EnvEurope

Environmental quality and pressures assessment across Europe: the LTER network as an integrated and shared system for ecosystem monitoring

2010 - 2013
LAYMAN'S REPORT

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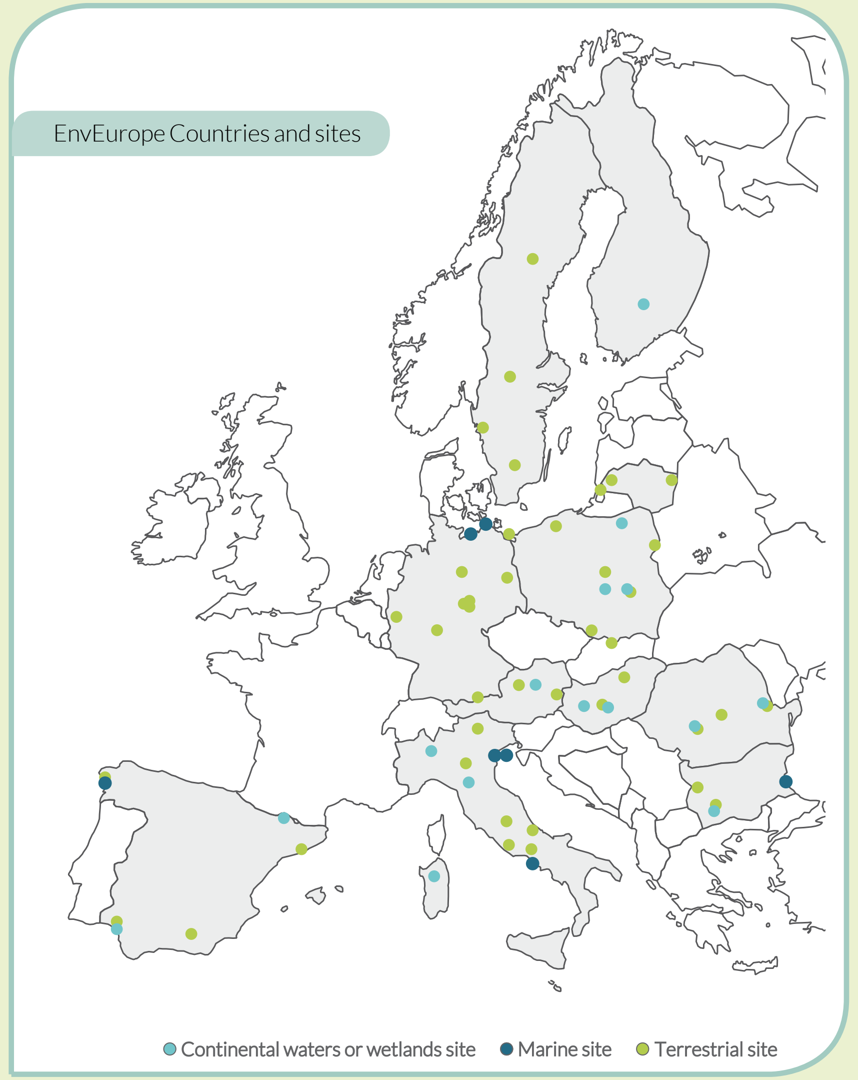
EnvEurope in a nutshell

The EnvEurope project was approved under the Environment Policy and Governance component of the European Union's LIFE+ programme, addressing the theme "Strategic Approaches".
Priority areas of action for this theme were (a) the strengthening of the scientific base for environmental policy making; (b) contributing to the implementation a Shared Environmental Information System (SEIS[1]) and (c) supporting the development of Copernicus (formerly called Global Monitoring for Environment and Security, GMES[2]).
Within this LIFE+ context, EnvEurope was conceived in response to ecological research challenges in the European Long-term Ecosystem Research (LTER-Europe[3]) site network. EnvEurope was the first project completely dedicated to the LTER-Europe network.
The project's tasks were to:
- harmonize LTER-Europe network activities
- streamline standard procedures required to support LTER scientific research
- increase the visibility of LTER-Europe as a reference network for policy makers and environmental managers at the European level.

EnvEurope involved 11 LTER-Europe countries, 17 partners and 67 LTER sites (around 20% of LTER-Europe sites), shared among terrestrial sites, continental and transitional waters, and marine sites.



