut für Ökologie, Universität Innsbruck	Ruben Sommaruga ruben.sommaruga@uibk.ac.at Ulrike Nickus ulrike.nickus@uibk.ac.at	
Rofental LTER_EU_AT_042	Complex Site	LTSER TA	Regular	Montane	Institut für Meteorologie und Geophysik und Institut für Geographie, Universität Innsbruck; Kommission für Glaziologie, Bayerische Akademie der Wissenschaften	Georg Kaser georg.kaser@uibk.ac.at Ulrich Strasser ulrich.strasser@uibk.ac.at Ludwig Braun ludwig.braun@lrz.badw-muenchen.de http://imgi.uibk.ac.at/research/ice-and-climate/projects/hef	> 20

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SITE NAME	SITE-TYPE	BE-LONGS TO	CATE-GORY	HABI-TAT-TYPE*	INFRASTRUCTURE HOLDER	CONTACT E-MAIL & WEBSITE	SCIEN-TISTS **
Schrankogel (GLORIA Master Site) LTER_EU_AT_021	Complex Site	LTSER TA	Extensive	Montane	Univ. Wien, Department für Naturschutzbiologie, Vegetations- u. Landschaftsökologie	Harald Pauli; harald.pauli@univie.ac.at www.gloria.ac.at/?a=42&b=56	
Stubacher Sonnblickkees LTER_EU_AT_023	Simple Site	LTSER TA	Extensive	Montane	Hydrologischer Dienst Salzburg Universität Salzburg	Hans Wiesenegger hans.wiesenegger@salzburg.gv.at Bernhard Zagel bernhard.zagel@sbg.ac.at	
Stubai LTER_EU_AT_015	Complex Site	LTSER TA	Master	Grass-land	Institut für Ökologie, Universität Innsbruck	Ulrike Tappeiner ulrike.tappeiner@uibk.ac.at Georg Wohlfahrt georg.wohlfahrt@uibk.ac.at Michael Bahn michael.bahn@uibk.ac.at www.uibk.ac.at/ecology	75
LTER Standorte ohne Zugehörigkeit zu einer LTSER Plattform							
Fuchsenbigl LTER_EU_AT_030	Simple Site		Extensive	Cropland	Österr. Agentur für Gesundheit und Ernährungssicherheit (AGES)	Heide Spiegel adelheid.spiegel@ages.at www.ages.at	10
Fürstenfeld LTER_EU_AT_025	Simple Site		Regular	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Michael Englisch; michael.englisch@bfw.gv.at	4
Hochwechsel LTER_EU_AT_026	Simple Site		Extensive	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Michael Englisch michael.englisch@bfw.gv.at	4
ICP Forest Jochberg LTER_EU_AT_033	Simple Site		Emerging	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@bfw.gv.at http://bfw.ac.at/rz/bfwcms.web?dok=3833	10
ICP Forest Klausen-Leopoldsdorf LTER_EU_AT_031	Complex Site		Regular	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@bfw.gv.at http://bfw.ac.at/rz/bfwcms.web?dok=3983	10
ICP Forest Mondsee LTER_EU_AT_034	Simple Site		Emerging	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@bfw.gv.at http://bfw.ac.at/rz/bfwcms.web?dok=3827	10

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	SITE NAME	SITE-TYPE	BE-LONGS TO	CATE-GORY	HABI-TAT-TYPE*	INFRASTRUCTURE HOLDER	CONTACT E-MAIL & WEBSITE	SCIEN-TISTS **
	ICP Forest Murau LTER_EU_AT_032	Simple Site		Regular	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@ bfw.gv.at http://bfw.ac.at/rz/bfwcms. web?dok=3832	10
	ICP Forest Mürzzuschlag LTER_EU_AT_035	Simple Site		Emerging	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@ bfw.gv.at http://bfw.ac.at/rz/bfwcms. web?dok=3831	10
	ICP Forest Unterpullen-dorf LTER_EU_AT_036	Simple Site		Emerging	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Markus Neumann markus.neumann@ bfw.gv.at http://bfw.ac.at/rz/bfwcms. web?dok=3818	10
	LTSER Plattform Neusiedler See – Seewinkel (NSS) LTER_EU_AT_028	LTSER Platform		Emerging	Fresh-water	Biologische Station Neusiedler See, Illmitz	Thomas Zechmeister thomas.zechmeister@ bgld.gv.at www.burgenland.at/natur-umwelt-agrar/natur/ biologische-station-neusiedler-see	25
	Lysimeter-Station AGES LTER_EU_AT_040	Simple Site		Extensive	Cropland	Österr. Agentur für Gesundheit und Ernährungssicherheit (AGES)	Helene Berthold helene.berthold@ages.at Andreas Baumgarten andreas.baumgarten@ ages.at	
	Mondsee LTER_EU_AT_039	Complex Site		Regular	Fresh-water	Forschungsinstitut für Limnologie, Mondsee, Universität Innsbruck; Interfakultärer Fachbe-reich Geoinformatik, Paris Lodron Universität Salzburg	Thomas Weisse thomas.weisse@uibk.ac.at Rainer Kurmayer rainer.kurmayer@uibk.ac.at www.oeaw.ac.at/limno Hermann Klug hermann.klug@sbg.ac.at	8
	Rosalia Lehrforst LTER_EU_AT_037	Simple Site		Emerging	Forest	Universität für Bodenkultur	Josef Gasch josef.gasch@boku.ac.at Michael Zimmermann michael.zimmermann@ boku.ac.at; www.wabo.boku.ac.at/ lehrforst	20
	Sonnblick LTER_EU_AT_022	Simple Site		Emerging	Montane	Zentralanst. für Meteo-rologie u. Geodynamik ZAMG/Sonnblickverein	Bernhard Niedermoser bernhard.niedermoser@ zamg.ac.at www.sonnblick.net	50
	Weitra LTER_EU_AT_027	Complex Site		Regular	Forest	Bundesforschungs- u. Ausbildungszentrum für Wald, Naturgefahren u. Landschaft (BFW)	Michael Englisch michael.englisch@ bfw.gv.at www.sustman.de	5

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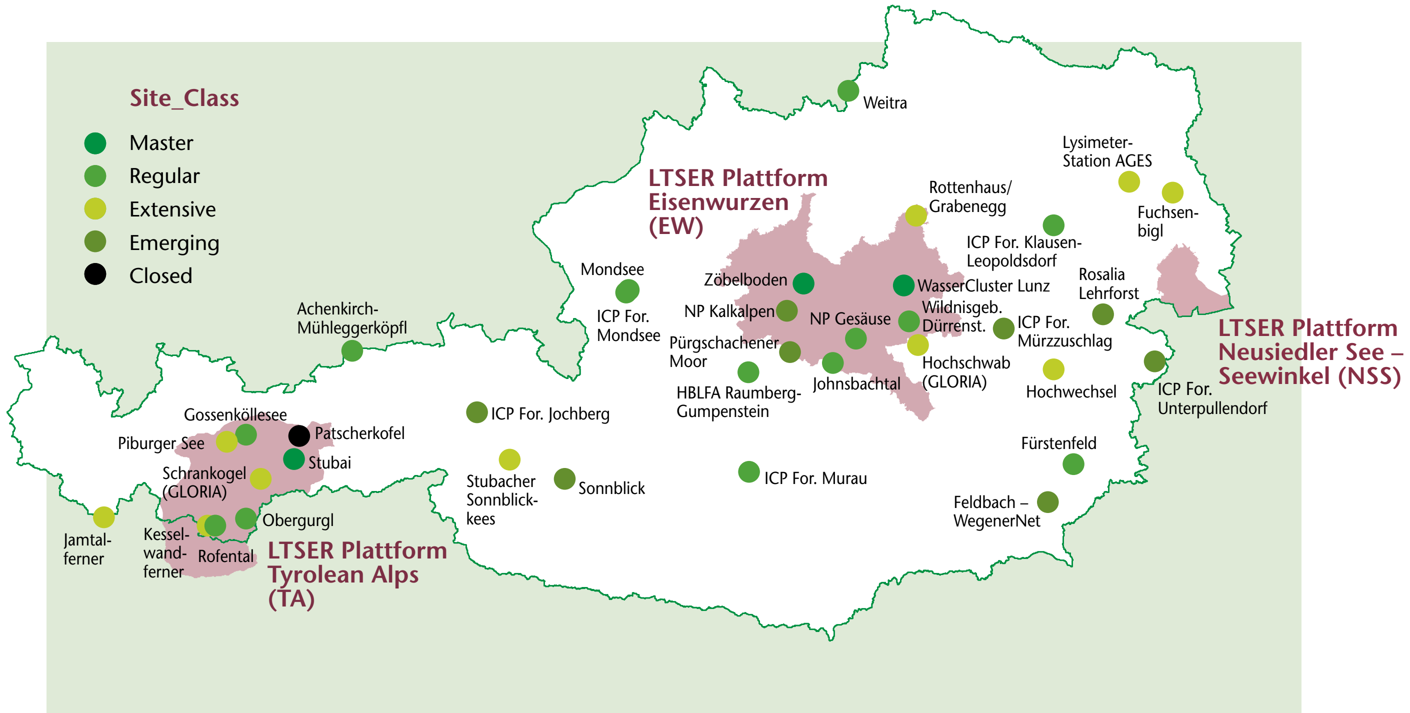

Fig. 6: Map showing the Austrian LTER Sites and LTSER Platforms

38 Austrian LTER Sites and LTSER Platforms are registered within the European and global LTER network. One site was closed (Patscherkofel), but still serves as data source. The LTER Sites are subdivided into the categories of "LTER Master Site" (3), "Regular LTER Site" (15) and "Extensive/Emerging Site" (remainder). The description of these categories can be found on the LTER-Europe website (http://www.lter-europe.net, sections "Organisation/key documents/criteria" and "Sites and Platforms"). LTER-Austria thus represents all relevant Austrian ecosystem types and contributes to the division of work in the European network of 24 countries.

Of particular importance (see chapter 1.3) are the two LTSER Platforms in the regions of "Tyrolean Alps" and "Eisenwurzen" as focal areas for LTER-Austria, and these include 11 sites in the case of Eisenwurzen and 10 sites in the case of the Tyrolean Alps.

Since the sites were established, in some cases as far back as 100 years ago, more than 700 scientists have worked there, producing unique hot spots for ecological knowledge in the process. Currently, c. 300 national and international scientists are working at these sites or with the data from these sites, excluding the duplicated addition of those working at more than one of these sites. In total, c. 500 projects have taken place. These figures are based on ongoing collection of metadata, with a current return rate of 90% and can thus be extrapolated for 100%. Because of its particular terms of reference and form of data utilization, the figures for Sonnblick cannot be included in these statistics.

The infrastructures are managed by 19 institutions. The accumulated infrastructure value of the network is calculated to be c. 7 - 9 Mio EUR (6 Mio EUR more, if the Sonnblick site is included). Austrian was one of the first countries in Europe to launch an initiative towards integrating existing in-situ infrastructures by bringing together suitable sites of ICP Integrated Monitoring, ICP ¬Forest, ICP Waters, EMEP, etc. (network analysis from COST FP0903, October 2010), with this being a first strategic step towards that goal. The necessary operational integration, organisational requirements and funding for this were key motivations for this position paper. Chapter 6 expands on the current strategic framework in the European context.

A brief description of the sites, their research foci and respective related key publications can be found in the Annex in Chapter 8.1.

1.5.3 STATUS

The focus of LTER-Austria to date has been the endeavour to bring together the relevant infrastructures and research teams. A research community of more than 200 researchers, working in c. 25 institutions, takes its frame of reference in terms of social responsibility and orientation from the the concepts developed since 2005 for European LTER (www.lter-europe.net) as well as the new framework conditions of the ESFRI landscape (with LTER forming part of the "Environment" area).

In as much as the bottom-up approach was feasible, a network emerged that has consolidated its position in a European context. This consolidation is largely the result of the involvement of individual researchers, sites and institutions in a wide variety of projects. LTER-Austria functions to an increasing degree as a platform, by means of which further national institutions can move beyond traditional relationships based on competition to become involved in suitable projects (z.B. FP7/ INFRA-2010 Projekt „EXPEER", Horizon2020 FORESTING and eLTER, FP6/ ALTER-Net). In 2012, 156 sites from 20 countries responded in concerted fashion to the "Infrastructure Survey" of the EC, among them 24 Austrian sites.

The still fragmented character of ecosystem research in Austria, both in terms of infrastructures and research projects and increasing demands for strategic approaches and centralized services (data management, the coordination of activities across the sites both at national and international level, standardisation and a basic measurement programme) provide the key motivation for developing this position paper. Key qualities and requirements for research into long-term trends in our systems (research teams above a critical size, which f acilitate interdisciplinary working; basic monitoring, etc.) and the competitiveness of Austrian infrastructures in the European Research Area (ERA) need to be secured. Multiple utilization, both of the sites themselves and the data (both nationally and internationally), is a key criterion in this respect.

In this sense, the synthesis chapter 7 of this document formulates a vision for overcoming existing weaknesses and achieving the optimal utilization of the potentials created.

2 THEMATIC AREAS OF LTER IN AUSTRIA

2.1 DEFINITION

LTER-Austria provides a platform for ecological and socio-ecological research, as facilitated on one hand by exclusively national framework programmes, such as the KLF (Cultivated Landscape Research, or Kulturlandschaftsforschung) and ProVision in the past, and as suggested on the other hand now by European strategies (ENVRI+).

LTER-Austria unites and links the key thematic areas in a consistent manner, as these are found in recognised conceptual models (see below, Fig. 7) and as characterised in the following key words:

Process-oriented ecosystem research:
- Natural sciences basic research
- Investigation of functionally and structurally important ecosystem compartments
- Long-term impacts of drivers and combinations of drivers upon ecosystem functions and services)

Biodiversity and nature conservation research:
- Recording the status, trend and functional relationships of species
- Ensuring the long-term survival of species, their genetic diversity and ecological integrity and functionality of habitats
- Long-term safeguarding of biodiversity supported ecosystem services
- Analysis and scenarios for the adaptation of species and habitats to global change (including climate change)

Deadwood in the forest: © Irene Oberleitner

Socio-ecological research:
- Socio-ecological basic research: Society-nature interaction, socio-ecological transitions, changes in resources use
- Environmenal history and historical sustainability research
- Integrated socio-ecological modeling: Process and systems knowledge, scenarios, interdisciplinary integration
- Helping the effective response to grand societal challenges (e.g. sustainable water, food and energy supply, population growth, health)

If ecological research is to deliver results that are both socially and politically relevant, the complexity of our socio-ecological systems requires that the formulation of research questions must consider or include more than one of these areas. A key aim is to achieve the best possible consolidation within the European Research Area.

LTER-Austria facilitates this through:
- Interdisciplinary expertise (scientific research forum)
- Concrete research sites and regions (expertise and data hotspots)
- International networks (project-level; LTER-Austria as one of 24 national networks in LTER-Europe)

LTER-Austria and the White Paper on long-term ecological research in Austria have faced and continue to face the challenge of covering the breadth of expertise encompassed by ecosystem research, without diluting the weight and the specific requirements of the key thematic areas.

2.2 LINK TO CONCEPTUAL MODELS

The decision to define thematic areas was taken as much on pragmatic grounds as on account of the linkage to conceptual models: It reflects groupings within the scientific community, their different clients, funding bodies, aspects of practical implementation, and political and management requirements. The thematic areas encompass key building blocks of recognised conceptual models of society-nature interaction, which are employed in current sustainability research and in environmental and sustainability reporting, as well as in monitoring:

- DPSIR (Driver-Pressure-State-Impact-Response): The DPSIR schema systematises the interdependencies between societal activities and changes in ecosystems. It assumes that "drivers" (e.g. economic or population growth) lead to "pressures" (e.g. emissions). These in turn produce changes in the "state" of ecosystems, which can threaten ecosystem services ("impacts"). Society attempts to take counter measures by means of "responses" (e.g. environmental protection measures, sustainability policies). This schema is used particularly in order to systematise environmental and sustainability indicators (EEA 2007).

- SES (Socio-Ecological Systems research): The research into complex socio-ecological systems, which arise through the interaction between societies and their natural environment, has been driven forward by groups such as the "Resilience Alliance" (see http://www.resalliance.org/). At its centre lies the theory of complex adaptive systems, applied to the question of under which conditions socio-ecological systems may prove themselves to be "resilient", i.e. capable of maintaining their key functional relationships even under conditions of environmental change. This focuses primarily upon system dynamics considerations such as non-linearity ("expect the unexpected"), vulnerability and adaptability. This approach is explicitly related to different scale levels and the pace of change (Gundeson und Holling, 2002). A key demand concerns "adaptive management", i.e. a way of managing ecosystems, which explicitly acknowledges the unknown, the uncertain, and the mutability of systems and framework conditions (Vadineanu, A., 2004). A concept that is compatible with this approach is the model of socio-ecological interaction that has been developed by the Vienna Institute for Social Ecology, which focuses particularly on the analysis of material and energy flows between society and ecosystems and their changes due to socioeconomic and natural factors (Fischer-Kowalski M. & Weisz H. 1999).

- Human-Environment Systems (H-E Systems). This approach, which is strongly influenced by geography, plays an important role particularly in the area of land use research, which in recent times has often been termed "integrated land-change science". It is based on the assumption that land systems are integrated complex systems, which are the result of interaction between socio-economic components, such as population, economy, institutions, culture, etc., with ecological components, such as soil, water, organisms/biotic communities, biogeochemical cycles, etc. The aim of integrated land systems research is to understand processes of change and vulnerabilities in order to provide scientific foundations for more sustainable forms of land use (GLP 2005, Turner et al 2007).

- ISSE/PPD (Integrated Science for Society and Environment/ Pulse Pressure Dynamics, US-LTER, Collins et al., 2011): The ISSE (or more recently, PPD) model emerged from the US-LTER programme based on a project from the National Science Foundation (NSF) and gives structure to an integrated research programme for socio-ecological research. The central feature of the model concerns the interactions between human awareness, human behaviour and societal institutions and the structure and function of ecosystems. This distinguishes between long-term pressures, or "long-term press" and short-term fluctuations, or "short-term pulse". Ecosystem services are seen as the result of ecosystem function, which in turn impacts on society. The model also takes account of "external drivers", such as climate change (see the document "Integrative Science for Society and Environment – A Strategic Research Initiative" www.lternet.edu/decadalplan). The ESI (Ecosystem Service Initiative) of the global LTER network, ILTER, builds upon ISSE, in its attempt to describe socio-ecological systems through a worldwide comparison.

Using these various conceptions as a basis, the conceptual model of society-nature interaction presented in Fig. 7, was developed, encompassing the research areas covered by this White Paper and indicating the interactions between different (regional – global) scales. Process-oriented ecosystem research focuses on researching the function of ecosystems, including their changes as a result of human interventions or the impacts of global change. Biodiversity and nature conservation research concentrates on baseline surveys of the status quo and on changes within species distribution and ecosystems, and also includes socio-economic aspects, particularly when these concern the protection, manifestation and alteration of biodiversity. Socio-ecological research concentrates on the analysis of interactions between socio-economic systems and ecosystems. In all cases, interactions with natural and socio-economic factors at other spatial scales – indicated here by the term "Earth System" – must be taken into account.

Intensive plot at Zöbelboden: © Smidt

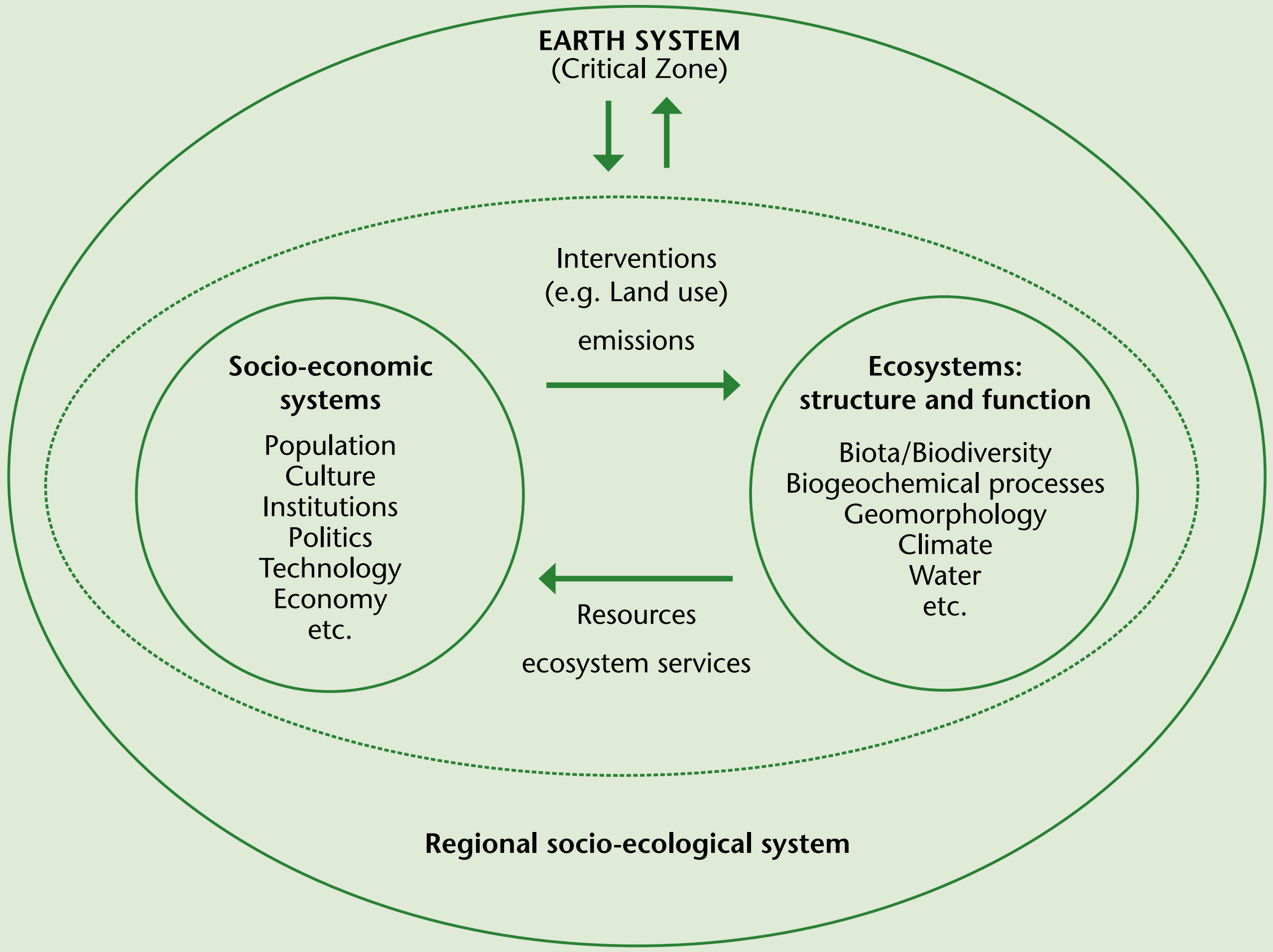

Fig. 7: Concept of society-nature interaction for regional soci-ecological systems, e.g. LTSER Platforms. Created on the basis of Fischer-Kowalski and Weisz, 1999; EEA 2007, GLP 2005 and the ISSE model.

The term "Earth System" was chosen in reference to the "Earth System Science Partnership" (ESSP), since this union of research programmes concerning global change encompasses all the components considered here: Biodiversity (DIVERSITAS), biogeochemical cycles (IGBP), climate (WCRP) and socio-economic aspects (IHDP). More recently, the zone between deep geosphere and stratosphere, where all these occur, has also been named "Critical Zone".

2.3 STRUCTURE OF THEMATIC AREA CHAPTERS

Each of the three following thematic area chapters follows the basic structure set out in Info-Box 2, to enable comparison between the thematic areas and to facilitate the synopsis (Chapter 7).

Priority research themes
LTER-Austria provides a platform for the development of research projects with high-quality research in the individual thematic areas, which are harmonized as far as possible with the research foci of the other thematic areas (thematic, temporal, spatial, infrastructural and logistic). N.B.: priority research can also refer to methods (in contrast to the next chapter).

Approaches and methods
A description of the approaches and methods (existing tools), which are of key importance for or specific to the thematic area.

Requirements
Focus on those requirements, which are specific to the thematic area.

Products and addressees
Products and addressees of the research results within the thematic area (across all stakeholders).

Networks with other thematic areas
The most important or innovative connecting points respectively to the other two thematic areas.

Info-Box 2: Basic structure for the chapters on the 3 thematic areas of LTER-Austria.

3 PROCESS-ORIENTED ECOSYSTEM RESEARCH (THEMATIC AREA I)

The previous sections have described the special characteristics of this thematic area as a core element of natural sciences and the starting point for the more comprehensive current LTER concept. Despite all the successes to date, many LTER networks and thus also the thematic area of process-oriented ecosystem research have been and continue to be confronted by structural challenges, which a) may be explained by the pronounced "bottom-up" nature of its emergence over recent years, and b) result from the long-term nature of e.g. resources, technology and meta-information, which represents a unique core quality of LTER (ILTER Strategic Plan, 2005).

These include:
(1) the fact that investigation sites have not been selected according to the best available representation of eco-climatic gradients or other such criteria, which would enable the identification of patterns or an "up-scaling" of processes to large spatial units (e.g. regions or continents), but that instead, existing sites must be utilized (LTER Sites are maintained on a voluntary basis and are not (yet) centrally funded).

(2) the fact that the further development of the networks requires a huge effort in terms of coordination, which at European level is only supported by the Network of Excellence ALTER-Net for a fixed term. Ecosystem research must orient itself conceptually not only in relation to the spatial scales and patterns of the processes under investigation but also in relation to temporal aspects. Alongside the frequently investigated short-term to mid-term processes, ecosystems are impacted strongly by long-term processes, the existence or significance of which is often only recognised or estimated ex post. Examples of this are the hole in the ozone layer over Antarctica or global change. In long-lived ecosystems, such as forests, many processes can only be recorded at all by means of long-term ecosystem research. Since the beginning of formalised forest research at the start of the 19th century, only one or two forest cultivation cycles have taken place within domestic forest ecosystems. Furthermore, the feedbacks of social processes with ecosystem processes usually extend over decades (land use change).

3.1 RESEARCH QUESTIONS

The general aim of this thematic area is to analyse spatial and temporal changes in systems caused by different influencing facts – including climate and land use change – and their impacts upon biogeochemical cycles. The integration of terrestrial and aquatic systems within ecosystems is an important consideration within this research endeavour.

The thematic area of process-oriented ecosystem research examines the impacts of drivers that are external and internal to the system under investigation upon the material cycles within ecosystems.

The following key processes are central to this research area (Fig. 8):
I. Regulation of primary and secondary production, the removal and accumulation of dead organic material in terrestrial and aquatic ecosystems with particular reference to the problem of greenhouse gases.

II. Interactions between carbon-, nutrient- and water-cycles in natural and disturbed ecosystems and their feedback effects on the climate system

III. Impact of spatial-temporal patterns and the intensity of disturbances (such as neobiota, pathogenic pests, droughts, storms, heat waves, etc.) on the stability of biological systems.

Where the formulation of concrete research questions is concerned, it is helpful to sub-divide the questions into four categories: (1) stability and disturbance, (2) interactive effects, (3) feedback effects, and (4) scaling.

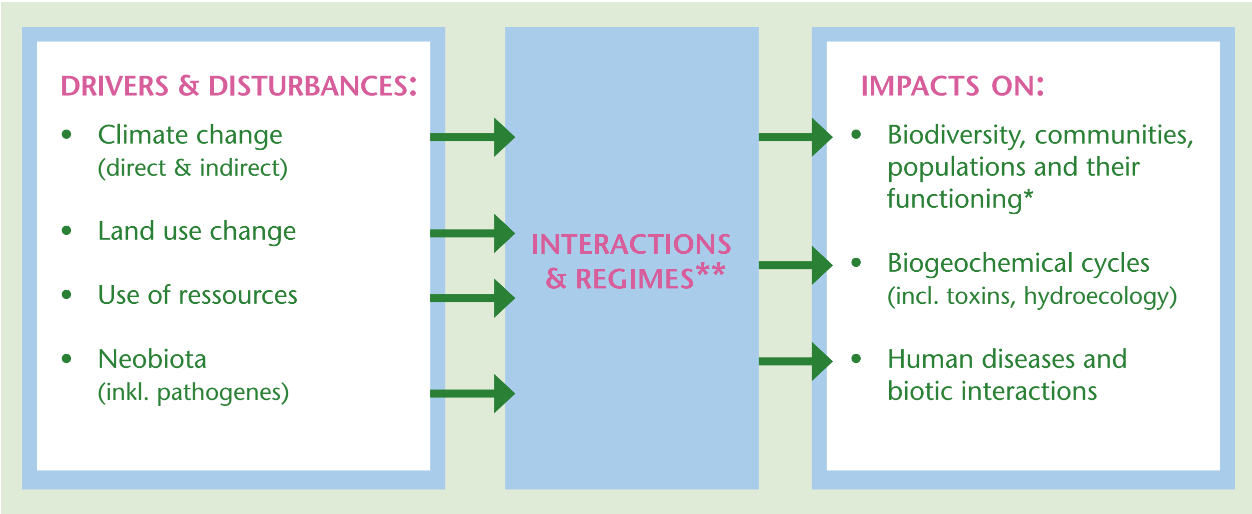

Fig. 8: Overview of and relation between research questions in process-oriented ecosystem research: Drivers and disturbances impact upon a system. They alter interactions within the system or regime (regime = the sum of interactions and specific combinations of drivers). These changes in turn influence the ecosystem and its functions.

(1) Stability and disturbance
Ecosystems are affected by interactive effects on one hand and on the other, are characterized by different degrees of resilience with regard to disturbances. For this reason, the definition of characteristic threshold values at which irreversible changes take place (e.g. degradation through massic erosion in mountain environments), is highly relevant in ecosystem research, since they can have a direct impact upon the degree to which ecosystems can be utilized by human societies. The focus lies particularly with the interactions between disturbances and the effects of such disturbances upon ecosystems. Research questions in this area can include:

- How do climate variability and extreme events (extreme weather events, pest infestation, pathogens, neobiota) affect material flows and the stability of ecosystems? Fig. 1
- How (far) dioes biodiversity affect the resistence and resilience of ecosystems to/after disturbances?

(2) Interactive effects of explanatory variables upon ecosystem processes
By interactive effects of different explanatory variables on ecosystem processes in space and time, we refer to the reciprocal reinforcement or superimposition of disturbances and their effects on both population dynamics and on the material flows of ecosystems. Of particular interest here are both short- and long-term interactive effects. Concrete research questions within this category include:

- How do disturbances and population dynamics interact in their effect upon material flows within ecosystems in the long term?
- How do interactive effects impact on nutrient inputs and climate changes impact upon primary and secondary production and the removal of organic materials?
- What interactive effects do land use changes and climate changes have upon material flows in ecosystems?
- How do interactive effects of greenhouse gases, pollutants, pathogens and neobiota affect material flows and the stability of ecosystems?

(3) Feedback effects and impacts on socio-ecological systems
Whereas the first two categories of research question are concerned with the processes within an ecosystem, at a larger integration scale, feedback effects and the effects of altered ecosystem processes upon other (especially socio-ecological) systems and thus upon ecosystem services are investigated:

- What impacts do climate change and land use changes have upon the exchange of greenhouse gases between ecosystems and the atmosphere and how does this impact upon global climate change?
- What influence do climate change and land use changes have upon the energy balance of ecosystems and does this in turn have an impact upon radiative forcing?
- What influence do climate change and land use changes have upon the exchange of reactive trace gases between ecosystems and the atmosphere, how does this impact upon regional air quality and what changes in the structure and function of ecosystems thereby arise?
- What impact do climate change and land use have upon the regulation and storage of water in ecosystems?
- To what extent does a potential decrease in water quality lead to increases in the costs of water use?
- What effects do demographic changes and related changes in land use, together with the abandonment of formerly cultivated areas have on the relation of areal evaporation to runoff? How are the stability of ecosystems and the protection of settlement areas from natural hazards influenced by changes in the water balance of catchment areas? How do changes in land use affect drinking water quality? How do processes related to climate change, such as the retreat of glaciers and the creation of aquatic ecosystems, affect water quality?
- What impact does climate variability have upon human pathogens and what influence does it have upon the related societal dynamics and the material flows resulting from these?

(4) Spatial relation (scaling)
All the model research questions presented here have one thing in common: They are applied at different scale levels, or face the challenge of addressing different scale levels. It is characteristic of process-oriented ecosystem

Measuring weir: © Michael Mirtl

research that it is undertaken in small-scale, site-specific units. The question of scalability for the results of such research approaches is therefore a fundamental question for ecosystem process research, which is in itself a subject of research. Possible questions in this area include:

- Do the control parameters for ecosystem processes, such as primary and secondary production or carbon storage in soils, vary according to the scale level?
- How does the interaction between carbon and nitrogen cycles change at different spatial scale levels?

3.2 APPROACHES AND METHODS

Where the research into interactive effects and into stability and disturbances has a rather observational or experimental character, the analysis of research questions in the areas of feedback effects and scaling generally requires modeling approaches in terms of research methodology. The requirements in terms of the methods and approaches that find application in process-oriented ecosystem research vary accordingly.

In the interests of cost-effective and targeted use of resources ("It is not possible to measure and monitor everything, everywhere, all the time"), hypotheses need to be formulated and tested using modeling or exploratory statistics; in turn, this can lead to the development of measurement and monitoring concepts that are new and/or multi-scale in a spatial or temporal sense.

It will be crucial for the future of LTER, to integrate such combined approaches within one site concept. Base on the results and experiences of international LTER research, the next step would be to develop a structured design for LTER-Austria based on a "top-down" approach, which would allow for the later scaling of research results from local through regional to national level and beyond.

In the USA, the infrastructure requirements have led to the development of "top-down" concepts, the most important of which is NEON (National Ecological Observatory Network). NEON has not superseded LTER but instead represents a strong further development from LTER: here a research platform is currently being constructed with the aim of investigating the effects of climate change and changes in land use changes, together with the impact of invasive species upon the ecology of North America as a continental observatory, not as a collection of local or regional sites, and with a stringent methodological design across all research units. The revolutionary aspect of this lies in the administrative structure, which transcends particular interests and envisages dedicated units with the task of recording high-quality data series and able to make these accessible in real time to all interested researchers for analysis and processing – a concept, which incidentally has been a reality within meteorology for a long time already. The only notable criticism of the NEON concept relates to the focus on processes in natural spaces that employs a purely natural science approach.

Process-oriented ecosystem research has a high requirement for continual monitoring of physical and chemical environmental parameters as well as measurement of biotically controlled processes (such as the gas exchange between ecosystems and the atmosphere). The measurement methods used require a great deal in terms of scientific infrastructure and high-performance cyber infrastructure. This requirement increases where such monitoring activities employ greater automatisation and higher temporal resolution.

3.3 REQUIREMENTS

To give momentum to the spatial optimization of the design of LTER-Austria (research sites), the network needs to be able to function over the long-term. This requires management and administrative restructuring as an internationally established research cluster, in which context the international framework is currently more highly developed than the complementary structure at national level. Given the relatively high fluctuation in terms of scientific research staff at universities and the predominance of third-party funding for university research, these are less well-suited for long-term management roles.

The central coordinating body of LTER-Austria and project management should therefore be established within an institution such as the BFW or UBA. Establishing an appropriate structure for the management of data and research within the network is a critically important task, in the context of which standards and tools from the international context (ESFRI/LifeWatch, ILTER, LTER-Europe, INSPIRE, EML) could be made use of via a national coordinating body.

Considerations of needs related to the thematic area of "Process-oriented ecosystem research" regarding the structure of the network provide the basis for the suggested overall structure, which is presented in the synthesis chapter 7.3.1 on "Strategic Organisation" on p. 52. This organisation and its functions should thus be seen as core requirements of the thematic area.

3.4 PRODUCTS AND ADDRESSEES

The products of this thematic area within LTER-Austria are responses to the research questions presented above. In the area of process-oriented ecosystem research, this relates in the first instance to data collected via high resolution measurements and analysed both in terms of the potential for reconstructing past events and in order to estimate possible future developments. This means that in this thematic area, particular significance is assigned to the way in which data is processed.

We therefore recommend that a National Centre for Ecological Data Analysis should be established, which, supported by the data of LT(S)ER Austria and the expertise of participating scientists,

(1) effectively prepares and provides access to data for users from the social and political realms and the scientific community, and

(2) is also able to respond to enquiries from politically relevant bodies, agencies or interest groups and other stakeholders and, where feasible, to supply science-based frameworks for planning and decision making.

3.5 NETWORKING WITH OTHER THEMATIC AREAS

Fundamentally, current issues such as global change require networked collaboration between expert groups working on a multidisciplinary basis (EPBRS, 2010). In the area of long-term ecosystem research, LTER offers an excellent framework in terms of its research regions and platforms for the development of transdisciplinary cooperation. Interdisciplinary cooperation is characterised by the high scientific standards within the LTER network, particularly through efficient information transfer between the research teams and optimized communication within a scientific "Community of Excellence".

Significant networking aspects for biodiversity and nature conservation research and for socioeconomic approaches (LTSER) are envisaged in the area of research into the functional biodiversity of ecosystems.

Where all sub-areas of this field of research are concerned, this involves on one hand an understanding of processes and on the other, the evaluation of ecosystem functions with regard to ecosystem services (ESS), which encompass auxiliary, supply-related, regulatory and cultural services (Millennium Ecosystem Assessment 2005). The great challenges of the present and the near future (sustainable supply of raw materials, water, food, and energy, health and leisure) require the networking and coordination of the research areas, since there are points of conflict in many fields, e.g. potentially between biodiversity and/or climate adaption measures (competing land use interests), which ultimately also lead to a consideration of values or to political discussions. In such cases, only effectively networked research can deliver a well-founded basis for decision making.

4 BIODIVERSITY RESEARCH AND CONSERVATION BIOLOGY (THEMATIC AREA II)

Natural ecosystems provide a wealth of services that are useful, or even critical to humans (Daily, 1997; MEA, 2003). Biodiversity, while being of intrinsic value per se, is meant to be a system property crucial to the provision of many of these services (Kremen, 2005; Luck et al., 2003). However, the link between diversity, ecosystem function and ecosystem services is complex and multi-layered (Hooper et al., 2005, Mace et al., 2012). Given the many threats to the future of biodiversity (Ehrlich & Pringle, 2008; Sutherland et al., 2014; Tittensor et al., 2014), our limited knowledge of how human uses depend on and influence biodiversity is particularly alarming. Developing an agenda that links biodiversity research to socio-ecology in general, and to the study of ecosystem service provision and resource management in particular is hence an urgent issue.

The European Commission recognized the importance of biodiversity and the ecosystem services it provides and states in its "biodiversity strategy to 2020" that by 2050 biodiversity and ecosystem services are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity (COM, 2011). By 2020, biodiversity loss should be halted and ecosystem services should be restored so far as feasible, and six targets and twenty actions were defined in an action framework for 2010-2020 (COM, 2011). The European Platform for Biodiversity Strategies (EPBRS) compiled a research strategy (EBPRS, 2010) and defined research priorities (EPBRS, 2013) that support the implementation of the six targets of the EU Biodiversity Strategy 2020. However, it is clear that additional efforts are required to meet the actual policy targets und to halt biodiversity loss (Tittensor et al., 2014).