The project was organized into several Actions addressing key project issues:
- Development of a common set of key long-term ecological parameters and measurement protocols for use in the field
- Collection of data in the field in a coordinated, site-based exercise
- Management of information and datasets
- Investigation of shared scientific hypotheses using case studies aiming at long-term data analysis
- Network design aimed at producing better information about the key components of LTER-Europe (sites, datasets, people, etc.).

[1] http://ec.europa.eu/environment/seis/
[2] http://www.copernicus-masters.com/; http://land.copernicus.eu/
[3] http://www.lter-europe.net/

What the project EnvEurope is about

The main subject of EnvEurope was LTER, or Long-Term Ecosystem Research and Monitoring (**BOX 1**).
LTER is especially important in our rapidly changing world: climate change, land and sea exploitation, and global trade are dramatically affecting the environment and altering e.g. the ecosystem services we depend on, like provision of food and water, air and water quality, and the aesthetic value of a landscape. We need a sound base of long-term ecological observations and data in order to detect current changes in ecosystems, develop scenarios for the future and adapt natural resource management practices.

LTER is organised in site networks at the national, regional and the global level (**BOX 2**).
The regional network LTER-Europe is quite complex.
It is composed of a high number of LTER sites representing different ecosystem domains (terrestrial, freshwater, marine). These sites have been established for multiple reasons and are used for both research and monitoring leading to a large heterogeneity of parameters and measurement methods.
This has resulted in a huge amount and diversity of LTER data connected to many different themes.
EnvEurope was conceived as a means addressing this complexity, by harmonizing and improving LTER-Europe's operations, and at the same time dealing with several of the network's key aims. The project had a cross-domain approach, using 67 LTER-Europe sites covering terrestrial, wetland, continental water, transitional and marine ecosystems in 11 LTER-Europe countries.
The project involved 17 beneficiaries and many other institutions as external partners, all committed to the management of LTER-Europe sites.

BOX 1. *Long-term Ecological Research (LTER) and Monitoring*

Long-term Ecological Research *(LTER) and Monitoring is based on gathering and analysis of multi-decadal ecological observations and data, at an appropriate temporal scale to support understanding and management of the environment. Many components of ecosystems are studied including living organisms and non-living components like air, water, mineral soil and sediments. LTER has both a question - (or problem-) driven research approach and a strong monitoring component. Thus LTER provides essential information about how ecosystems respond to global change: LTER data can be used to describe the state of an ecosystem, how the ecosystem may be changing, what may be driving that change, and the probability of the ecosystem shifting to another state, such as a higher or lower ecological quality.*

Our main tasks in the project concerned:

- Establishing a conceptual framework allowing comparability and ranking of ecological parameters and data gained at LTER sites across Europe
- Testing the LTER network as a harmonized set of sites, through measurements in the field of a broad spectrum of parameters and environmental quality indicators with common methodologies
- Gathering in a structured way, managing and making available information (the so-called "metadata") about sites, persons and datasets across LTER-Europe
- Defining and providing tools and recommendations for LTER dataset reporting and sharing, and for integrated data management in the domain of long-term ecological research
- Investigating scientific hypotheses within the LTER community, through case studies aimed at long-term metadata and data analysis, involving as many sites as possible
- Producing better information about the organization of LTER-Europe, to improve information flow and increase the visibility of LTER-Europe as a reference network for scientists, policy makers and environmental managers at the European level.

Within these main tasks, EnvEurope was structured to also play a role in the conceptual and operative context of the Shared Environmental Information System (SEIS) promoted by the European Commission, and to initiate collaborations with Copernicus (formerly GMES), a joint initiative of the European Commission and European Space Agency. The permanent LTER-Europe site network may indeed represent a valuable system for in situ validation of satellite data, thus supporting the implementation of the Copernicus programme.

BOX 2. *The LTER networks*

LTER networks *consist of sites covering different ecosystems, each with research and monitoring facilities. Such networks are usually organised at a national level. The International LTER[4] network (ILTER) was set up in 1993 by the US LTER[5] and it was driven by the need to collaborate at local, regional and national levels through sharing and integrating knowledge and data, creating synergies and delivering scientifically sound results to decision makers and the public. At the European level, the LTER-Europe networking process started in 2004, fostered by the Network of Excellence "ALTER-Net" ("A Long-term Biodiversity, Ecosystem and Awareness Research Network). As of 2013, LTER-Europe comprises 21 formal national LTER member networks and more than 300 LTER sites in continental Europe and Israel.*