In December 2014, the "Austrian Biodiversity Strategy 2020+" (BMLFUW, 2014) was published. It underpins the importance of biodiversity and nature protection in Austria. In particular the recommended measures in the field of biodiversity research and monitoring (target 2) are ideally suited for implemententation by biodiversity research within LTER-Austria.

In compliance with the requirements above, we hereby present a research framework for Austrian biodiversity research under the umbrella of the Long-term Ecosystem Research (LTER) network (Mirtl, 2010; Mirtl et al., 2010). We elaborate research recommendations for the topics conservation of species and habitats, structural changes, and adaptation to climate change, and for the development of new methodological approaches.
We further discuss institutional requirements for achieving a successful, efficient and competitive biodiversity research in Austria. We address the products of such research and their users as well as interlinks with the other thematic areas of LTER, namely process-oriented ecosystem research and socio-ecological research.

Lake Lunz: © Günther Eisenkölb

4.1 PRIORITY RESEARCH THEMES

Biodiversity research in the context of LTER is conducted over long periods of time, considers the full range of relevant scales, and/or relies on the LTER in situ infrastructure (Dirnböck et al., 2013). The biodiversity research priorities presented here are based on several strategic documents targeting the Austrian and the European level. We used only strategic documents, which had been compiled by a wide range of scientists and stakeholders to guarantee the integration of the breadth of the national research communities' priorities. The Austrian perspective is provided by documents compiled at the national level, such as the Hardegger Declaration ("Hardegger Erklärung"), which was elaborated at the kick-off meeting of the Austrian Platform for Biodiversity Research (Plattform Biodiversität Forschung Austria – BDFA) and signed by 172 Austrians active in the field of biodiversity research and management. We also considered a survey on the prioritization of issues in Austrian biodiversity research, which was conducted by the BDFA (Platform for Biodiversity Research in Austria, 2008), and was based on a British shortlist of the 100 most politically relevant ecological questions (Sutherland et al., 2006).
In addition, the members of the conservation platform at the Federal Environment Agency – mainly including representatives of administrative bodies, NGOs, and businesses – were questioned. We focused on research that is of outmost importance taking the Austrian biophysical conditions and land use patterns into account, i.e. high importance of mountains, forests, freshwater and agricultural ecosystems. As the Austrian biodiversity research priorities are strongly linked to the European research agenda, we included the European perspective which is provided by several strategic documents elaborated by the EPBRS; this especially applies to "Mountain Biodiversity" (EPBRS, 2006), "Biodiversity in the Wider Countryside" (EPBRS, 2007a), "Biodiversity and Ecosystem Services" (EPBRS, 2007b) and "Freshwater Biodiversity" (EPBRS, 2008), being of particular relevance for the most important Austrian ecosystems. Consideration was also given to the EPBRS recommendations regarding ecosystem services (EPBRS, 2011) and to the EPBRS Biodiversity Research Strategy 2010-2020 (EPBRS, 2010), which calls for a strong focus on research areas that generate the knowledge necessary to fulfil the political goals of

(I) ensuring the long-term survival of species in their habitats, their genetic diversity, and the ecological integrity and functionality of habitats and ecosystems,
(II) adapting to global change (including climate change),
(III) ensuring the long-term provision of ecosystem services,
(IV) contributing to meeting other challenges such as water, food, and energy supply, population growth, and human health.

More recently, the EPBRS gathered under the Irish presidency to define research priorities that support the implementation of the six targets of the EU Biodiversity Strategy 2020. Several key research issues are matching perfectly with the LTER approach. Research is needed to (cf. EPBRS, 2013):

(I) build and improve the network of sites across Europe to test different monitoring techniques to determine which are most cost-effective and on procedures to validate criteria and thresholds using monitoring data in support of target 1 that is dealing with the full implementation of the birds and habitats directive;
(II) further develop methods and instruments for managing human interactions with ecological systems, taking better account of complex and non-linear dynamic processes in support of target 2 on maintaining and restoring ecosystems and their services;
(III) assess the effectiveness of measures taken to conserve biodiversity and ensure sustainable use of ecosystem services and to develop new measures, including restoration and intervention measures in support of target 3 on increasing the contribution of agriculture and forestry to maintaining and enhancing biodiversity;
(IV) understand long-distance cause-effect relations over time in support of target 5 on combating invasive alien species, and
(V) explore the role of the biodiversity component in global change mitigation and adaptation strategies in support of target 6 on helping avert global biodiversity loss.

4.1.1 CONSERVATION OF SPECIES AND HABITATS

This topic covers research on one or more species or habitats and their interactions with ecosystem processes. LTER allows for a close alignment of biodiversity research and traditional ecosystem research, which primarily focuses on energy and material flows. Studies about utilization and conservation of biodiversity as well as on the consequences of changes in land use are of particular importance. LTER Austria is an optimal frame to provide answers to research questions such as: To what extent does Austria meet a given set of goals, e.g. halting the loss of species, protecting endangered populations, protecting habitats and species despite climate change and land use change? What is the entire distribution of FFH-species and habitats in Austria (guideline 92/43/EWG)? What measures are necessary to protect rare/endangered/endemic species and their populations? What is the adaptive potential of FFH species/habitats to ongoing changes? What are the consequences of the various forms of land use on the conservation of biodiversity? What are the impacts of climate change on biodiversity, endangered and/or endemic species, on diversity of habitats? What is the impact of EU regulations and how can land use management be optimized in terms of biodiversity and ecosystem services? To what extent do individual forms of land management, such as farming, forestry, hunting and fishing, affect endangered populations?

Of the research recommendations made by EPBRS, those relating to mountain and freshwater biodiversity are most relevant for biodiversity research at LTER Austria (cf. EPBRS, 2006, 2008). Of particular interest are:

- a better understanding of the role of genetic, species, ecosystem and landscape diversity for ecosystem dynamics, functions, and services;
- the coupling of research and long-term monitoring to assess the status, patterns and drivers of biodiversity at multiple scales;
- the definition of favourable states for habitats and populations and the identification of reference states for ecosystems evaluating and taking into account ecosystem services;
- the definition of criteria, indicators, methods and processes for efficient conservation and sustainable management of biodiversity under climate change/land use pressure;
- the knowledge of species' and habitat's adaptive ability to changed climate and/or land use;
- assessment of status and distribution of little-studied, ecologically important, or endangered taxa, FFH taxa, habitats, and ecosystems, including sensitivity analyses, and risk assessment;
- a better understanding of the functioning and role of soil biodiversity and subterranean freshwater biodiversity, especially as they relate to ecosystem services.

For this topic, we want to exemplify recent studies conducted at Austrian LTER Sites. They deliver insights about the role of diversity for ecosystem dynamics, functions, and services dealing with under-researched habitats (e.g. Fontana et al. 2014) and endemic or cryptic species (Rinnhofer et al. 2012; Arthofer et al. 2013). They also demonstrate the unique opportunities to investigate biodiversity and ecosystem processes under extreme environmental conditions such as terrestrial food webs (König et al., 2011; Raso et al., 2014) seed dormancy, establishment and traits (Cichini, et al. 2011; Erschbamer and Mayer, 2011; Marcante et al., 2009a, b, 2012; Schwienbacher et al., 2011a,b; see also Mayer and Erschbamer, 2011, 2014) in glacier foreland and vegetation/snowcover relationships at the upper limit of the alpine vegetation (Gottfried et al. 2011).

Biodiversity research in the Seewinkel area (Eastern Austria) investigates bryophytes (Zechmeister, 2004, 2005), spiders (Zulka et al., 1997), dragonflies (Benken & Raab, 2008), and zoobenthos and - plankton (Metz & Forro, 1991; Wolfram et al., 1999; Zimmermann-Timm Herzig, 2006) under the extreme conditions of saltpans and salt meadows. Recent biodiversity research in lakes of the high alps deals with the effects of radiation on bacteria (Hörtnagl et al., 2011; Pérez et al., 2011; Sonntag et al., 2011) and of temperature and nutrients on phytoplankton (Thies et al. 2012; Tolotti et al., 2012). Current research foci in the lakes of the alpine foreland are for instance dealing with genetics, ecology, and population dynamics of European Whitefish (Coregonus lavaretus L. complex) including exploited and endangered species (Pamminger-Lahnsteiner, 2011; Winkler, 2011; Pamminger-Lahnsteiner et al., 2012; Wanzenböck et al., 2012).

4.1.2 ADAPTATION TO CLIMATE CHANGE

The interactions between organisms and biotic communities with the main driving forces of global change are of particular interest and the scatteredness of related knowledge requires more targeted research to guide effective conservation measures. Ideally, experimental and observational studies on ecosystem functioning should be nested in the long-term monitoring schemes, which document changes of biodiversity and the environment over longer timeframes (Dirnböck et al., 2013, 2014). This is especially true when it comes to climate change, climate policy and climate change mitigation and adaptation measures, a set of research topics that was specified as particularly important by the Austrian biodiversity researchers (Platform for Biodiversity Research in Austria, 2008). Climate change mitigation and adaptation measures are currently implemented in agriculture, forestry, energy production and tourism. In view of the potentially severe effects of climate change in high mountain ecosystems (Engler et al., 2011), research in high-alpine territory is particularly important for LTER Austria (Dirnböck et al., 2011; Gottfried et al., 2012; Pauli et al., 2012). Austria coordinates the global project GLORIA (Global Observation Research Initiative in Alpine Environments), a long-term assessment of changes in high altitudes (multi-summit approach, Pauli et al. 2001, 2004; Gottfried at al. 2012) and provides methodological know-how.

The following topics are suggested for LTER Austria:

- Risk assessment of high altitude species and vegetation
- Assessment of migration tendencies of lowland species and migration potential of high-altitude species
- Investigations of the adaptive potential of species involved in migration processes
- Assessment of indicator species (considering all organisms) for climate changes processes
- A special focus should also be given to the long-term effects of global change on biotic communities such as extinction debt and invasion debt (Essl et al., 2011; Dullinger et al., 2013), which represent both a hidden threat and an opportunity for timely countermeasures.

4.1.3 STRUCTURAL CHANGES

Structural changes of ecosystems have been massively accelerated by industrialization, land use change, habitat loss and fragmentation, and increased human mobility. The latter factor is the main driver of the spread of invasive non-native species (Pyšek et al., 2010; Essl et al., 2011). The progressive loss of traditional landscape structures drives a massive crisis of farmland biodiversity that will probably not be completely realized until several decades into the future (Kuussaari et al., 2009). This opens a window of opportunity for rapid rethinking and the development of sustainable forms of utilization. Higher altitudes in the Alps still harbour many natural habitats. In the lowlands, natural and semi-natural habitats, which are important for biodiversity conservation (e.g. dry grasslands, meadows, pastures, old-growth deciduous forests, and riverine areas) occur currently mainly as fragmented remnants of often an unfavorable status. Thus, studies related to cultural landscapes, landscape fragmentation and ecological corridors are required (Kreiner et al., 2012; Kuttner et al., 2013). Core research areas should include the effects of agriculture policies and changes in land use (intensification, but also land abandonment and subsequent afforestation of traditional cultural landscapes) on the species richness and composition of ecological communities (Wrbka et al., 2008; Prévosto et al. 2011), the soil, and the vegetation structure. The use of genetically modified organisms and associated risks for the ecosystem should also be an essential focus of future research (e.g. Pascher & Gollmann, 1999; Pascher et al., 2011).

The following topics were recommended as research themes by EPBRS (2007a, 2008) and should be considered at LTER Austria biodiversity research:

- the importance of landscape structures, patterns and gradients for biodiversity across different scales;
- the role of refugia in maintaining the long-term adaptive and evolutionary capacities
- invasiveness of plant communities and risk assessment
- dispersal and impact of neobiota
- effects of demographic, social, and economic trends, and of EU policies and their national implementation on biodiversity;

- indirect effects of climate changes on biodiversity (e.g. biofuel production);
- improving agri-environmental schemes so that they deliver more measurable positive impacts for biodiversity; and
- risks of genetically modified organisms for ecosystems.

4.2 APPROACHES AND METHODS

In view of progressive soil sealing, eutrophication, increasing energy consumption and the generally reckless use of limited resources, biodiversity and conservation research has expanded its focus from the protection of species to the conservation, or indeed the restoration, of biotopes (habitat conservation) and to securing natural processes (process conservation). The most important approaches in biodiversity and conservation research in the framework of LTER are:

- collection of biodiversity data (e.g. mapping)
- long-term (biodiversity) monitoring
- research on multiple spatial and temporal scales
- techniques for genetic analysis
- experimental approaches
- remote sensing (evaluation of satellite and aerial images, infrared and radar technology)
- ecological modeling (geographic information processing, ecoinformatics, etc.)
- ecological indicators
- data management (internet infrastructure, online databases, public reporting systems, progressive plausibility checks and data evaluation)
- inter- and transdisciplinarity

Within the framework of the "Hardegger Erklärung zur österreichischen Biodiversitätsforschung" 2008 (Platform for Biodiversity Research in Austria, 2008), the following three questions on methods were prioritised (compare also EPBRS, 2010, 2013):

- What are the most effective strategies and methods to assess, conserve, restore and sustainably use biological diversity?
- How do methods for evaluating the function of biodiversity in ecosystems need to be improved to capture its importance in supporting ecosystem services crucial for human wellbeing?
- How do biodiversity indicators and monitoring systems need to be improved to identify and prospectively assess the interaction between biological diversity and the drivers of global change?

4.2.1 APPROACHES FOR CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY

To conserve habitats and species in the long term, we have to increasingly address syn-ecological aspects and studies on population and meta-population levels. In this context, the methodological question of choosing the "right" spatial and temporal scale is of crucial importance for the design of new concepts of conservation and sustainability (Dirnböck et al., 2013). Long time series of biodiversity data are prerequisites for answering all kind of research questions dealing with environmental change. Good data coverage also increases the precision of ecological models used for interpolation of biodiversity data (Elith et al., 2006; Guisan & Thuiller, 2005) aiming for instance at detecting changes of the composition of communities and population trends. The longer the units of observation (time series) and the greater the precision of models, the easier it is to find trends in slow, episodic or irregular processes.

The human use of ecosystems is omnipresent. LTSER Platforms (Mirtl et al., 2010; Singh et al., 2010) provide an optimal infrastructure for research that links biophysical processes to governance and communication, consider patterns and processes across several spatial and temporal scales, combines data from in-situ measurements with

Meadow with narcissi: © Maria Deweis

statistical data, cadastral surveys, and soft knowledge from the humanities (Haberl et al., 2006, Tappeiner et al. 2013). The inclusion of society into the existing research infrastructure facilitates transdisciplinary approaches. These approaches, including knowledge of stakeholders as constitutive elements of the research, are crucial when the research focus lies on the indirect drivers of biodiversity loss (Balian et al., 2011; EPBRS, 2010, 2011), or when the gap between science (e.g. conservation planning and research based conservation recommendations) and action (e.g. implementation of conservation actions) should be bridged (Reyes et al., 2010; Schindler et al., 2011). They are also indispensable for the restoration of the ecological integrity of traditional cultural landscapes (ERPBS, 2013). While LTSER Platforms provide ideal infrastructure for regional case studies, particularly in the context of transdisciplinary research (Singh et al., 2013), LTER Sites may serve as a pool for long-term monitoring data and sites for experimental approaches. Stakeholder involvement can also be of advantage when defining conservation priorities. For this purpose, transnational conservation initiatives such as the European Habitat and Birds Directives as well as biodiversity-related multilateral environmental agreements have to be innovatively applied (Mauerhofer, 2010, 2011) along with local or national assessments (e.g. national red lists, assessment of global conservation responsibilities).

4.2.2 INDICATORS

Indicators simplify, quantify, and communicate information on ecosystem processes that are too complex to be measured directly (Hammond et al., 1995). Biodiversity and sustainability in their entirety require very complex methods of measurement, which is why indicators are usually applied (Walpole et al., 2009; Tittensor et al. 2014). The indicators that are most relevant in terms of environmental policy are those that are easy to survey, efficient, cost-effective, sensitive to processes of change and robust against other influences (e.g. Dirnböck et al., 2014; EEA, 2007; Gottfried et al., 2012; Gregory et al., 2009; Pauli et al., 2012; Schindler et al., 2013; Tasser et al., 2008). Frequently, environmental indicators are related to habitat and species diversity, land use and land cover, and invasive species. The development of standardized methods to harmonize and supplement indicators for biodiversity as well as for its driving forces and the causes of endangerment is a European biodiversity research focus (EPBRS, 2007a). Even well established indicators, such as the IUCN Red List Index, can undermine their own indicator performance as conservation actions become targeted towards Red List species (Newton, 2011).

To ensure that naturally species-poor habitats (e.g. mires or acidic beech forests) are adequately represented, the contribution of such areas to overall biodiversity must be considered. Current indicators of species diversity have to be expanded towards genetic diversity and ecosystem diversity (Walpole et al., 2009), and multi-taxa approaches are required to assess indicator performance in a robust way (Schindler et al., 2013). Due to long time series, simultaneous in-situ data of environmental and human pressures and its effects and integrative approaches, LTER Austria provides an outstanding opportunity for testing and improving indicators for biodiversity and for taking better into account complex and non-linear dynamic processes (cf. EBRPS, 2013). For instance, Nitrogen deposition that exceeds habitat-specific empirical critical loads for eutrophication effects, was recently established as useful indicators for the sensitivity of forest floor vegetation to N deposition (Dirnböck et al., 2014). LTER Austria also provides the opportunity to obtain time series for indicator taxa to determine the impact of long-range air pollution on coverage, diversity and community composition of lichens (Mayer et al., 2013) bryophytes (Zechmeister et al., 2007) and forest floor vegetation (Hülber et al., 2008; Dirnböck et al., 2014). Recent studies at the LTER Site Zöbelboden also uncovered the direct effects of air pollution on tree recruitment (Pröll et al., 2011), as well as its indirect effects, mediated by nitrogen-dependent patterns in forest understoreys (Diwold et al., 2010).

4.2.3 ECOSYSTEM FUNCTIONS AND SERVICES

The concept of ecosystem functions and services (Costanza et al., 1997; De Groot et al., 2002; MEA, 2003; TEEB, 2010) has been increasingly employed during recent years, since it facilitates an approach to evaluating the importance of intact ecosystems for humans. Flexible and hierarchical classification systems for ecosystem services have been recently developed and applied (Haines-Young & Potschin, 2013; Maes et al., 2013; Schindler et al., 2014). The contribution of biodiversity to ecosystem services and the influence of drivers and pressures on conservation and use of ecosystems are research aspects of particular importance (Kremen, 2005; EPBRS, 2007b, 2011; Mace et al., 2012). Austrian LTER Sites are particularly suitable for investigating ecosystem services related to forest biodiversity, alpine biodiversity, and dynamic habitats such as avalanche tracks and natural rivers. Recent studies at the LTER Site Stubai examined for instance the relative contributions of plant traits and soil microbial properties to mountain grassland ecosystem services (Grigulis et al. 2013), as well as the impacts of agricultural activities and climate change on multiple ecosystem services delivery from past to future (Schirpke et al., 2013).