LTER-Europe Countries

[4] http://www.ilternet.edu/
[5] http://www.lternet.edu/

The toolbox for effective work and networking: demands from LTER-Europe and solutions provided by EnvEurope

DEMANDS FROM LTER-EUROPE	SOLUTIONS OFFERED BY ENVEUROPE
How to harmonize the LTER parameters?	Conceptual framework of **Ecosystem Integrity** **Ranking** of top LTER parameters **Testing in the field** of Ecological Integrity parameters
How to make parameters and methods available?	Interactive tool "**ECOPAR**": collection of abiotic and biotic indicators and internationally established methods
How to manage LTER datasets?	Organization of and access to LTER information: **DEIMS** tool for metadata delivery, search and view Establishment of a common controlled vocabulary for machine-based retrieval: **The thesaurus "EnvThes"**
How to share and make accessible LTER datasets?	Common **reporting format** Testing of distributed **online data access** LTER-Europe **data policy**
Is LTER-Europe prepared to catch ecosystem change?	Trans-ecodomain approach to environmental **"Grand Issues"** Analysis of LTER-data in **case studies**
The link of LTER-Europe with Remote Sensing (Copernicus)?	**Strategic contacts** at the national level in most LTER Countries First tests for LTER networks as **service user and data provider** for Copernicus

Demands from LTER-Europe and solutions from EnvEurope

What and how to measure?

A framework for selection of parameters

A huge amount of ecological data related to a high variety of ecological themes is collected over the long-term at LTER sites. One of our main challenges in EnvEurope was to identify appropriate indicators describing the main features of ecosystems. To tackle this issue, we created an extensive set of recommended indicators, targeting key elements of ecosystems.

It was based on the conceptual "Ecological Integrity" framework, which focuses on the ability to sustainable self-organisation of ecosystems (BOX 3).

Our choice of parameters was based on some crucial requirements, i.e. that they should be commonly measured at many sites, be regarded as important for the monitored ecosystem, enable indication and comparison across sites and different ecosystems and include the focus of individual sites with specific research and monitoring programs.

BOX 3. ***The Ecological Integrity concept***

According to the Ecological Integrity concept, the main components to describe the pressures on, and state of, ecosystems are their structures and processes.

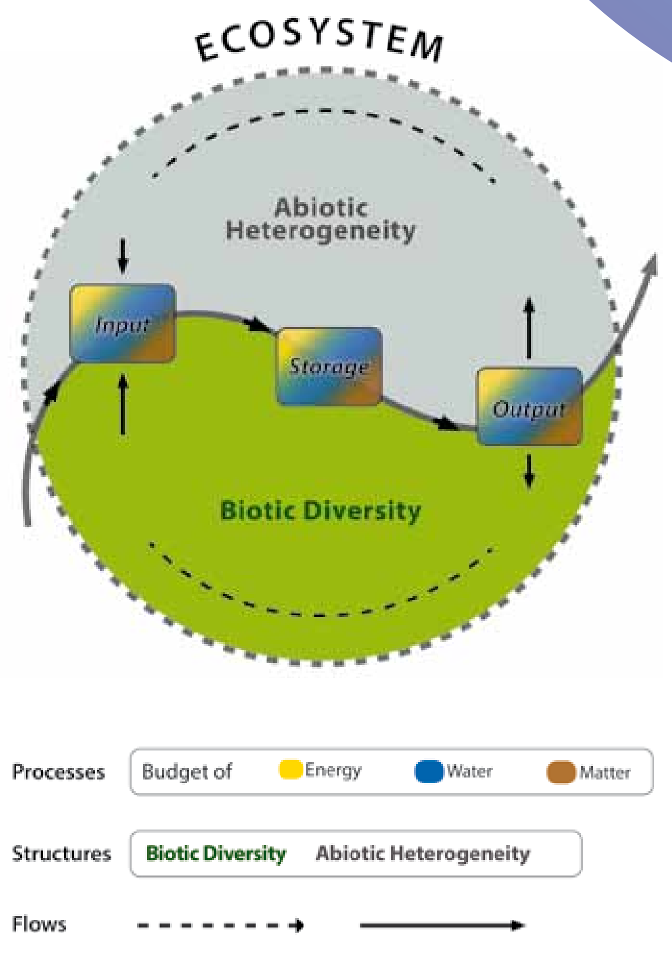
Ecosystem structures are well characterized by biotic diversity (of flora and fauna) and abiotic heterogeneity (of soils, sediments, water, air) forming habitats.

Ecosystem processes (cycling of energy, matter and water) are characterized by indicators of inputs, storages and outputs.

The indicators of "Ecosystem Integrity" are represented by parameters accessible by conventional methods of ecosystem quantification ending up in a set of parameters recommended to be calculated or measured in many local instances.

This set is based on the focal parameters of ecosystem research which can be provided by LTER networks.

This approach facilitates one of the major challenges for LTER trans-domain indication, aiming at comparability of measurements for terrestrial, freshwater and marine sites, trying to find suitable indicator-parameter sets from all sites.



The overall picture of pathways and interactions of the elements of Ecological Integrity

	Elements of Ecological Integrity	Indicators of Ecological integrity	Examples for parameters
STRUCTURES	Biotic Diversity	Flora Diversity	Species list and abundance of vascular plants
		Fauna Diversity	Species list and abundance of breeding birds
		Within Habitat Structure	Vegetation structure within habitats
STRUCTURES	Abiotic Heterogeneity	Soil	Bulk density
		Atmosphere	Air temperature
		Habitat	Land cover
PROCESSES	Energy Budget	Input	Photoshynthetic active radiation
		Storage	Above-ground Net Primary Production
		Output	Respiration
		Efficiency measures	Respiration per biomass
PROCESSES	Matter Budget	Input	Wet and dry deposition of atmospheric nitrogen
		Storage	Nitrogen fixation
		Output	Nitrate leaching
		Efficiency measures	Litter decomposition
PROCESSES	Water Budget	Input	Precipitation
		Storage	Soil moisture
		Output	Surface runoff
		Efficiency measures	Ratio transpiration / evaporation

Parameters, Indicators and Elements of Ecological Integrity

A hitlist of top parameters?

Based on the comprehensive parameters list obtained by this approach, we launched an online ranking survey about the "preferred parameters for (Long-term) Ecosystem Research". The idea was to boil down the number of parameters based on rankings by experts in the international LTER community. Through this process we created a sound base for the recommendation of parameters for long-term ecosystem research and monitoring (**BOX 4**).

BOX 4. ***The international ranking survey of parameters***

We applied four ranking criteria for each parameter: (i) Ecological relevance, (ii) Sensitivity to changes, (iii) Measurement effort, (iv) Instrumentation level.

The parameters covered different ecodomains (terrestrial, rivers, lakes and marine ecosystems) and they were ranked by more than 300 participants from 33 countries.

Participants were mainly researchers with different disciplinary backgrounds (plant, animal and landscape ecology, soil science, ecohydrology, modelling).

Most participants were dealing with terrestrial ecosystems (around 60 %), reflecting the predominant component of the LTER-community. The result of this survey (which covered about 200 parameters) shows that the relevance of parameters selected for the survey was supported by the overall high ranking values given by the participants.

However, although this did not help to separate the "good" from the "bad" parameters, it confirmed the agreement of the scientific community to the selected parameters based on the Ecological Integrity approach.

Making parameters and methods available: the interactive tool ECOPAR[6]

Based on the Ecological Integrity-driven parameter selection, we collated established methods and fed these into the newly developed interactive web tool ECOPAR (ECOlogical PARameters for ecosystem research).

ECOPAR is a living database that provides a comprehensive collection of abiotic and biotic indicators and internationally established methods. It covers parameters and respective measurement methods including the relevant references for terrestrial, freshwater and marine sites, along with the parameter properties important for comparison of data (e.g. measurement scale, frequency, level of precision).