The following research recommendations regarding ecosystem services adopted by EPRBS (2011) are specifically relevant in the context of Austrian biodiversity research in the frame of LTER:

- Understand the ecological, economic and social aspects of the multiplicity of ecosystem services, identify trade-offs and synergies occurring between services, and develop management mechanisms and innovative uses;
- Identify and characterize linear and non-linear social and ecological dynamics and their interactions, to foster ecosystem service resilience;
- Improve existing and develop innovative management techniques to reduce or eliminate drivers of dangerous change in ecosystem services or disservices such as biological invasions, chemical pollution including pharmaceuticals, and eutrophication;
- Assess the impacts on ecosystem services of novel or emerging pressures, such as alternative energy production, abrupt changes in management regimes in an oil-constrained world, and pollution by light and noise, nano-particles and micro-plastics;
- Better understand the disruption of ecosystem services, at various scales in time and space, caused by natural and anthropogenic drivers operating through phenomena such as mismatch in processes related to phenology, trophic interactions, and migration;
- Take into account uncertainty, complexity, and all relevant knowledge including local and traditional knowledge, in developing tools and methods to support the integration of ecosystem services into management and decision making in public and private sectors;
- Understand and evaluate ecosystem services provided by poorly known ecosystems such as glaciers, groundwater, and aquatic microbial communities;
- Identify the main threats to soil biodiversity (including to specific functional groups) and quantify their impacts on ecosystem processes and services;

4.3 REQUIREMENTS

4.3.1 STRUCTURAL REQUIREMENTS

Concerted research efforts on biodiversity are crucial for developing an evidence base that enables informed environmental decision making. Therefore, a research strategy founded upon a general consensus of the Austrian research community and approved at an international level is of great importance. To further strengthen research efforts, an even more efficient network of existing research facilities, initiatives, nature reserves and conservation programmes is needed. A close connection to European and international ecosystem research (e.g. LTER-Europe) is desirable; education in schools and universities must be encouraged and research institutions such as museums or universities and research sites such as National Parks or Wilderness Areas need increased long-term financing. Cooperation and communication between science and the interested public need to be specifically promoted (EPBRS, 2013).

4.3.2 INSTITUTIONAL REQUIREMENTS

Implementing the above-mentioned structural requirements implies institutional changes. Within the framework of the EPBRS biodiversity research strategy 2010-2020, five fields are presented for developing the research environment that is needed (EPBRS, 2010):

- continuous identification, revision and "horizon scanning" (i.e. wide, interdisciplinary early recognition of future developments; cf. Sutherland et al., 2014) of research foci;
- support of European and international platforms (e.g. GEO Bon, ILTER, GBIF, Biodiversity-Knowledge) and projects (e.g. GLORIA);
- increasing capacity through general and advanced education;
- creation of links between research and politics (e.g. via the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES); and
- regular evaluation of European biodiversity research with particular reference to its practicability and the applicability of research findings.

From the Austrian research community`s point of view, highest priority should be given to a better access to biodiversity-relevant information and databases (e.g. geodata, environmental data, biodiversity data,), long-term nature and continuity of research networks and projects, integration and networking with international biodiversity research and related initiatives, and improved access to research funding (Platform for Biodiversity Research in Austria, 2008). A central data collection hub that is easily accessible for LTER researchers, the "Data Center for Biodiversity and Conservation Research", is to function as an infrastructural institution in support of research activities and as such is seen as a vital prerequisite for improving the quality of research. Another key factor is ensuring the long-term support of existing institutions contributing to biodiversity and conservation research (e.g. research institutes, museums and collections, nature reserves,) as well as access to the data stored at these facilities. A consensual approach to the establishment of future research foci also seems to be of particular importance. This is where the concept of LTER comes into play, without which it would be almost impossible for particular LTER Sites to manage data in a competent way, i.e. linked and made accessible to individual research groups.

The international LTER network offers the advantage of access to international data collections related to sites, where a wide range of potential drivers of biodiversity are measured simultaneously. As a first step, it provides meta-information on the existence of data sets and their holders and supports Austrian research teams to disseminate and promote studies and data – a fact that is highly relevant with respect to acquiring European research funding. Mapping the research foci seems to be imperative and would give funding bodies a better overview of the entire research landscape. The current attempt to organize European research infrastructures alongside pressing research topics such as climate change and biodiversity loss forms a major step in this direction. The plan is that research infrastructures and programmes should become more explicit in how they tackle these research topics and that they specify the related measurements, parameters, activities and handover points with other infrastructures (see chapter 6 and specifically Fig. 12).

In this context, the ESFRI project LifeWatch is of high relevance (www.lifewatch.eu). It links "resources" (elements producing biodiversity related data like LTER Sites or collections) with the scientific users of such resources by supporting data mining, access and workflows related to complex analyses. LTER-Europe represents complementary in-situ components to the supporting and e-Infrastructure LifeWatch (see chapter 6). LTER and LifeWatch are closely co-operating (e.g. H2020 proposal "eLTER") on the basis of a formal Memorandum of Co-operation (see annex chapter 8.4). Communities as well as national organisations engaged in LTER-Europe and LifeWatch are highly overlapping in about 50% of all LifeWatch countries, securing efficient lobbying and maximum use of synergies. In Austria a national LifeWatch strategy has been developed (Mirtl et al., 2011), integrating LTER-Austria, the BDFA and the Austrian Biodiversity Documentation (museums and collections organized as national GBIF consortium). In the context of developing a national ESFRI Roadmap in the field of environmental research with LTER as the central pool for in-situ infrastructures, LifeWatch will be an important functional component.

Grid frame for sampling: © Michael Mirtl

4.4 PRODUCTS AND USERS

The driving forces of global change force public officials and conservation bodies to deal with complex questions, such as "Where do conservation measures make sense from an ecological and economic standpoint?" or "On which spatial scale are they likely to provide most positive results?" The more precisely it is possible to assess future developments, the easier it is to successfully counteract undesirable developments. Reflecting the wide spectrum of involved expertise, the range of results from biodiversity and conservation research is immensely varied. Their products should be made available to the research community, but should also serve policy makers and society as a basis for future planning and decision-making. Precisely because of the many interfaces between them and the various land use sectors, agriculture, forestry and recreational industries, the transdisciplinary results of biodiversity and conservation research provide practical approaches to the sustainable exploitation of traditionally used resources. Decision-makers and in many cases the custodians of essential goods (e.g. water) are thus direct beneficiaries.

4.5 NETWORKING

It must be clearly stated that monodisciplinary basic research on at all levels of biodiversity (genetic, species, ecosystem diversity) is still required. However, many research topics related to biodiversity and its conservation require multidisciplinary research teams (EPBRS, 2010). The LTER network is beneficial for networking Austrian biodiversity research, because it provides the option to link (I) different sites with different ecological conditions for answering biodiversity research questions at the broader scale, (II) biodiversity research to socio-ecological and socio-economic research at the LTSER Platforms, and (III) Austrian biodiversity research with partners at LTER Europe and global partners at ILTER.

Many issues in biodiversity research, particularly when dealing with conservation biology, have to be considered in a multidisciplinary way. Biodiversity research is thus often strongly linked to the other columns on ecosystem processes and socio-ecology. The Austrian Biodiversity Research Platform (BDFA) was inaugurated in 2008 to network the Austrian Biodiversity Research Community, and to link with international activities, funding agencies, political decision makers on environmental issues and the wider public (BDFA, 2008). However, funding ceased in 2010 and the platform strongly decreased its activities. New broad biodiversity initiatives are currently emerging in Austria (e.g. Austrian Barcode of Life) but do not aim at fulfilling the network functions supposed to be covered by BDFA. Thus, Austria is far from a situation such as in Belgium, Switzerland or Germany, where Biodiversity Platforms play an active and import role in the biodiversity research community, which is turn is well connected to other research disciplines, policy makers and the wider society.

LTER might play an even stronger role in this context as it offers excellent conditions for transdisciplinary cooperation at its research sites and platforms. As a result, funds can be assigned to specific research foci in a targeted way in spite of cost-cutting measures for environmental budgets. Interdisciplinary cooperation is characterized at a high scientific standard within the LTER network especially by the efficient transfer of information between research teams. A crucial factor is the increase in the potential for synergies, which are more easily identifiable, also for funding providers, due to the improved coordination between scientific disciplines within the framework of LTER.

5 SOCIO-ECOLOGICAL RESEARCH, LTSER (THEMATIC AREA III)

5.1 DEFINITION AND THEMATIC AREA

The rapid pace of environmental changes in the context of global change calls for responses that have a sound scientific basis. This requires research into causes and processes as well as the development of information and monitoring systems.

Since global change has long-term impacts, short-term research projects can only deliver inadequate answers. Monodisciplinary approaches are equally unsatisfactory. Human-environment systems can only be recorded and understood using a multisciplinary approach. This involves capturing the complex interaction of physical-chemical, biological and sociocultural (or social and cultural) processes, in which context humans are both the responsible and the affected parties and yet may also be the creators (Steffen et al. 2002). Equally, solutions and adaptation strategies require a comprehensive approach, which takes account of the interrelations between society and the biotic and abiotic components of the Earth System and of its development to date and into the future. Environmental phenomena must be seen as complex societal problems and not as purely natural occurrences (Ehlers 2008).

Such knowledge is needed to support society, politics and economics in forging sustainable development pathways for the long term. Sustainability is seen as a policy objective to avoid placing the ecological basis of life at risk, avoiding social conflicts and to create economic stability. Sustainability is thus a strategy that serves to secure the basis of life for future generations. Among others, this includes ensuring that the capability of the ecosystem to provide the services required by society ("ecosystem services") is continually maintained. In this sense, sustainability must be seen as a dynamic concept (Haberl et al. 2004). Research that is dedicated to this paradigm must therefore be conceived as integrative, inter- and transdisciplinary and long-term (cf. Kates et al. 2001; Parris & Kates 2003a; Parris & Kates 2003b; Turner et al. 2003a). The LTSER programme enables such a conception for the future.

Long-term ecological research (LTER) needs to be expanded to include socioeconomic dimensions, if it is to create understanding of the interactions between economic, on the one hand, and ecological factors on the other in human-environment systems (Redman et al. 2004; Singh et al. 2013). Social ecology is understood as the science of societal relations with nature (Becker & Jahn 2006) and of the interactions between society and nature (cf. E.g. Fischer-Kowalski & Erb 2006). The interrelation between socioeconomic activity and the natural environment is also central to "sustainability science", in which society and nature exert mutual influence upon one another as a coupled system (Kates et al. 2001). The challenge facing research lies in understanding these non-linear, complex and self-organising systems and deriving appropriate solutions (WBGU 2007). Such an approach may be defined as socio-ecological, integrative and fundamentalas well as being site- and regionally specific (Gallopin 2002). These are requirements which the research in LTSER platorms must comply with in full (Mirtl et al. 2013).

Six socio-ecological core areas of research can be defined (cf. Haberl et al. 2006). These must be sufficiently flexible in their design that they allow for modifications in order to adapt to the constantly evolving overall conditions of global change. These are:

- **Biophysical (material and energetic) interactions between society and ecosystems.** The long-term development of socioeconomic systems is determined by the functional services of ecosystems and the human utilization adapted to these. The research of the material and energy flows which society requires in order to maintain its biophysical structures ("social metabolism") holds great relevance (Haberl et al. 2013a, b). The long-term development potentials of the system are influenced both by the quantitative dimensions of material and energetic interactions and by qualitative changes – such as chemical transformations or genetic modifications. Research of long-term processes and their interactions with processes at other scales provide the basic prerequisites for the development of long-term strategies for action and adaptation in the socioeconomic system.

- **Cultivated landscape research.** The natural potential of ecosystems provides the context for its valorisation by individuals and societies. These are subject to continually changing demands, which in turn originate from technological, economic, cultural and political conditions, and which have a decisive impact upon land use. Domestic and international economic interlinkages constitute further influencing factors. These too are subject to continual change. Current cultivated and riverine landscapes thus to some extent reflect the overall ecological conditions, which may be used but also affected by process developments in economy and society, leading to structural changes in the landscape. Finally, the cultivated landscape of the present day can only ever represent a "transitional stage". Its dynamic emerges through the interplay of natural and anthropogenic factors, in which socioeconomic changes alter nature and ecosystems and vice versa (Wrbka et al. 2004). Just as cultivated landscapes have changed throughout history, they will also be transformed into the future.

- **Communication and action research.** Theories of action deliver new approaches for the analysis of courses of action and their consequences. They ensure that actors and actions, which make stabilizing or disruptive interventions in ecosystems can be identified. Knowledge of such action or communication processes is necessary for the identification of unsustainable actions and developing models of best practice. Research into relevant knowledge banks within society as well as their transformation over time has a very important role to play in this area. The transdisciplinary integration of people from social practice ("stakeholders") within the research process is thus of particular value for long-term socio-ecological research.

- **Governance research.** Paving the way for sustainable development requires that the goal of maintaining the natural bases of life is established as being of equal importance to other social and economic goals. New governance structures are needed for this purpose. A better understanding of the conflicts of interest between different social groups is thus of decisive importance (Adams et al. 2003; Dietz et al. 2003). Only thus can the vulnerability of ecosystems and society in a regional setting be decreased. Sustainability requires the social acceptance of strategies and measures for the maintenance of natural conditions that support life. This needs the transformation of one-sided, top-down-oriented forms of organisation into those that support balanced interactions between top-down and bottom-up processes. To facilitate this, not only political decision makers but also actors from non-governmental organisations, the economy and wider society should in general be included in the development of sustainability strategies and measures.

- **Risk and resilience research.** Natural events only become risks when humans are affected by them. They comprise both threats and opportunities (Felgentreff & Glade 2007; Kulke & Popp 2008). Vulnerability and resilience act as binding elements between ecosystem research involving natural and social sciences (Blaikie et al. 1994; Turner et al. 2003b). They are dynamic in both a spatial and a temporal sense (Bohle & Glade 2007). Risk research can be characterised as a bridge between natural science-ecological research and socio-ecological research (Stötter & Coy 2008).

These research approaches must adhere to the following principles:

- Decreasing the vulnerability and, where appropriate, strengthening the resilience of spatial systems (ecosystem, social system, economic system; cf. Holling 1973; Blaikie et al. 1994).
- Interdisciplinarity, ultimately even postdisciplinarity (mode-2-approaches). Complex systemic interrelation ships can no longer be captured and comprehended by a monodisciplinary approach. Where it becomes possible to transcend disciplinary structures through the highest possible integration in a postdisciplinary form, a new level of understanding can be achieved (Kates et al. 2001; Hirsch-Hadorn et al. 2008).
- Transdisciplinarity. Only a systematic integration of stakeholders into the research process can facilitate the development of future-oriented and socially acceptable solutions (cf. Maihofer 2005, Dressel et al. 2014). In this context, it is important to ensure a majority consensus is reached in the case of both stakeholders and researchers (Newig et al. 2008a).

It follows from all the foregoing: LTSER facilitates an understanding of the complexity of interdependencies between ecosystems and social systems. These systems act upon each other in reciprocal fashion, with feedback effects being the rule rather than the exception. A key question in this respect concerns how social structures and single events impact on, and have impacted upon, ecosystems. In this context, environmental history offers a suitable framework for research (Winiwarter & Knoll 2007). Environmental history has a procedural focus and includes aspects of perception research. Environmental history also enables the long-term perspective of LTSER to be extended through application to pre-industrial history.

Sustainability research requires an understanding of socio-ecological transitions, which represent fundamental transformations in the relationship between natural and social systems (Fischer-Kowalski & Haberl 2007). During such transitions, sustainability problems undergo fundamental change – for example, in the case of the sustainability problems of agrarian and industrial societies. A further major theme is the identification of "legacies", i.e. the long-term material and non-material impacts that past events continue to have in the present and into the future. An example of this is landscape composition, which is influenced by decisions and interventions in the past that stretches over centuries, and not uncommonly even millennia. Links may be drawn between historical farming systems in relation to land use and regional development processes in the present day. This includes, for example, the importance of humans' perception of and identification with the landscape in which they live.

LTSER has set itself the challenge of analysing the long-term interactions of ecological and social systems (encompassing politics, economics and society), to identify current and future problem areas and to produce solutions that are sustainable in the long term. The influence of nature on society, the utilization of natural resources and the repercussions for ecosystems of economic and landscape-altering decisions made by humans is in this respect an important research focus. The interrelations between humans and the environment are subject to constant change. Historical approaches are therefore as necessary as considerations about the future, for example in the form of scenario-building. In concrete terms, this involves the identification of the resource use strategies of specific actors, for example, in the case of decision making in agriculture and land use processes. The analysis of economic structures is plays an important role in this context, since these have a significant influence on decision making. Another research focus concerns social perceptions of the patterns that arise (perception, identity). Last but not least, it is important to identify relevant institutions and their role in the development of regional sustainability.

5.2 METHODS AND APPROACHES

Socio-ecological research within LTSER has taken up the challenge of integrating different disciplines from the natural science and cultural and social science sectors. Bringing together such different approaches means that a variety of methods must be used. Thus methodological pluralism is characteristic of the work of socio-ecological research in LTSER, which, among others, includes the following methods and approaches (and combinations of these):

- Process-oriented methods (e.g. socio-metabolic methods such as material and energy flow analysis, socio-ecological indicators, toxicology methods, etc.)
- (Environmental) history and archaeology methods
- Geographical methods (integrated science, synergetics, land use research, local knowledge analysis, systems analysis, GIS, GIS, remote sensing, laser scanning, field research, mapping)
- Economic methods (Input/Output-analysis, etc.) incl. Methods of environmental economy and ecological economics
- Social science methods (qualitative and quantitative)
- Demographic methods (population structure, mobility analysis)
- Vulnerability and resilience analysis
- Interdisciplinary synthesis and modeling (formal models, heuristic models, mind maps etc.), scenario analysis
- Inter- and transdisciplinary methods
- Transdisciplinary/participatory methods

Sheep grazing in the mountains: © fotolia

Socio-ecological research is a relatively young and dynamically evolving field of research, the contours of which are just beginning to take shape. The development of new approaches and methods thus occupies a key position, particularly where inter- and transdisciplinary syntheses are concerned. LTSER calls for, among other things, innovative approaches to integrate the methods of social and natural sciences. Equally, LTSER requires the integration of methods of basic research (e.g. monitoring, measurement methods, empirical social research, theory development, etc) through evaluation of projected processes through to methods of applied research, such as the preparation of planning recommendations and intervention strategies, which contribute to decision making within the region. Networking with process-oriented long-term ecosystem research and with biodiversity and nature conservation research is extremely important. This affects, for example, the interdependencies of ecosystem processes and socioeconomic transformation, the socioeconomic significance of biodiversity and the threat posed by economic activities to biodiversity. Ecosystem services can only be understood in the context of this complex interaction between society and nature.

5.3 REQUIREMENTS

Just as with disciplinary work in the natural and social sciences, the availability of data and sources form the basis of all socio-ecological research. Individual research groups have created valuable spatial-temporal databases and have harmonised these through the intensive investment of human capital and partly integrated them in online GIS systems, which in project-oriented science often develop rapidly into "data graveyards". LTSER has an important role to play in ensuring that this socially funded work is of enduring benefit. Combined with one another, these discrete and isolated data series can accrue new potential. The infrastructure prerequisites are very similar to those within the natural sciences. The challenge now is to integrate these existing databases – which in some cases are extremely disparate – within a harmonised system.

Significant requirements follow from this:

- The integration of real-space data (particularly from ecology), raster data (primarily from biodiversity research), temporal data and administrative space data (particularly from social science research and from – which requires dedicated funding - special analyses by Statistik Austria).
- The integration of historical data incl. The digitalization of historical sources (primarily by setting up a commented metadata set for this unique data collection).
- The creation of interfaces between different scale levels, which support the use of data from different spatial scales.
- The development of scenario techniques, which allow not only for forecast statements but also support the acquisition of orientation- and action-related knowledge (both "what if" and "forced future" scenarios).

Measuring station at Zöbelboden: © Franz Rokop

5.4 PRODUCTS AND ADDRESSEES

From the above-described reserch questions and methods of the socio-ecological strand within LTSER, the following products from this research area may be provisionally identified:

- Innovative methods of interdisciplinary basic research and transdisciplinary research in the field of interactions within the human-environment system;
- Long-term analysis of socio-ecological transition processes to support and advise on sustainable regional development strategies for the future;
- Estimation of risks, vulnerability and resilience;
- Integrated socio-ecological models, which can be applied in transdisciplinary processes and enable stakeholders to be supported through the development of sustainability strategies;
- Scenarios for future spatial development, which facilitate the shaping of adaptation strategies.

Interdisciplinary socio-ecological basic research and applied transdisciplinary research lead to new insights in science and regarding social practice. As a form of basic research, socio-ecological research contributes to interdisciplinary sustainability research, and knowledge feeds into the disciplinary sciences as a result. As transdisciplinary research, the socio-ecological component of LTSER generates knowledge and products for stakeholders, such as decisions makers at various scale levels and thus contributes to the development of regional sustainability.

5.5 NETWORKS

LTSER investigates the impacts of resource use upon biodiversity and ecosystem functions (e.g. material flows). Research into resource use includes explicit social and economic research questions. Different processes can unfold at different temporal and spatial scales and influence one another to a greater or lesser extent and can move in different directions or progress at different speeds.

Should LTSER be concentrated at platforms such as the Tyrolean Alps and Eisenwurzen? How might LTSER be networked to an optimal degree with socio-ecological research taking place outside the platforms? Long-term socio-ecological research (LTSER) benefits from an approach that takes account of the different scale levels of spheres of social activity and ecological processes, and that analyses the interelations between these scale levels. The great challenge for the socio-ecological strand within LTSER consists of the bringing together of people

from different disciplines of natural and social sciences and cultural studies and of people and institutions from the sphere of everyday practice. The choice of research area and study level plays a key role here and has a significant impact upon whether and how social and cultural studies (human geography, sociology, history, political science, economics, etc.) and technical sciences (mathematics, physics, IT, statistics, etc.) can and wish to contribute to the research.

6 EUROPEAN FRAMEWORK CONDITIONS

One of the core objectives pursued by the European Commission from 2004 through the instrument of the "Networks of Excellence" (NoE) was the integration of institutions and infrastructures (ALTER-Net for terrestrial and aquatic research, MARBEF for the area of marine research and EDIT for the taxonomic collections). These all have in common the fact that in contrast to other research areas with cost-intensive infrastructures (particle physics, astronomy), they have no secured long-term funding for their infrastructures, either at national or international level. Moreover, they have until now lacked strategic instruments to couple European funding schemes with national funding schemes, as is the case with particle physics and astronomy, through the **European Strategy Forum for Research Infrastructure (ESFRI):** At European level, an ESFRI Roadmap has been developed for 5 years at a time, which is (or should be) being translated into national ESFRI Roadmaps. Through this, the EU is making substantial funding support available for infrastructures, which are available for use by the European Research Area as a whole. Prominent examples are the particle accelerator in CERN or the European telescope array in Chile (ESO). Available annual funding lies in the range of tens of millions of Euros per country.

Although outstanding **ecosystem research** generally requires a commensurate level of funding, the nature of its research facilities has so far hindered the development of a similar strategic approach: These are **comparatively small-scale specific sites located across the biogeographical regions** and countries of Europe, hosted by a multiplicity of institutions and responsible government ministries. According to LTER-Europe surveys carried out in 21 Member States, these scattered infrastructures (c. 400 sites) represent a cumulative investment value of c. 450 Mio €, with some sites having operated continuously for over 100 years. However, these investments have been undertaken without any centralised control according to institutional mandates and specific scientific interests. The transition to a multiple-use, distributed research infrastructure would require a small proportion of the original investment value, yet could only take place through the interplay between Europe and the research infrastructure networks of nation states (site hosts).

The above-mentioned **European Strategy Forum for Research Infrastructure (ESFRI)** comprises thematic areas with strategic working groups. Alongside thematic areas such as physics and engineering, the area of "Environment and Earth Sciences" has been created, which since 2006 has increasingly incorporated distributed infrastructures in the area of biodiversity and ecosystem research.

The **ESFRI pilot projekt „LifeWatch"** (see Fig. 9) provided a platform for all Networks of Excellence (ALTER-Net, MARBEF, EDIT), as well as for networks that develop from the NoEs (such as LTER-Europe) and those that develop in parallel (e.g. BioFresh for aquatic sites). In this context, LifeWatch initially attempted to cover the entire spectrum of requisite **Data-services** (e-infrastructure) for research **up to and including the research sites** (in-situ components). In Austria, at the initiative of LTER-Austria, a national LifeWatch Consortium was established, which put together an Austrian LifeWatch concept and undertook consultations with the responsible ministerial departments (BMWFW, BMLFUW). By 2013 it had become clear, however, that LifeWatch would focus **on the function of an e-infrastructure,** to support access to biodiversity data, its management and data analyses (workflows).

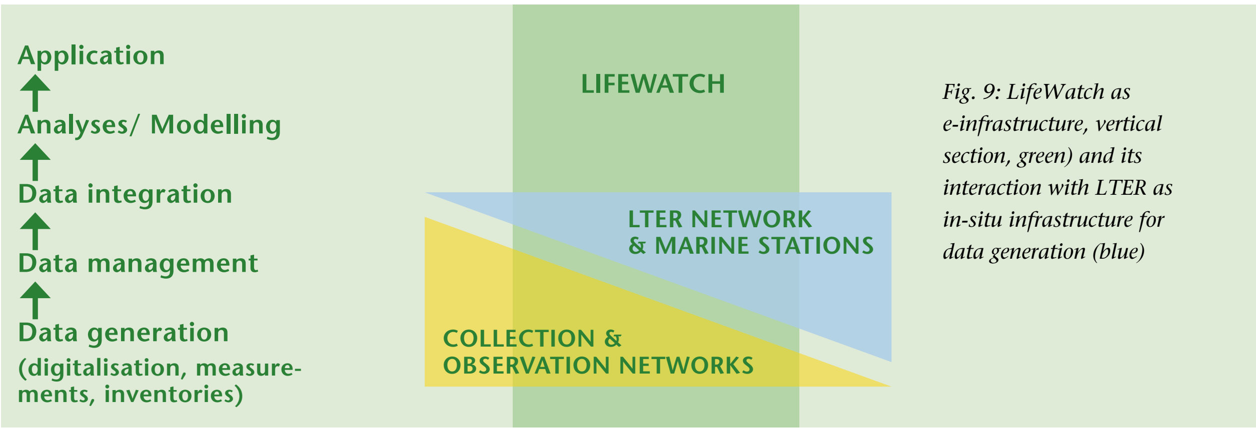

Fig. 9: LifeWatch as e-infrastructure, vertical section, green) and its interaction with LTER as in-situ infrastructure for data generation (blue)

The current plan envisages LTER-Europe representing a major complementary site network, which generates data and uses the services of LifeWatch. The national LifeWatch teams and LTER-Europe cooperate closely with one another. LTER-Europe and LifeWatch signed a formal Memorandum of Co-operation, which regulates their roles and forms of interaction (see Annex Chapter 8.4).

A further initiative with great relevance for LTER-Austria was created in the context of the INFRA-2010 Call 1.1.17 for a I3-Project on "Sites and experimental platforms for long-term ecosystem research": The **EXPEER consortium**, composed of LTER-Europe and AnaEE (Analysis and Experimentation in Ecosystems). EXPEER focuses on **Key infrastructures of ecosystem research** (Highly Instrumented Experimental/ Observational Sites, HIES, HIOS) and their integration including analyses and modeling (see Fig. 10). As part of efforts to establish the infrastructures sustainable and after a MoU in 2009, **AnaEE** now operates an ESFRI pilot project in the area of medical and biological sciences (experimental approaches with a focus on agrosystems/JPI FACCE). LTER-Europe has applied for a Horizon 2020 infrastructure project **(eLTER)**, together with the Critical Zone Community. A concept is currently in development, looking at how sites that operate long-term monitoring-related ecosystem research can be combined with small-scale experimental research (AnaEE).

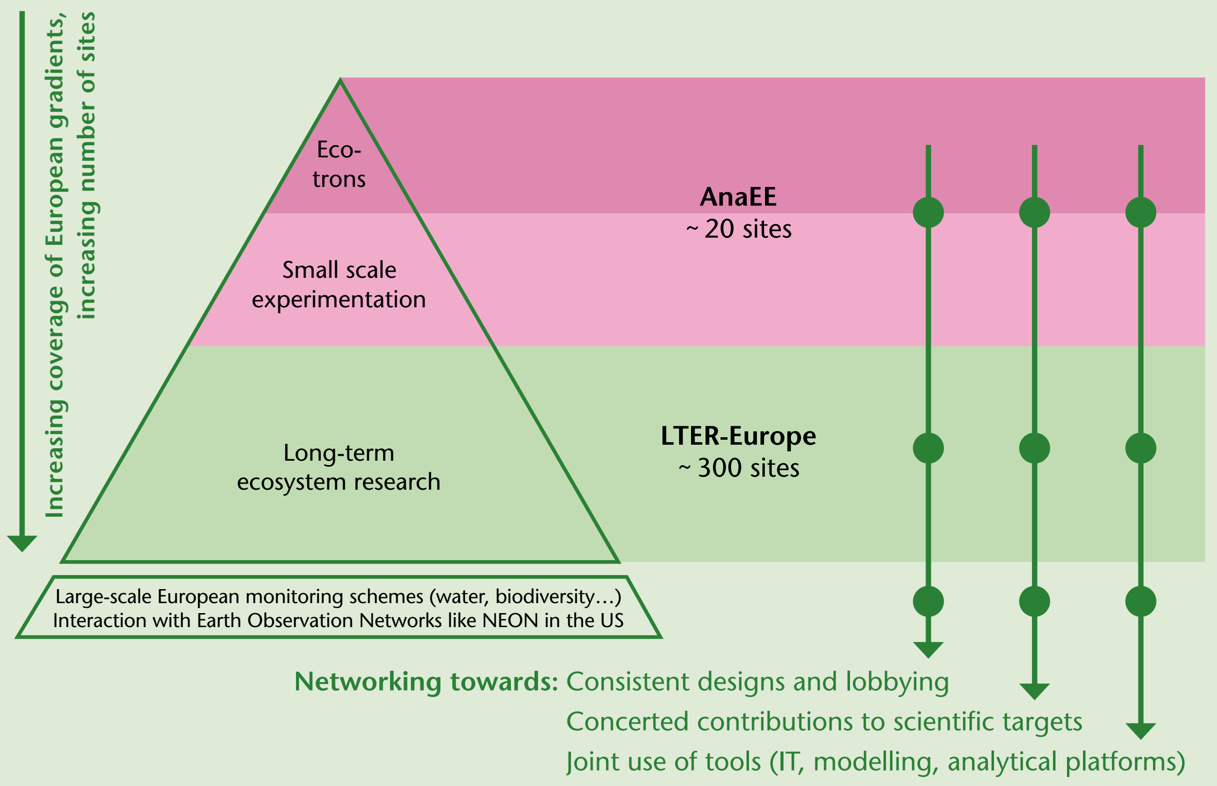

Fig. 11: The ExpeER project worked on the interactions between experimental (top) and observational (mid-section) ecosystem research and large-scale environmental monitoring (bottom). Highly instrumented sites should integrate observation and experiments wherever possible and be effectively coupled with larger scale monitoring activities. There are almost no limitations on the siting of ecotrons (indoor experiments, top). Expensive experiments will only be possible to undertake at a few sites (AnaEE, mid-section), while European ecosystem research (LTER) requires significantly more sites in order to cover all European environmental gradients.

Also included in the Environmental Roadmap from ESFRI is the Integrated Carbon Observation System **(ICOS)**, which will become a formal European Infrastructure Consortium (ERIC) by 2015 at the latest. The core object of ICOS is to provide European research on greenhouse gases with harmonised data, which are acquired through an association of monitoring stations (terrestrial, marine). The terrestrial sites combine partly atmospheric components (high measurement towers) with ecosystem approaches (outgassing, vertical profiles). ICOS is thus an important infrastructure component with which the LTER network should be harmonized (joint utilization of the most suitable sites).

During the preparation of the ESFRI Roadmap 2016, the above-mentioned Environmental Strategic Working Group (Env SWG) from ESFRI worked from May 2014 to produce an overall picture of the "Landscape of Environmental Infrastructures", in which these were classified according to their core working areas (e-Infrastructures and reference data, analyses and modeling, in-situ infrastructures subdivided according to those that are primarily "observational" and those that are primarily "experimental"). Thereupon, the most important elements in each respective area were identified. The results of this work were presented by the managing board on 25 September 2014 at the ESFRI 2016 Startup in Trieste (Fig. 11).

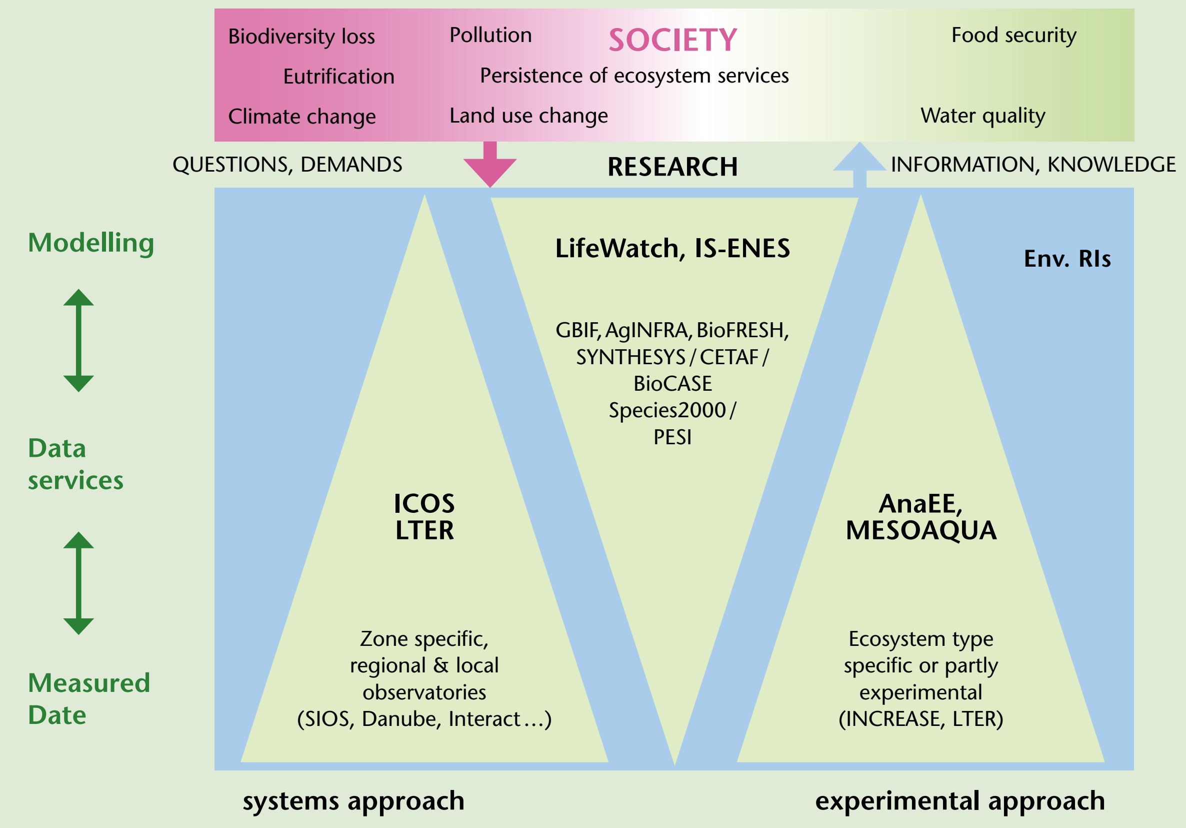

Fig. 12: Research infrastructures (blue box, bottom) provide a working context for the research, together with information regarding research questions that are generated by societal requirements (green-yellow box, above). Within the research infrastructures, distinctions must be made between data-generating infrastructures for systems research and experiments (blue box, bottom), data services (mid-section) and e-infrastructures (top). The aim is to achieve the closest possible coupling of all these areas. The existing infrastructures, networks and concepts are grouped in the blue box according to the focus of their activities. The font size of the text indicates their significance in the respective areas for ecosystem research.

Subsequently, at the expert workshop of Env SWG on 22 May 2014 in Paris, the most important infrastructures were located (Fig. 12) according to the spatial scales at which they operate, as well as according to the primary research themes, in respect of which the various research infrastructures in Europe should in future be more effectively coordinated (climate change and greenhouse gases, biodiversity and loss of species, pollution, eutrophication). LTER was categorized according to the spatial scales from 1 to 10 000 000 m and ranges across the Grand Challenges of climate change, biodiversity, pollution and eutrophication, since it operates sites from plot size to research regions (LTSER Platforms) and research is based in each case on an ecosystemic approach.

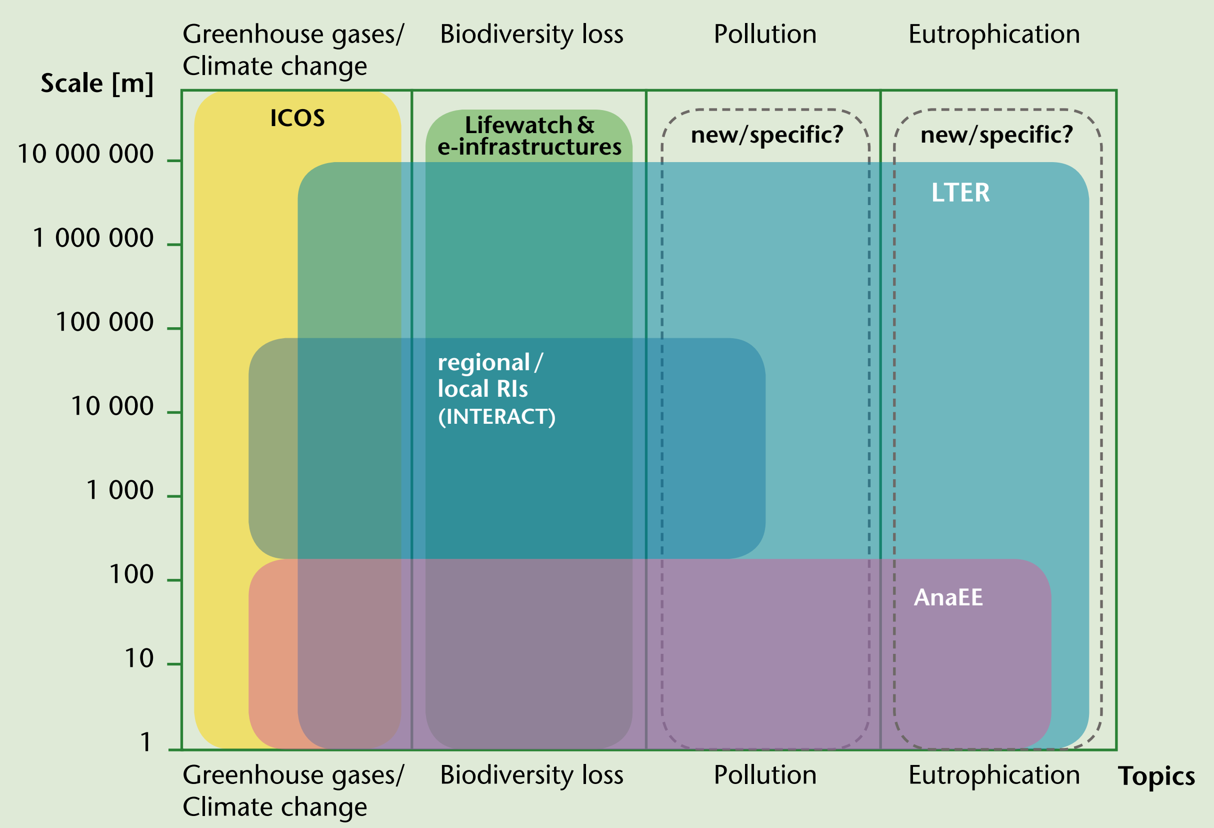

Fig. 13: For the ESFRI Roadmap, the idea has been mooted since 2014 of linking diverse research infrastructure by means of key research issues within a scale-explicit approach. The figure shows important infrastructures grouped according to the key research issues and spatial scales. Some niches may require further infrastructures (ESFRI Environmental Strategic Working Group start-up meeting for the ESFRI 2016 Roadmap, 22 May 2014, Paris; Michael Mirtl, Wouter Los, Werner Kutsch, Sanna Sorvari, Ari Asmi & Abad Chabbi)

A **focus on the in-situ infrastructures**, suggests a necessary interweaving of key elements, as depicted in Fig. 13.