[6] http://www.enveurope.eu/products

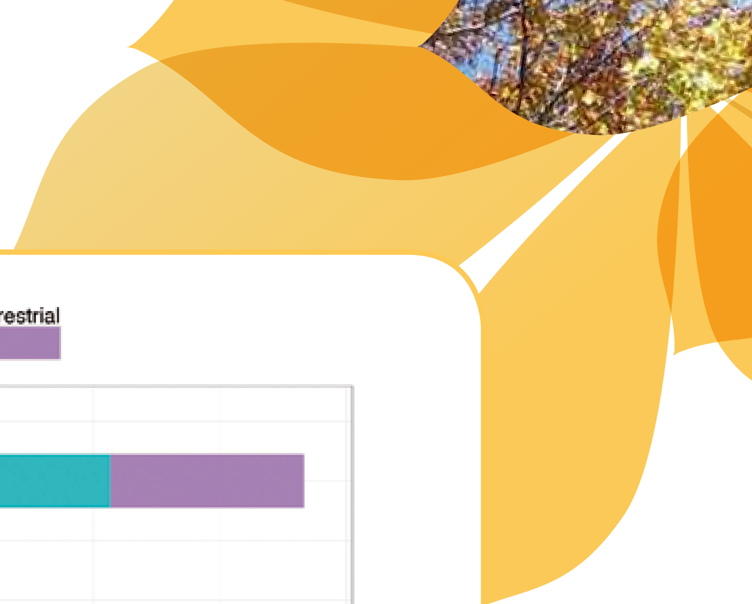
Putting concepts into practice: testing the Ecological Integrity approach in the field

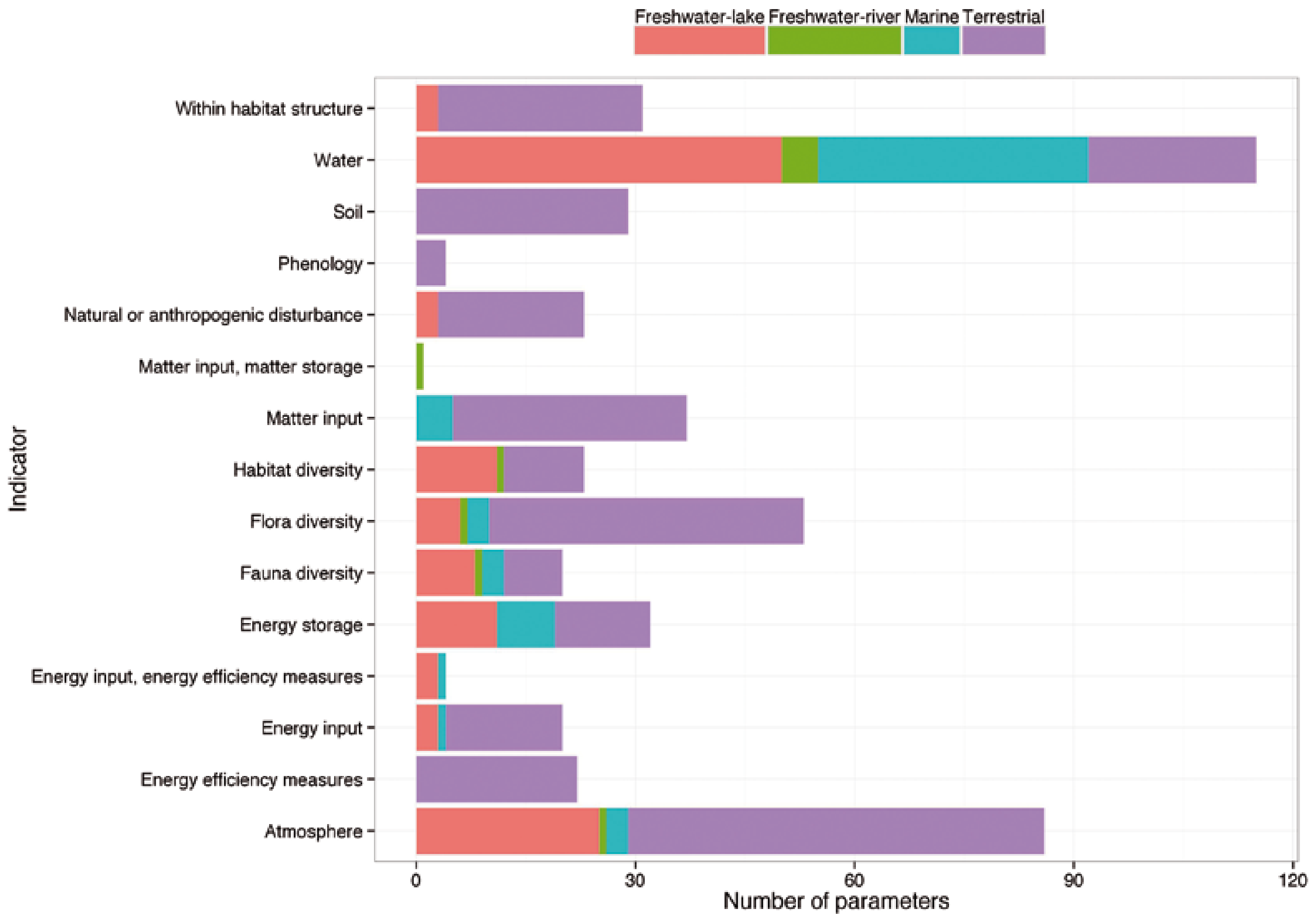
As the first project dedicated to the LTER-Europe network, EnvEurope provided the umbrella for a set of harmonized field activities, focussing on an agreed core set of commonly established ecological parameters and related methods. All 67 LTER sites - terrestrial, freshwater and marine - involved in EnvEurope participated in this field activity, which was performed in 2011 and 2012.

Our choice of the parameters to be field-tested was framed within the Ecological Integrity concept and based on some other key selection criteria:

- Feasibility for partners
- Relevance for different ecosystems (same or similar parameter tested in different ecodomains)
- Complementarity of measured parameters
- Relevance for LTER scientific analysis
- Relevance for indicator assessment
- Suitability for up-scaling and remote sensing

Some of the selected parameters are specific for a certain type of ecosystem (e.g. terrestrial or marine). Nevertheless, the originality and strength of this EnvEurope activity lies in the fact that some parameters are crosscutting among ecosystem types (e.g. meteorology, substrate chemistry, habitat structure, phenological cycle, diversity of plant and animal species, primary productivity), forming a common base for a trans-ecodomain comparison and environmental quality evaluation.
The field exercise produced more than 300 datasets and more than 15,000 raw data values that were aggregated and analysed to provide an overview of ecological trends at European LTER sites.





Testing in the field: parameters measured in EnvEurope, grouped by indicator and colour-coded by ecodomain

How to deal with data? The need for overarching information management

A lot of data have been collected from LTER sites without following any standards in terms of content, file format, metadata and storage, or following only site-specific standards.

Today the heterogeneity of past and present data is a big challenge that modern LTER information management must deal with in order to make the information available.

This situation hampers easy data integration and distribution as well as cross-ecodomain and cross-site analysis.

Addressing the need for ecological knowledge synthesis and availability in the near future requires the application of good information management approaches that go beyond simple data storage, to develop a living, globally-integrated information network with the capacity to discover, access, interpret, process and distribute data. Analysing trends of environmental changes, identifying drivers and providing options for mitigation and adaptation are key challenges for long-term ecological research and monitoring in Europe.

Access to reliable and harmonised databases is essential to address these challenges.

In EnvEurope, we tested and provided tools and technologies in order to enhance the accessibility of data from different LTER-Europe sites and delivered recommendations for site and network level data management.

Making available information about data

Organizing and providing clear and reliable information about available LTER observations (so called "metadata") is one of the key aspects with regard to usability of data and successful data sharing.