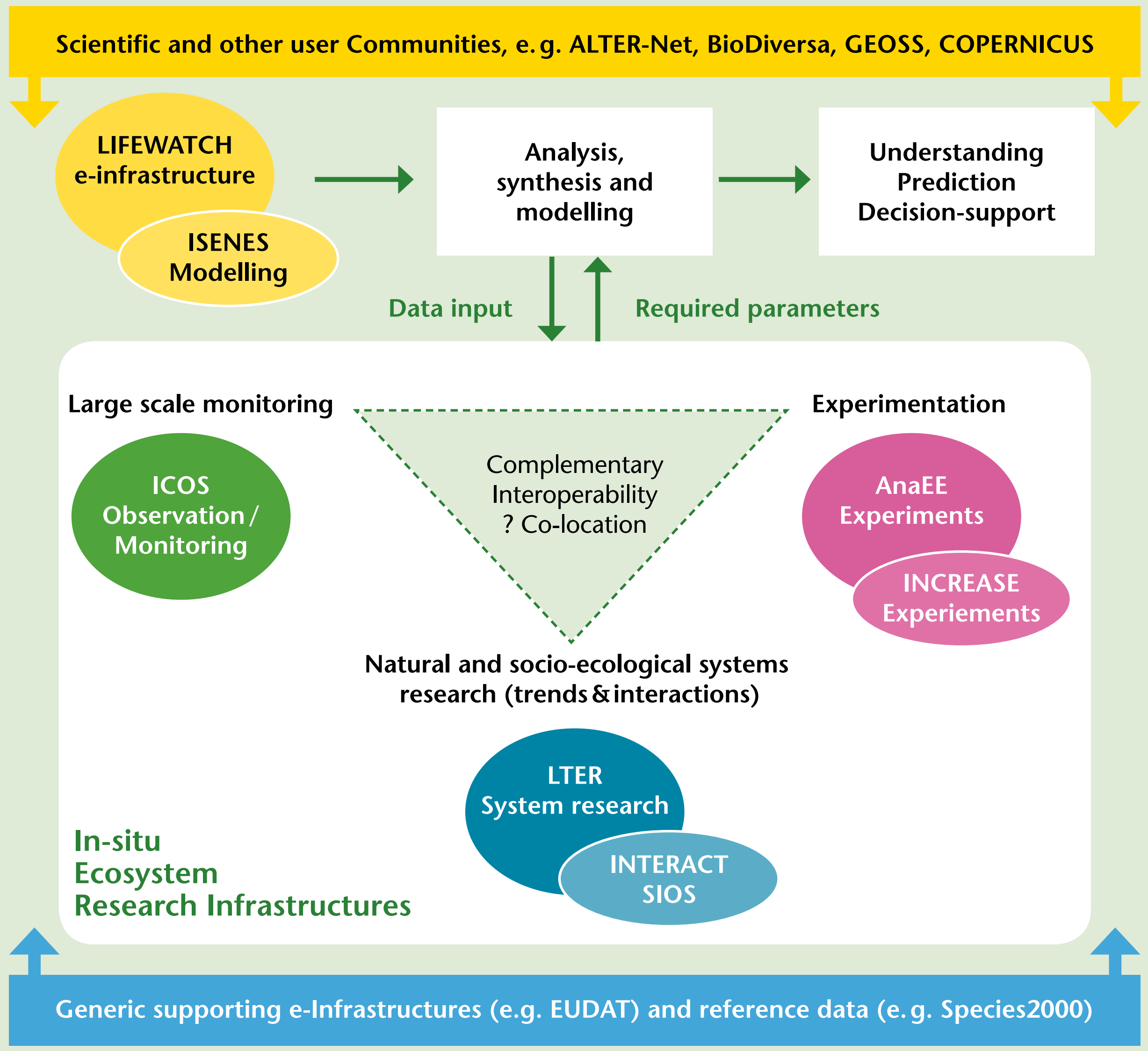

Fig. 14: The central part represents the need to create complementary, effectively interoperable, and – where possible – spatially coupled in-situ infrastructures, which combine standardised large-scale monitoring with long-term observational ecosystem research and experiments. The pool of LTER Sites offers an excellent basis for this. The in-situ infrastructures provide data for the projects and e-infrastructures mentioned in conjunction with them for workflow automatisation, data analysis and modeling. These in turn also define the parameter requirements for data. The lower section of the figure indicates generic services, of which joint use should be made wherever possible (data management and security, metadata systems etc. such as EUDAT). Diverse user groups (top) make use of these infrastructures and e-infrastructures (multiple use of sites by projects, etc.) (ESFRI Environmental Strategic Working Group start-up meeting for the ESFRI 2016 Roadmap, 22 May 2014, Paris; Michael Mirtl, Wouter Los, Werner Kutsch, Sanna Sorvari, Ari Asmi & Abad Chabbi)

From these representations, which arise from the key European development processes, the functional niche of LTER may be seen as a logical step. Chapter 7.3 focuses on the shaping of this niche in Austria. In this context, the research community and the site hosts see themselves as a pool from which all European infrastructure components within the scientific field should be made use of in a concerted manner. The fundamental securing of the key sites for ecosystem research (ultimately also known as "Critical Zone Observatories") is therefore a priority.

7 SYNTHESIS AND IMPLEMENTATION RECOMMENDATIONS

7.1 SYNTHESIS

The previous three chapters have sketched out the themes of long-term ecosystem research. This touches burning questions with sociopolitical importance in Austria and at the global level.

The following characteristics of the scientific field may be derived from the representation of LTER right across all the thematic areas:

- The drivers and pressures of ecosystems and biodiversity have long-term impacts (climate and land use change, invasive species, etc.). Alongside this, short-term events also play a significant role.
- Many ecosystemic processes are only recognisable as such through long-term research and continual monitoring with an appropriate testing frequency. Only thus can they be accorded signficance respectively and explained in terms of cause-effect patterns.
- The increasing complexity of ecological research issues requires ever more complex instrumentation and improved data quality for resilient long-term data series.
- Ecosystems and socio-ecological systems therefore cannot be researched through individual short-term projects.
- Significant bases for efficient, long-term research activity at the research sites (basic monitoring, management of long-term experiments, long-term data series, etc.) are not possible on the basis of random selection.
- To make the best possible use of funding, agreed disciplinary and interdisciplinary projects as well as a harmonised distributed infrastructure are required at priority sites.

Aside from scientific interdisciplinarity, ecosystem research is increasingly developing into a process based on the division of labour across four levels:

- Individual research sites and their hosting institutions (or future hosting associations)
- National networks
- European research association
- International networks

On all four levels, there is interaction between three key components:

- Infrastructure: sites, together with their building facilities, instrumentation and accessible data stocks (as a service, including the maintenance and expertise that facilitates the correct use of this infrastructure)
- Research activity including analysis and reporting on trends (central user level)
- Matrix functions (e-Infrastructure for data management and workflows, networking, concept development, interface to political implementation and training/education)

These characteristics of the scientific field, the division of labour across four levels and the three key components together form the basis for the **recommendation for a "research cluster",** through which Austria can provide excellent contributions of great benefit to the country itself within the European and global research environment and as a result of which Austrian sites will be rendered more attractive to international research teams.

The synthesis of this White Paper builds **a bridge between the vision and the current status quo.** Since this vision is based substantially upon the infrastructures and organisation of the research field, the **time horizon** for implementation extends to **2020 and beyond.** For Austria as a small country in particular, the reorganisation of such a complex area needs to be related to **conditions within the European framework.** This is all the more important in the context of ecosystem research because the European Commission is currently defining research foci and establishing mechanisms for which the envisaged implementation period is around a decade (ESFRI, Joint Programming, EU Structural Funds).

The LTER-Austria White Paper and this synthesis are to be understood **simultaneously** as the **conclusion** of a decision making process **and as a handover point:** In the following section, the positions of the scientific community and the hosting organisations for infrastructures in the field of scientific research require further harmonization with those of the relevant stakeholders. This involves evaluating and prioritizing sites, content-related foci and contributions to the European Research Area.

7.2 CENTRAL MESSAGES (OVERVIEW)

If Austria wishes to ensure it does not fail to connect with international developments, securing the long-term sustainability of ecosystem research infrastructures and project work is urgently needed. This should have its conceptual basis in European reference projects such as ICOS and Life-Watch (in ESFRI/Environment), ExpeER und ENVRI (FP7/INFRA) and LTER-Europe. There is a clear tendency in favour of prioritizing the effective equipping of sites and recognizing them as key infrastructures. This recognition will be increasingly decisive regarding their inclusion in European calls for tender (e.g. H2020 calls), whether their use by international research teams will be fostered and whether the Austrian domestic expenditure can be seen counting towards European Research Infrastructure (ERI).

In other words, this involves a combination of

a) A more effective use of the funding and facilities currently employed in this field,
b) A necessary stimulus funding and further financing for ongoing operation, and
c) Cost-neutral, targeted measures in the context of a medium-term strategy for the reorganisation of this scientific field.

All this becomes more important given that the ecosystem research community (LTER with its LTSER components) in Austria is relatively small, that the small amount of available national project funding necessitates a switch of focus to European projects and that the multiple involvement of Austrian sites and data depend upon their organisation and accessibility.

Before addressing recommended solutions, a short overview of the central messages is presented here in the same order as the "key messages" in the introductory chapter:

- (A) The three thematic areas described in the current White Paper encompass the scientific field. Although the authors have made every effort to identify synergies and disciplinary interactions, each thematic area possesses a specific requirement profile. The necessary framework conditions discussed here with regard to **the scientific field as a whole** and its components require a **holistic perspective** and can therefore not be achieved by focusing only on the individual components themselves.

- (B) With respect to the creation of appropriate **funding conditions for distributed research projects** regarding complex ecological and socio-ecological phenomena as a strategic and regulatory measure: theme-specific award procedures with classic disciplinary and interdisciplinary quality measures can be implemented via relevant criteria in existing or new funding mechanisms, where the setting up of and adequate funding for a reseach framework programme is not possible.

- (C) **Framework conditions for research projects** need to facilitate the **use** of in-situ infrastructures and e-infrastructures **across all affected national stakeholders** and funders of environmental research and monitoring according ot international examples (see Info-Box 3: German Biodiversity Exploratories and TERENO, but also US-LTER and NEON, EU Infrastructure Calls, LTER Japan).

- (D) The long-term and complex character of the neceesary basis for individual research projects (data series etc.) requires the creation of an **association of** sites with nationally agreed, distributed funding and operational site hosting as **service** with adherence to European frameworks (ESFRI/LifeWatch, ESFRI/ALEC, Infrastructure call projects EXPEER, boosting "Multi-use" and "Transnational Access/TA": see explanations in the main text and glossary).

- (E) The coordination and documentation of LTER in Austria requires an **operational headquarters** (central body) as the hub for building networks of activities both nationally and internationally, the interface with stakeholders and political representatives and the establishing of e-infrastructure for general use and integration of data stocks from individual sites (information portal).

TERENO is a German programme for recording long-term time series of ecosysem parameters in order to analyse and forecast the impacts of global change in natural science and socioeconomic terms. The data acquired through TERENO facilitate the validation, improvement and integration of terrestrial modeling, which will make a significant contribution to the management of agricultural and forest ecosystems. Over a period of five years, c. 15 Mio. Euros have been invested in the establishment of technical equipment-related infrastructure for four observatories. The TERENO observatories, the envisaged operation of which is planned for a minimum of 15 years, are managed by an association of six Helmholtz Centres, in which well over 100 scientists are involved in long-term project activities.

Biodiversity Exploratories
The platform researches functional biodiversity and ecosystem processes in a range of land use types. It includes three exploratories with 300 plots and 27 highly equipped focal sites along a use-gradient. The core funding is secured by a coordinating office, three exploratory teams and a database team, as well as the first inventarising of biotic and abiotic resources in the areas. Where the exploratory infrastructure including human and material resources, is concerned, an additional c. 1.4 million Euros are available each year. Complementary DFG funding supports c. 40 research projects. Through these, c 250 scientists from 40 institutions make use of the infrastructure.

Comparison with Austria
If one were to apply only these two programme examples proportionally through GDP (1:10) to Austria, then the c. 1 Mio. Euro per year for infrastructure would mean an involvement of research funding of c. 2 Mio. Europe per year for projects and operational costs!

Alongside this, in Germany there are however still a number of permanent and large-scale research centres (e.g. the Environmental Research Centre at Halle-Leipzig, the UFZ, or the Jülich Research Centre), which are able to focus the work of their large teams upon issues regarding ecosystem research and which also receive substantial resources for their operational activities from sites and the management of LTER.

Info-Box 3: Investments in the area of ecosystem research: international comparison with Germany: TERENO

The following section sketches out a packet of measures aimed at facilitating the key messages in practice. This packet of measures combines activities that were already initiated and decision-making parameters for setting agendas that are still to be defined, and which are to be arrived at in consultation with the Austrian stakeholders and funders.

7.3 ORGANISATION AND DATA MANAGEMENT

7.3.1 STRATEGIC ORGANISATION

The research cluster organisation depicted in Fig. 14 would interlink science and research users, services (operational coordinating body, data portal, infrastructure/sites), content and strategy coordination (stakeholders, Scientific Advisory Board, funding mechanisms), and policy consultation. This organisation would have the capability to bridge the gap between the status quo and identified requirements and thereby ensure the following added value:

- Central contact partners for the scientific field of "Ecosystem research" for stakeholders and policy makers (rapid and effective communication for policy input; political consulting)

- Valorisation of national pre-investments in sites, data series, results and models from earlier research programmes (cultural landscapes research KLF, forest degradation research, proVision)
- Exploiting the pioneer status of Austrian research in integrated environmental research (e.g. in development and testing of the LTSER concept), particularly with regard to the development of inter- and transdisciplinary modeling and theory
- Integration of long-term monitoring research and experimental approaches
- The development of an integrated network of national "super-sites" as a nationally agreed contribution to high-value ecosystem and biodiversity research infrastructure in Europe (e.g. ExpeER, Horizon2020 Infraia projects such as eLTER and ENVRI+, ESFRI projects like AnaEE and especially in the "Environment" field: LifeWatch, ICOS)
- Platform for the development of an Austrian ESFRI Roadmap in the "Environment" field.
- Services for scientific teams and research projects, the activities of which are increasingly difficult to support in a project context and through individual institutions (e.g. metadata and data management)
- Rapid identification of suitable Austrian sites with regard to addressing specific research questions (via metadata on the sites themselves, the data and expertise available there and the provision of socio-economic and historical sources, data and metadata)
- Simplifying searches for data stocks (Step 1) and direct access to data (Step 2)
- Framework conditions that provide young scientists working in ecosystem research with rapid access to the research community, to projects, to research sites and to their data landscape
- Structure for multi-site projects and national and international evaluations (e.g. meta-analyses for the impacts of climate change and changes in land use across habitat types and environmental gradients)
- Increasing the attractiveness of Austrian research teams through the opportunity to contribute long-term data series to project work
- Standardisation, improvement of comparability and quality assurance of measurements for key parameters (e.g. temperature, biodiversity indicators)
- Coupling of long-term research sites with national and international monitoring networks (integration of the in-situ networks of e.g. EMEP, ICPs of the UNECE Working Group on Effects)
- The opportunity to assert the position of the site network of LTER as a contributor to international projects (ESFRI, projects with transnational access)

Sonnblick Observatory viewed from Heiligenblut (Fleißkehre): © Ursula Nasswetter

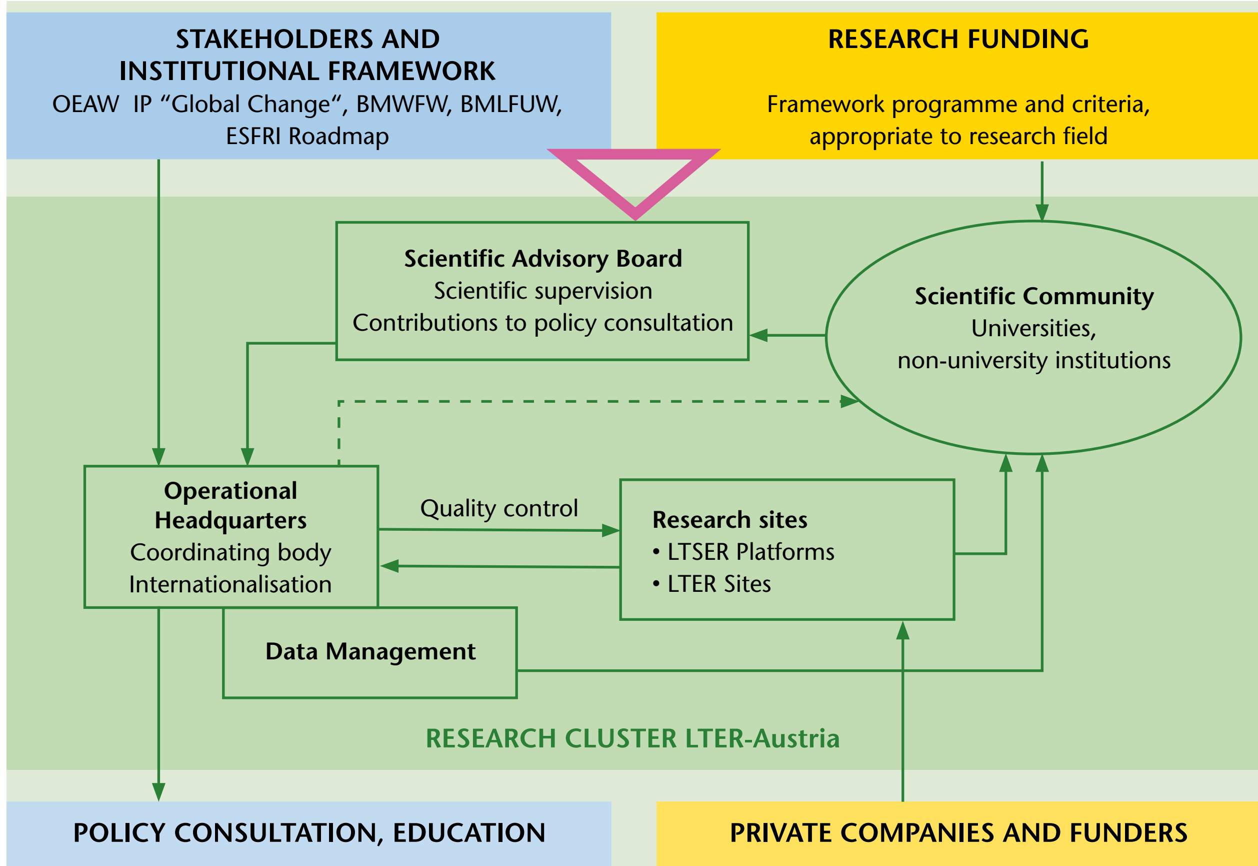

Fig. 14: Structure of LTER-Austria as a research cluster for ecosystem research in Austria. Elements and interactions are set out in the text below.