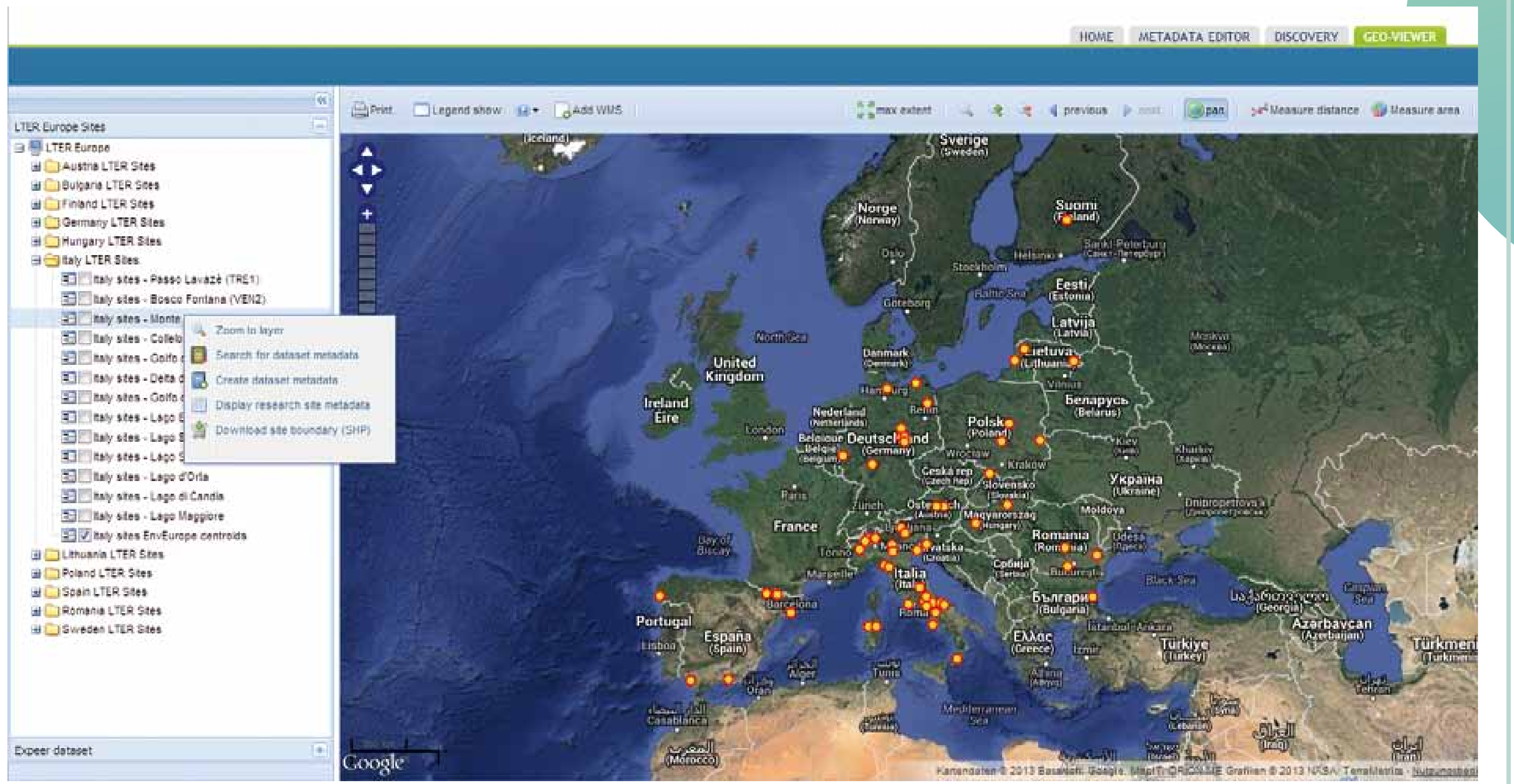
Creating an easily accessible and comprehensive catalogue of existing data is therefore an important task for integrated ecological data management. In this respect not only do we require metadata about datasets (e.g. which parameters are measured, for how long, with which methods), but also about LTER sites (e.g. site location, kind of long-term research) and persons involved (e.g. site manager, field staff).

Using existing standards, user requirements and related legislation, we developed a new tool for delivering metadata, providing standards and guidelines for the entire LTER-Europe network.

The core component of metadata management within EnvEurope is "**DEIMS**[7]", the Drupal Ecological Information Management System.

The metadata specifications within DEIMS aim to ensure interoperability within the international LTER network.

[7] http://data.lter-europe.net/deims/



Geo-viewer in DEIMS enabling to zoom in to the site level to retrieve information about single sites

Benefits from reduced diversity: controlled vocabularies

A common descriptive vocabulary is crucial for machine-based exchange, and search for metadata and datasets. Therefore we set up a common controlled vocabulary within EnvEurope, implemented in the thesaurus "**EnvThes**"[8] (Environmental Thesaurus). EnvThes is based on related existing thesauri and other controlled vocabularies, and was extended to meet the needs of the international LTER community. It now serves as the basis for language integration to aid the description of datasets and parameters in LTER-Europe.

Towards greater accessibility and sharing of datasets

The majority of data from the LTER sites of the EnvEurope community is stored in simple file formats and offline data access is the most common means. In this respect EnvEurope resembles a characteristic subset of the LTER-Europe network and provides a good test environment both for data exchange and technical evaluation. The design of a common reporting format in order to facilitate the delivery of existing data in a structured, harmonised way was an important first step carried out in EnvEurope in order to build a common database of LTER data. We also tested tools and applications for distributed on-line data access, like Linked Data Services[9] and Sensor Observation Service[10].

Information management strategies at European and global scales are currently focusing increasingly on open access to data. However, access to LTER data is still hampered by a diversity of access rules, mostly defined at the organisation or even the research team level.