THE RESEARCH CLUSTER, EMBEDDING AND OPERATIONAL COORDINATION

An **operational coordinating body** documents and links together the **research sites** (in-situ infrastructure of LTER Sites and LTER platforms, see central part of Fig. 14). The central tool for documentation will continue to be the web-based platform DEIMS, initiated by ILTER and LTER-Europe (http://www.lter-europe.net/info_manage/deims), within which an increasing number of project and network sites are managed (ExpeER, ENVRI+, FORESTING, CZOs). For the entire network, long-term **funding and operating models** need to be secured for clusters of sites and also for individual sites (contributions from funding institutions, private firms and funders, European funding pots). The research sites with responsibility for data measurements, make these accessible to the **data management** of the operational coordinating body (data from all three thematic areas, including reports and publications), which is also responsible for **quality** assurance. This includes both the data and the sites and their operating activities. The **operational coordinating body** promotes international networking and lobbying activity for the Austrian sites within the European Research Area (ERA). The Scientific Advisory Board (SAB) is responsible for providing advice on the direction of research and the standard measurement programmes required for this. The SAB is constituted from the scientific community (from both university and non-university settings) and is in dialogue with stakeholders regarding the strategic interests and framework conditions for research funding.

At the present time, some of the functions of an operational coordinating body are undertaken by the secretariat of the LTER-Austrian association, the activities of which are funded on an annual basis, together with the sections for the two research platforms of Eisenwurzen and the Tyrolean Alps.

PUBLIC STAKEHOLDERS, INSTITUTIONAL FRAMEWORK AND NATIONAL RESEARCH FUNDING

The activities and infrastructure of Austrian ecosystem research fall within the spheres of activity of numerous government ministries, subordinate agencies and university and non-university institutions as **stakeholders.** At the initiative of the Federal Ministry of Science, Research and Economy (BMWFW), LTER was thematically anchored in the Austrian Academy of Sciences (ÖAW) as part of the reorganisation of the **ÖAW International Programme** within the “Global Change“ International Reseach Programme (contact point for the operational coordinating body).

The above-mentioned thematic diversity within the scientific field of “ecosystem research” and the lack of integrative access contribute to the **inadequate degree of support provided by research funding mechanisms.** If there is no dedicated and appropriate **research framework programme** for this field of science, then adequate funding of these research components can only be achieved through the **creation of relevant criteria** across all the funding mechanisms in consultation with stakeholders. The research cluster can support this via the operational coordinating body or the SAB (red triangle in Fig. 14).

POLICY CONSULTING, EDUCATION AND PRIVATE STAKEHOLDERS

LTER generates insights that are fundamental in addressing politically important issues such as the carbon stocks of ecosystems (Kyoto) and adaptation to climate change. The thematic area of LTSER (socio-ecological research) holds particular relevance where policy and implementation measures are concerned (e.g. public awareness of protected assets such as biodiversity, conflicts over resource use, future scenarios for socio-ecological systems, support for sustainable development through science-policy interfaces). In cooperation with Austrian environmental monitoring, LTER can play an active role in providing policy advice, via access to a large pool of experts. At the LTER research sites, the pulse of Austrian ecosystems can be taken in a tangible and visible way (“open air laboratories”). Given the current spirit of the times and the predominant use of leisure time by children and young people, communicating a basic understanding of our natural resources (complementary to technical knowledge) is becoming increasingly important, both in relation to an informed and responsible citizenry and to **ensure the development of a future generation of scientists.** It will in future be necessary to devote particular attention to **alternative funding pathways.** Until now, there has been barely any involvement by private sponsors in environmental research in Austria, as is commonly the case in US research programmes (e.g. tropical biodiversity research in TEAM). Also in the USA, leading private firms are involved in the national high-tech environmental monitoring programme NEON, which produces long-term data that is complementary to that of LTER. However, initiating and implementing such models requires resources if this is to be undertaken in a professional manner.

7.3.2 DATA MANAGEMENT (E-¬INFRASTRUCTURE, “DATA CENTRE”)

The primary aim of the data and information management of LTER-Austria is to make the results of monitoring and analysis available through the development and implementation of a decentralised data and information network. This should comprise all the relevant data types and sources through the optimal use of available tools and standards (e.g. the LifeWatch reference model). In creating common guidelines for the dissemination of scientific results and data from the LTER network, not only technical and semantic aspects but also organisational aspects of integrative data management need to be considered.

Currently, the existence of different data strategies, forms of organisation or data rights within both the various host organisations and the scientific community constitute obstacles to the accessibility and utilization of data and results beyond the individual research sites that should not be underestimated. This problem is exacerbated by the lack of a coherent data and information strategy. The organisational structure and funding approach recommended here will make it possible to undertake knowledge management with the help of integrated technology and a homogenous system of documentation. This would allow the research cluster to employ standards and tools, which currently emerge from a range of projects and processes, since the whole issue of managing environmental research and monitoring data receives a great deal of attention (metadata standards such as INSPIRE, ISO19115/19138 or EML; core ontologies and thessauri for environmental monitoring activities such as SERONTO, observation and measurement or EnvThes and web-based services for site documentation, such as DEIMS, http://data.lter-europe.net/deims/).

Access to information and data is organised on two different levels. On one hand, it encompasses the level of **information about existing research sites and their available data stocks** (metadata level) and on the other hand, the level of **concrete data stocks** (data level). Metadata represent an important source of information enabling the suitability of sites and the accessibility of data for a wide range of research issues to be evaluated. While metadata are freely available, it is often the case that different data access rights are applied at the data level. The creation of a clear and transparent presentation of data access rights, together with communication of responsibilities pertaining to these, will thus lead in the longer term to **broader access to research and monitoring data.** In this context, particular attention must be paid to determining the traceability of data and thus also their provenance in the context of longer term processes of evaluation (keyword: data provenance).

The **"data centre"** for the research cluster would thus not be a centralised data holding facility but rather would make use of state-of-the-art technologies in order to:

a) enable an overview of existing data stocks,
b) describe these in a semantically correct way over the long term (interoperability in the time axis and across all disciplines), and thus
c) facilitate the decentralised holding and provision of data by the sites/originators via online access (e.g. through OGC Web Feature Services for spatial data or OGC Sensor Observation Service for monitoring data).

The data centre would thereby act on one hand as a docking station for international documentation systems (metadatabases such as DEIMS or the LifeWatch e-infrastructure), and on the other hand also as a national hub, so that data access regulations can be compared and harmonised. Thus it is not only an information service provider but also a platform for exchange between data originators, managers and providers on one hand and scientific users and their evolving requirements on the other. The research cluster's data management should thus provide the best possible support for the **standard processes** of scientific projects, such as the research of suitable data, clarification of ownership rights, the physical exchange of data and the documentation of results. **Supporting sites with their own data management** is particularly important for increasing efficiency. Identifying (national and international) examples of best practice, from recommendations for software tools and standards (through ongoing checks with international developments) to training information managers at the sites, would be key services. These contribute to the convergent further development of data management across the entire network, where centralised administration is neither advisable nor possible. General workshops, such as information management workshops to present and discuss overall developments, and workshops with a thematic focus, such as hands-on workshops for those using specific technologies, provide an important element of building know-how and capacities as well as contributing to the better integration of functions/roles in a complex interdisciplinary research community involved in close cooperation between participants.

A further significant challenge concerns the **documentation and provision of already existing data and results (legacy data).** These often exist in very different data formats and storage media. The spectrum ranges from analogue (e.g. field notebooks or maps) and semi-analogue forms to outdated digital media or data formats. Alongside the technical problems of updating data formats, incomplete documentation of data and results mean that a great degree of effort is expected to be required in terms of research and documentation. Furthermore, clarifying the legal situation regarding data stocks (e.g. property and distribution rights) can often prove to be time and energy intensive. The failure to process, document and digitalise these data stocks would, however, not only represent a waste of large sums of public money (the price of data collection over several decades), but also the destruction of valuable long-term information. The investment made to date in securing information within this field of science thus stands in glaring contrast to the resources provided and expended in other scientific fields and cultural sectors (e.g. for the documentation of publications by the National Library).

Support and coordination of these activities, similar to the digitalisation of herbarium records in the Global Biodiversity Information Facility (GBIF), is thus a priority undertaking.

7.4 ADEQUATE FINANCING FOR RESEARCH PROJECTS

The integration of individual projects within a larger research context (linked clusters of research issues) both nationally and internationally, the valorisation of existing data, the long-term optimisation of the data basis for future research into Austrian ecosystems (data hot-spots), the sustainable utilisation, maintenance and competitiveness of Austrian infrastructures, the priority response to research issues holding particular relevance in the Austrian context, and political relevance of, for example, inter- and transdisciplinary research, etc. are despite their indisputable importance not decisive criteria in the evaluation of national research funding applications e.g. with the FWF. With this in mind, there are two options for ensuring ecosystem research receives adequate support in Austria.

OPTION 1:

Through the development of a research framework programme for funding ecosystem research in Austria based on the model of the Cultivated Landscapes Research programme (KLF) and proVISION, Austria's current (strongly conceptual) pioneer status, resulting from successful participation in strategic initiatives such as ALTER-Net (NoE in the 6th EU Framework Programme) and the LTSER development, will be maintained through concrete research projects. The successful participation of LTER researchers in the Research Excellence programmes (ERC, the Start and Wittgenstein prizes, etc.), and in the Horizon 2020 research requires that costs not covered by these programmes be funded. Given the existing capacities, a funding volume of initially 1.5-2 Mio. EUR per year, and after five years of c. 3 Mio EUR per year are seen as a minimum for a successful programme.

Based on the character of the thematic areas described in Chapters 3-5, the requirements of such a programme would be as follows:

- Roughly 70-80% of the costs, to a roughly equal degree, fall upon three programme strands aligned with the thematic areas of process-oriented ecosystem research, biodiversity and conservation research, and long-term socio-ecological research, with the remainder devoted to crosscutting synthesis projects and related activities (networking meetings, symposia /conferences, publication projects, etc.)
- Focusing on established LTSER Platforms or integration of established LTER Sites as an important criterion for project funding allocation (utilisation of data, existing expertise and infrastructures)
- Integration in European and international LTER initiatives as well as EC infrastructure programmes
- Support should be given to mono- inter- and transdisciplinary basic research projects on the basis of their research excellence and their connection to LTER-relevant research issues. Purely disciplinary basic research without proven integration within an overall LTER concept would continue to qualify for funding as they currently do, through funding mechanisms such as the Austrian Science Fund (FWF).
- Projects within the thematic areas of biodiversity and conservation research and long-term socio-ecological research must be carefully evaluated in terms of their adoption of inter- or transdisciplinary approaches. Such projects must be able to show that they can provide answers to issues and problems within social practice and wherever possible, supply interdisciplinary synthesis services responding adequately to the problems addressed. Research excellence is also a decisive criterion in such cases.
- The reviewing and awarding conditions must be developed in line with the specificities of LTER (inter- and transdisciplinarity, and integration within the LTER context), such that sufficient account is also taken of inter- and transdisciplinary quality criteria (where relevant to the research problem).
- Reflection upon methodology and theory as well as a focus on the continuing development of the LTER concept (including LTSER) must play an important role.

OPTION 2:
If a research framework programme such as the one described in Option 1 cannot be put in place in the short to medium-term, then funding for the research components of LTER can only be achieved via the creation of appropriate criteria within existing funding mechanisms based on consultation between the stakeholders, the Scientific Advisory Board and the funding mechanisms themselves.

The list of criteria would correspond to those set out under Option 1. An appropriate portion of the available funding resources would need to be secured for projects that match these criteria.

7.5 INFRASTRUCTURE ASSOCIATION: NETWORK OF SITES

Strategic decisions made by a small country such as Austria should be embedded as effectively as possible within the European context and at the same time, should secure research interests that evolve from national conditions (climate change adaptation in mountain regions, sustainable small-scale agriculture, etc.)

The European framework conditions were described in Chapter 6. The position of LTER-Europe within the overall project, process and infrastructure landscape can be found within Chapter 1.2 In any case, these strategic references provide an excellent framework within which to achieve an agreed European guarantee for national ecosystem research infrastructure via e.g. the ESFRI Roadmaps. In numerous countries, national dialogue has begun between networks and infrastructure hosting institutions, with the aim of achieving progress in the multiple utilization and further development of infrastructures (Finland, Italy, Germany). Platforms for such dialogues are a part of numerous projects commissioned by Horizon2020 (ENVRI+, eLTER). The following suggestions thus represent concepts for strategic processes, for the implementation of which EU framework projects are very likely to be put in place.

In Austria too **the infrastructures of LTER are spread across a range of host institutions in the university and non-university sectors** (see site overview in Chapter Table 1). The sites work under the umbrella of LTER, exchange experience and cooperate with one another – usually on a bilateral basis – in research projects. The explicit integration within a functional infrastructure pool as Austria's contribution to the European Research Area has yet to be confirmed. Without this perspective of a strategic national and European context, it is becoming increasingly difficult to secure the activities of the individual sites through single host institutions, and universities in particular are poorly equipped to undertake long-term operations and basic monitoring because of their strongly project-based approach.

On this basis, the division of roles was defined and is reflected in the "strategic organisation" of the proposed research cluster: the service provision and structural components (site operations and basic measurement programme) are matched by scientific utilization. This takes place either through the host institutions themselves or through other national and international users. This interaction requires a complementary **funding and operational model** for (1) the entire site network, (2) clusters of sites, and (3) individual sites. This should also be considered within the development plans and service agreements with the universities, in order to ensure the permanent operation of sites.

We concentrate in the following section primarily upon the network as a whole (the core responsibility of LTER-Austria), but thereafter wish to give two examples of ecosystem type-specific site clusters.

7.5.1 THE AUSTRIAN SITE NETWORK AND THE PATHWAY TO EUROPE

The experiences since the initial focus upon Austrian contributions to ESFRI infrastructures in the environmental sector (LifeWatch/ 2008) have shown that key stakeholders such as the Federal Ministry of Science, Research and the Economy (BMWFW) are not prepared to support isolated initiatives, where the relevance and broad backing for such initiatives from both the scientific community and infrastructure host institutions has not been clearly demonstrated.

Milestones along the path to such clarification were the founding of LTER-Austria, the first LTER-Austria White Paper (Mirtl et al. 2010) and the location of the scientific field within the "Global Change " International Research Programme of the Austrian Academy of Sciences. The pool of Austrian LTER Sites and LTSER Platforms includes the majority of permanently operated ecosystem research sites. In addition, LTER is anchored at European level in the ESFRI "Landscape" Roadmap in the environmental sector. Thus instead of deciding to which more specialised infrastructures Austria might contribute with individual sites, it seems more meaningful given this approach to continue to develop Austrian ecosystem research in line with an ESFRI initiative for LTER. An important building block for this conceptual and contextualising European initiative is the Horizon 2020 proposal "eLTER", in which LTER-Europe cooperates with the Critical Zone research community (see Chapter 1.1 And Chapter 1.2):

> *A collective effort is needed to create the environmental research infrastructure for answering pressing questions in a world of rapid social, economic and environmental change.*
>
> ***The overall aim of the eLTER project is to advance the European network of Long-Term Ecosystem Research sites and socio-ecological research platforms to provide highest quality services for multiple use of a distributed research infrastructure.***
>
> ***eLTER´s major objectives and methods are to:***
> ***(1) identify user needs for the research infrastructure in relation to major societal challenges*** *through consultations with scientific, policy and business stakeholders and horizon scanning;*
> ***(2) streamline the design of a cost-efficient pan-European network, able to address multiple ecosystem*** *research issues, in collaboration with related global and European research infrastructures, e.g. LifeWatch;*
> ***(3) develop the organisational framework for data integration and enable virtual access to the LTER data*** *by enabling data publishing through distributed Data Nodes and by providing access to data on key research challenges through a Data Integration Platform;*
> ***(4) foster the societal relevance, usability and multiple use of information, data and services*** *through new partner ships with the providers of remotely sensed data, analytical services and scenario testing models, and via the adoption of new measurement technologies.*
>
> *The* ***LTER-Europe network and the European Critical Zone community*** *will collaborate to achieve these goals. 162 sites in 22 countries will provide data on long-term trends in environmental change, some reaching back 100 years. Test cases using these data will address a range of environmental and social issues to push innovation in network level services and steer conceptual developments.*
>
> ***The envisaged "LTER Infrastructure" will enable European-scale investigation of major ecosystems and socio-ecological systems, and support knowledge-based decision making at multiple levels.***

In September 2014, the 16 leading LTER hosting institutions in Austria addressed a petition to the Austrian Science Minister, calling for the ESFRI initiative on LTER to receive active support:

➡ *"In the course of the discussion around the ESFRI (European Strategy Forum on Research Infrastructures) Roadmap 2030, important decisions in the area of environmental research infrastructures need to be made. Austrian infrastructures have been organised strategically through consensus among the major infrastructure host organisations. It is now necessary to secure the Austrian contribution to the European Research Area by adopting measures to support high quality ecosystem research within this country…*

… The signatories to this letter appeal to the BMWFW as a matter of urgency to act to ensure the inclusion of LTER within the ESFRI Roadmap…

… This appeal is a significant aspect of concerted efforts to operate the site infrastructures as with the greatest possible cost-efficiency…"

Cultural landscape: © Richard Schambruck

Vienna University for Natural Resources and Life Sciences, Alpen-Adria-Universität Klagenfurt – Institute for Social Ecology, Karl-Franzens-Universität Graz, University of Innsbruck, Austrian Academy of Sciences – National Committee of Global Change, Austrian Academy of Sciences – Institute for Interdisciplinary Mountain Research, Austrian Federal Environment Agency GmbH, Austrian Agency for Health and Food Safety, Federal Research and Training Centre for Forests, Natural Hazards and Landscape, Agricultural Research and Education Centre Raumberg-Gumpenstein, Gesäuse National Park, Upper Austria Limestone Alps National Park, Biological Station Neusiedler See, Water Cluster Lunz, Central Institute for Meteorology and Geodynamics, University of Vienna– Institute of Geography/Geo-ecology.

In parallel with this, the following tests can be applied:

- What e-infrastructures are so relevant and helpful for the Austrian network that Austrian participation would be advantageous (e.g. LifeWatch, EUDAT)?
- What sites could contribute to more specialised infrastructures (e.g. ICOS in the environment domain of ESFRI, AnaEE in the experimental sector or DANUBIUS). This task receives significant support from the comprehensive documentation of sites in DEIMS (incl. "LTER-Europe Site Classification")?

The operational coordinating body of the LTER research cluster could continue to promote the continuing development of this process (currently through the LTER-Austria Secretariat).

7.5.2 EXPERIENCES WITH THEMATIC AND ECOSYSTEM TYPE-SPECIFIC CLUSTER INITIATIVES

Since the first issue, two clusters of LTER Sites have been constituted. They are making efforts to implement the national LTER strategy within their narrower thematic area and for a smaller number of sites, and as such represent excellent test cases for the larger pool.

7.5.2.1 Highly instrumented forest research sites (BIOS project „LTER For-Austria")

It is of great interest to Austrian forestry research to draw added value from the common utilisation of sites. As in other countries, the key infrastructure host institutions within the sector (Vienna University for Natural Resources and Life Sciences, Austrian Research Centre for Forests, Environment Agency Austria) have until now operated their sites alone and primarily for their own use. As research issues have become more complex in the context of climate change, material and energy balances and the impact of extreme events, the required investment in terms of equipment has increased. The central problem from the Austrian perspective is that it is hard to achieve larger scale new investments in the current economic climate, which makes it impossible to upgrade on an individual basis to the requisite standards and to operate many of the sites (costly basic monitoring). Only through national consensus on the priority sites, their joint utilization and operation, can sites be safeguarded and integrated in the international context. The association of host institutions thus joins seamlessly in relevant processes for infrastructure development, to ensure acceptance and a sustainable existence (LTER-Austria White Paper, BIOS Science Austria, processes connected to the ESFRI Roadmap). Within the association of host institutions, the three partners each make one site (Zöbelboden, Rosalia and Klausen-Leopoldsdorf) accessible for multiple utilization, so that individual research projects are provided with the framework and basic services they require. The sites cover important gradients within natural spaces in Austria. In the framework of the project, the sites´ scientific teams and potential users jointly formulate a portfolio of research themes, which builds upon the unique potential of these sites (benchmark systems in the landscape context for researching material balances as a basis for upscaling, model validation, etc.). The research themes are those having priority from an Austrian perspective and which are judged likely to be successful on the international research market, profit from being undertaken at multiple sites and make optimal use of existing data and infrastructures. On the basis of this thematic portfolio, options for joint operational activities are developed (requisite infrastructure, securing cost-effective basic monitoring, information management, institutional division of responsibilities) and alternatives for the institutionalisation of an infrastructure cluster (a strategy for securing the sites in the medium term in the national/European context).

7.5.2.2 Aquatic Sites

The ALEON project (Austrian Lake Ecological Observatory Network) is intended to link together the existing Austrian freshwater LTER Sites in a similar way, although it is currently still seeking funding. The aim is to provide the infrastructure to facilitate the documentation of long-term ecosystem trends at higher temporal resolutions and to undertake the comparative study of the short-term effects of extreme meteorological events upon five lakes. It is intended that ALEON should be integrated within the existing international networks, GLEON (Global Lake Ecological Observatory Network) and NETLAKE (Networking Lake Observatories in Europe, EU ESSEM COST Action). The lakes included in the study range from the shallow, nutrient-rich steppe lake of Neusiedlersee in eastern Austria to the high alpine nutrient-poor Gossenköllesee in the western part of the country. The ALEON project tests the hypothesis that the relative influence of meteorological extreme events (i.e. strong winds, heavy rainfall and extreme temperature changes) upon the phytoplankton community is specific to the type of lake. Since the nutrient input within a lake is dependent on e.g. land use and agricultural management practices in the catchment area, ALEON employs advanced GIS (geographical information systems) technologies together with remote sensing in order to estimate the pathways of phosphorus transport in the catchment area and to be able to make recommendations for effective measures to avoid nutrient outflow. The ALEON project represents a significant step towards linking both existing terrestrial and aquatic LTER Sites in Mondee with the catchment area and paving the way for the development of an LTSER Platform.

7.6 CRITICAL QUESTIONS AND POSSIBLE IMPLEMENTATION STEPS

The following critical questions will require clarification when putting the recommendations into practice:

- How can the university LTER Sites be consistently anchored in development plans and service agreements (the LTER Sites play very different roles, given the great variation in the size, thematic scope and orientation of different universities)?
- How can university and non-university sites be brought together in a coherent manner and according to a single concept within a national pool?
- How should previous and ongoing investments and the operating costs of sites be recorded and presented in a comparable way?
- What types of services should be provided by central components of European ecosystem research infrastructure?
- From an Austrian perspective, what should the relationship be between national investments and contributions, for use in Austria itself (at the sites), and contributions to the central part of a European infrastructure?
- What investments are needed across all the Austrian sites in order to establish a basic standard measurement programme?
- Where should the LTER-Austria research cluster establish its operational coordinating body?

POTENTIAL STEPS TO IMPLEMENTATION COULD BE:

- The development of a national LTER Stakeholder Board (environmental and ecosystem research infrastructures):
  - o Relevant ministries, the Federal Ministry of Science, Research and the Economy (BMWFW) and the Federal Ministry for Agriculture, Forestry, Environment and Water Management (BMLFUW)
  - o Austrian Academy of Sciences (ÖAW)/ IP Global Change
  - o Austrian Science Fund (FWF), Austrian Research Promotion Agency (FFG)
- Initiation of expert discussions between the Board of LTER-Austria and the infrastructure host institutions (signatories of the ESFRI/LTER Petition)
- Evaluation of the site network and development of operating models (distributed institutional hosting and utilization)
- Development of a funding model for LTER projects (criteria for existing mechanisms vs. framework programme) and implementation
- Consideration of the LTER requirements defined here in the recommendations for the future development of the Austrian FTI system on the part of the Austrian Council for Research and Technology Development (post-Strategy 2020)

8 ANNEXES

8.1 SHORT DESCRIPTIONS OF AUSTRIAN LTER SITES UND LTSER PLATFORMS

The text of this annex will be regularly updated. Therefore it as an inlay in the very back of this document.

This chapter provides an overview of Austrian LTER Sites and LTSER Platforms. The chapter structure reflects the achieved organization of the national ecosystem research infrastructure pool represented by LTER:

- LTSER Platform Eisenwurzen
    - Sites of the platform in alphabetical order
- LTSER Platform Tyrolean Alps
    - Sites of the platform in alphabetical order
- Other LTER Sites in alphabetical order

8.2 LINKS WITH „LONG-TERM ECOSYSTEM MONITORING (LTEM)“ IN EUROPE

A key factor in the initiation of LTER in Europe concerned strategic demands made by bodies responsible for environmental monitoring such as the European Environment Agency (EEA), currently challenged by multiple crises (energy, climate, food, financial) and requiring knowledge-based support for decision making. Many of the added values of LTER-Europe relate to requirements linked to the challenges of environmental monitoring, reporting, integrated assessment and valorization of ecosystem services, e.g.:

- indicator validation and development across scales, environmental and socioecological gradients
- optimization of monitoring schemes (scale-explicit, nested designs) across compartments and sectors
- policy support through assessing effects of measures (e.g. conservation measures on the (sub-)regional level within and outside protected areas)

Clearly, these values will only become effective in the mid and long term once **research projects (A)** have been carried out embedded within the restructured European Research Area and capitalizing on central services. As the results of these projects themselves will contribute to the hot spot nature of LTER facilities in terms of information density, data availability and understanding of complex phenomena (expertise), this is a self-reinforcing process which will significantly raise the costbenefit ratio of any type of information gathered. The benefits of the reorganization will also depend on the question of to what extent focused ecosystem- and socioecological research in LTER-Europe can be **linked with European environmental monitoring programs (B).** This implies (C) the functional (parameter sets, data) and spatial (design) and temporal (real-time) integration of in situ networks and the coordinated provision of central services. These services need to comply with internationally accepted standards to ensure seamlessly available semantic and technically harmonisation data across environmental or administrative boundaries. This includes enabling concerted public access points for data and metadata across legal and funding frameworks.

Once LTER sites and LTSER platforms in particular have been integrated within monitoring schemes, they can **provide the ecosystem- and socioecological context** of individual monitoring and sampling points (e.g. EMEP). Capitalizing on these context data gathered at different scales in nested designs as promoted by LTER, multivariate statistics, geostatistical methods and stratifications will help in quantifying the power and representativity of point data as well as their proper usability in models, e.g. for the testing of scenarios.

Organizing standard observations and measurements within LTER exemplarily revealed the **mutual interdependency and complementarity of long-term ecosystem research and monitoring:** A few groups of parameters are considered important, available and feasible at the same time, and as such they could be recommended immediately (partially down to the parameter level). However, the discussion about standard parameters also resulted in a recommendation concerning the selection of further LTER sites, in the sense that they are to be located in close proximity to or even overlapping with sites of existing longterm ecosystem/environmental monitoring

Mist at Zöbelboden and Weißenbach Valley: © Michael Mirtl

(LTEM) schemes. This relates to the question of **how environmental monitoring and research are organized** in Europe: Whereas the responsibility for research rests with universities and other academic institutions, mostly governmental bodies are in charge of monitoring. Yet funding mechanisms, mandates, internal organization and selfperception of staff roles favor either i) the production of high quality longterm monitoring data, applied research and the maintenance of infrastructure or ii) scientific projects and teaching. Whereas monitoring is defined as the continuous observation, control and measuring of the state and structure of a system (Meyers Online Encyclopedia; Wikipedia), research is the planned and targeted search for new findings in a specific realm (Neuer Brockhaus 2003). But applying a longer timescale, the designs and targets of monitoring are hypothesisdriven as well. The recent reorganization of LTER in the United States (NEON, see references/internet links) gives evidence that there is **no LTER without LTEM** and vice versa. Environmental research needs to trigger and optimize monitoring designs and methods and mutually monitoring data must form an integral part of the research. LTER Europe's design could provide a step towards integration and the synergistic use of potentials and division of tasks.

Very importantly, LTER plus LTEM also represent an enormous potential for **serendipitous science.** Serendipity is the effect by which one accidentally discovers something fortunate, especially while looking for something else entirely different (http://en.wikipedia.org/wiki/Serendipity). Firstly, sagacity is required to be able to link together apparently innocuous facts to come to a useful conclusion. But – equally importantly – one needs access to the facts in order to apply sagacity. Translated into environmental science and LTER, processes, cause effect relationships and mechanisms eventually driving our socioecological systems and significantly affecting ecosystem services can only be identified on the basis of well documented longterm data and information.

Creating such databases for a representative network of locations and securing the sustainable use of legacy information gathered at considerable cost belongs to the core of LTER-Europe's mission. Thus, while some scientists and inventors are reluctant to report 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 recognized that serendipitous discoveries are of significant value in the advancement of science and often present the foundation for important intellectual leaps of understanding. Bearing in mind the importance of LTER's precautionary principle, the 20 year 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.

8.3 GLOSSARY

ALTER-Net - FP6 Network of Excellence, which facilitated the development of LTER-Europe. Now a self-financing network of 27 institutions in the field of biodiversity & ecosystems research

AnaEE - ESFRI preparatory project on a RI for ecosystem experimentation

Belmont Forum - High level group of the world's major and emerging funders of global environmental change research and international science councils

BiodivERsA - Network of national funding organisations promoting pan-European research for the conservation and sustainable management of biodiversity (ERA-NET)

BioFresh - The Global Freshwater Biodiversity Information Platform

BISE - Biodiversity Information System for Europe (single entry point for data on biodiversity)

CLRTAP - Convention on Long-Range Transboundary Air Pollution in the UNECE

Copernicus - Global Monitoring for Environment and Security programme (remote sensing)

CRITEX - National network for the spatial and temporal study of the French Critical Watershed Zone

CSW - Catalogue Service Web (OGC Standard); service based publishing of metadata

CZ, CZO - Critical Zone concept; CZ research sites are Critical Zone Observatories

DataONE - Data Observation Network for Earth (US)

DEIMS - Drupal Ecological Information Management System operated by ILTER and LTER-Europe and providing a web client interface for documenting metadata and data from research sites

DMP - Data Management Plan

DOI - Digital Object Identifier (ISO 26324)

EcoPAR - Interactive web tool “Parameters and Methods for Ecosystem Research & Monitoring”

ECSA - European Citizen Science Association

EEA - European Environment Agency

EEF - European Ecological Federation

EF - INSPIRE data theme Environmental Monitoring Facility

EFI - European Forest Institute

EGI - European Grid Infrastructure

eLTER Site - Site within the LTER infrastructure pool, which contributes to eLTER

eLTER DIP - eLTER Data Integration Platform, providing interoperable data from different data nodes

eLTER DN - eLTER Data Node, the IT infrastructure providing service-based access to metadata and data

eLTER-S2 - eLTER Software Suite, the set of tools and services needed to set up an eLTER Data Node

EMBRC - European Marine Biological Resource Centre

EMEP - European Monitoring and Evaluation Programme (belongs to CLRTAP)

EML - Ecological Metadata Language, a standard metadata schemata for observation data

EnvEurope - European Life+ Project “Environmental quality and pressures assessment across Europe: the LTER network as an integrated and shared system for ecosystem monitoring”

ENVRI, ENVRI+ - FP7 project “Common Operations of Environmental Research infrastructures”, a collaboration in the ESFRI Environment Cluster. ENVRI+ might be a successor under H2020

EnvThes - Environmental Thesaurus. A multilingual thesaurus developed in the framework of the projects Life + EnvEurope and ExpeER

EPBRS - European Platform for Biodiversity Research Strategy

ERA - European Research Area

ERIS - Environmental Research Infrastructures Strategy (a product of ENVRI)

ESFRI, ESFRI ENV - European Strategy Forum on Research Infrastructures. ESFRI ENV concerns environmental research

EU NEC directive - Proposal for a directive on National Emission Ceilings

EUBON - European Biodiversity Observation Network (FP7)

EUDAT - European Collaborative Data Infrastructure (FP7)

ExpeER - A major European Infrastructure project (2010-2014) in ecosystem research

FOAF - Friend of a Friend (FOAF) metadata schemata

GEO BON - Group on Earth Observations Biodiversity Observation Network (part of GEOSS)

GIS - Geographic Information Systems

GLEON - Global Lake Ecological Observatory Network

GLORIA - Global observation network for climate change impact in high alpine areas

ICOS - Integrated Carbon Observation System. An ESFRI research infrastructure

ICP - International Co-operative Programs of the UNECE/CLRTAP. Specific monitoring programs are ICP Forests; ICP Integrated Monitoring of Ecosystems, ICP Vegetation

ILTER - International Long Term Ecosystem Research network

INCREASE - Integrated Network on Climate Research (FP7I3, experimentation)

INNGE - International Network of Next Generation Ecologists

INSPIRE - EU Directive, and aims to create an EU spatial data infrastructure

INTERACT - International Network for Terrestrial Research and Monitoring in the Arctic (FP7 RI)

IPBES - International Panel on Biodiversity and Ecosystem Services

IPCC - International Panel on Climate Change

IPR - Intellectual Property Rights

IS-ENES - RI of the European Network for Earth System Modeling

Jerico - Joint European Research Infrastructure Network For Coastal Observatories (FP 7)

JRA - Joint Research Activities

JRC - Joint Research Centre, the European Commission's in-house science service

LifeWatch - European e-Science infrastructure for biodiversity and ecosystem research

LTER Infrastructure - The integrated ecosystem research infrastructure to be established by eLTER

LTER infrastructure pool - The pool of long-term ecosystem research infrastructures on which eLTER builds (LTER-Europe network plus Critical Zone Observatory sites)

LTER Site - Natural scientific research sites of LTER-Europe

LTSER Platform - Regional infrastructure for socio-ecoological research (of the LTER-Europe)

LTER-Europe - European Long-Term Ecosystem Research Network, consisting of 21 formal national LTER networks and representing Europe as ILTER regional group

MD - Metadata

M&T - Mobility and Training

NA - Networking Activity

NEON - National Ecological Observatory Network, USA

OGC - Open Geospatial Consortium. 481 companies collaborating on interface standards

RCM - Regional Climate Model

RDA - Research Data Alliance

RI - Research Infrastructure

SensorML - Sensor Model Language (OGC Standard)

SoilTrEC - Soil Transformations in European Catchments (FP7 project)

SOP - Standard Operating Procedure

SOS - Sensor Observation Service (OGC Standard)

SWE - Sensor Web Enablement (OGC Standard)

TA - Transnational Access (in-person)

TERENO – Integrated “Terrestrial Environmental Observatories”, Germany

TERN - Terrestrial Ecosystem Research Network, Australia

TSAP - Thematic Strategy on Air Pollution

UNECE - United Nations Economic Commission for Europe

VA - Virtual Access

VRI - Virtual Research Infrastructure

WP, WPs - Work Package, Work Packages

WFS - Web Feature Service (OGC Standard)

WMS - Web Map Service (OGC Standard)

W3C - World Wide Web Consortium; standardization organization

8.4 MEMORANDUM OF COOPERATION BETWEEN LIFEWATCH AND LTER-EUROPE

LifeWatch   LTER Europe

MEMORANDUM OF COOPERATION

Between LTER-Europe and LifeWatch

1. Introduction

This Memorandum of Cooperation (MoC) provides the basis for the Long-term Ecosystem Research network Europe (LTER-Europe) and LifeWatch (hereinafter 'the Parties') to collaborate together to develop and share infrastructure and information, in order to further their respective mandates.

As both Parties comprise membership from countries and organizations, and mandates from these memberships to develop relevant operational partnerships, it is envisaged that the conditions of this MoC will apply to the coordinating facilities of both Parties as well as their joint and respective memberships. As such, reference to the Parties (i.e. 'LTER-Europe' and 'LifeWatch') incorporates the full organisational memberships respectively.

2. The Parties

The Long-term Ecosystem Research Network is a network of about 250 Long-term Ecosystem Research Sites and about 30 Long-term Socio-ecological Research Platforms. The mission of LTER-Europe is to investigate across Europe´s environmental gradients the drivers of major ecosystem types and socio-ecological systems and how changes affect ecosystem services. The distributed infrastructure is currently organized in 21 formal national LTER networks and contributing to the global umbrella network (International Long-term Ecological Research Network, ILTER). The conceptual pillars of LTER-Europe are "in-situ", long-term, process orientation and system approaches at different scales from plots to entire catchments studies. Data legacies and all issues related to the management and analysis of distributed data sources form an integral part of the infrastructure.

LifeWatch is becoming a consortium of European States and supporting scientific networks operating a research infrastructure for biodiversity and ecosystem research. The mission of LifeWatch is to construct and operate a distributed information management and analytical infrastructure for biodiversity and ecosystem science based upon Europe-wide strategies implemented at the local level: individuals, research groups, institutions, countries. Its objective is to accelerate scientific progress and societal use of such science by operating facilities for the integration, analysis and modelling of data, allowing users to build virtual collaborative environments for their specific modelling and analysis purposes. The LifeWatch Architecture, as described by the LifeWatch Reference Model (LifeWatch-RM) is the technical basis of European strategies for local implementation.

3. Objective of this Memorandum of Cooperation (MoC)

The services of LifeWatch to users are depending on a number of data generating facilities, including LTER-Europe. In turn, LTER-Europe organisations are potential users of the LifeWatch research infrastructure. Both benefit from cooperative developments, including data sharing and transfer, data standards and protocols, semantic capabilities, and supporting software.

The objective of this MoC is to formalise a framework for co-operative and collaborative work between LTER-Europe and LifeWatch initiatives while recognising their respective independent yet complementary missions as summarized under article 2 above.

Cooperative activities include:

a. promotion of a common, free and open access data and software policy;

b. fostering interoperability of facilties by cooperation towards a service oriented architecture for which the LifeWatch Reference Model may serve a guidance;

c. fostering the use of common standards and protocols;

d. development of joint demand-driven data discovery and mobilisation plans involving LTER-Europe partners and LifeWatch National Centres;

e. ensuring the interoperability of the LTER-Europe architecture and the LifeWatch architecture.

f. identifying and implementing collaborative projects of value to both organizations;

g. establishing a mechanism to secure the continued maintenance and improvement of cooperation to meet common goals;

h. developing joint thematic or training workshops and other meetings where appropriate, both at the European and national levels;

i. promoting the participation of European countries in both Parties by encouraging a close interaction of national LTER network offices and LifeWatch national Centres;

j. ensuring frequent two-way communication between the Parties on activities and joint publicity to audiences in support of these cooperative activities.

Specific agreed activities may be drafted as Addenda to this MoC with details, including personnel, funds and objectives captured on a case-by-case basis.

4. Conditions of Use

Both Parties agree that they will clearly label the source of all content and require users to indicate those sources in any subsequent re-use. Each Party agrees to fully acknowledge the other (verbally and by including logos) when citing or promoting jointly developed products.

5. Amendments and Modifications

Either Party may recommend amendments to this Memorandum of Cooperation by notifying the other Party in writing and, with the subsequent agreement of the other Party, then implementing those amendments.

Not withstanding the foregoing, both Parties undertake to jointly review and revise (as necessary) this Memorandum of Cooperation two years after it comes into force.

6. **Non-exclusive Agreement**

This Memorandum of Cooperation is non-exclusive, and in no way restricts either LTER-Europe or LifeWatch from participating in similar activities or arrangements with other public or private initiatives, organizations, or individuals.

For LTER-Europe: Date: 4.8.2014

Michael Mirtl
(Chair of LTER-Europe)

For LifeWatch: Date: 8-8-2014

Benjamin Sanchez Gimeno
(Chair of the LifeWatch Board of Directors)

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