In order to overcome this situation and to move towards opening data for scientific research and analysis, we developed a data policy. The purpose of the EnvEurope Data Policy is to set up fundamental principles concerning: (i) facilitating collaboration among the project's participants; (ii) ensuring timely submission of data for the use within the project; (iii) protecting researchers´ Intellectual Property Rights (IPR) and rights to publish their results; (iv) identifying rules for the use of data within the EnvEurope project and by third parties; and (v) providing the broader scientific community with easy access to data available within EnvEurope.

This Data Policy is a first step in providing harmonised access rules to LTER data. There is still a long way to go to but EnvEurope has taken the first steps towards opening up access to LTER-Europe data.

[8] http://vocabs.lter-europe.net/EnvThes.html
[9] http://linkeddata.org/
[10] http://www.ogcnetwork.net/SOS

Analysis of LTER data: catching ecosystem changes

Prove of concept: do LTER data hold the promise?

Large amounts of data, in particular observations over long time periods, have been collected at each LTER-Europe site to document the ways in which ecological systems are responding to changing environmental drivers (e.g. by shifts in species occurrence, loss of biodiversity, changes in air and water quality).

However, solutions to many environmental problems are still elusive, due to limited access to data and lack of synthesis studies.

Integration of datasets and scientific analyses from multiple sites is needed to compare continental-scale variation in multiple drivers, and to identify regions where multiple drivers are interacting to affect coupled human and natural systems.

Bringing together existing long-term datasets is beneficial not only for LTER networks but also for particular sites. It opens up the possibility of cross-site comparisons and new types of analyses, moving from the site to the regional scale.

This will improve the visibility of both the network and individual LTER sites, stimulating new site-based projects and providing insights for good environmental management, connecting science to policy.

EnvEurope took the opportunity to develop a shared database focused on the identified parameter list.

All sites contributed to this database, which now comprises more than 220 files from 67 sites across Europe, resulting in about 450,000 observation values starting from the seventies of the last century.

Addressing environmental "grand issues" through LTER data

Based on the available long-term data, we identified four main environmental "grand issues" to be addressed and fostered by EnvEurope, concerning changes in:

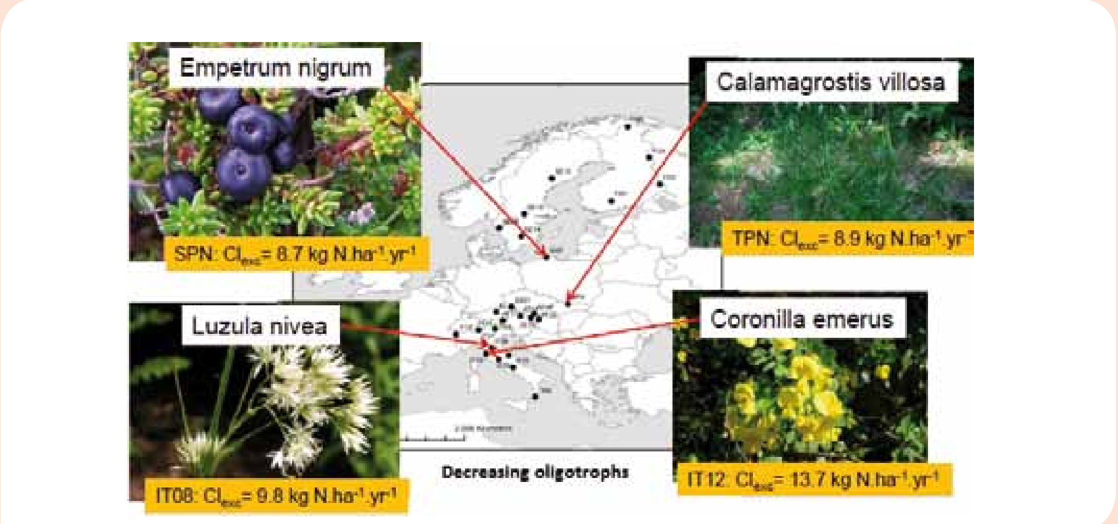
1. Biogeochemical processes, climate and biodiversity
2. Ecosystem processes and disturbances
3. Ecosystem services
4. Socio-economic pressures on the functioning of the ecosystems

Within these issues, we initiated several specific "case studies" focussing on long-term data analysis addressing different environmental issues (BOX 5, 6 and 7).

BOX 5. ***Does chronic airborne nitrogen deposition cause a threat to forest biodiversity?***

In many European countries airborne nitrogen coming from agriculture and fossil fuel burning exceeds critical thresholds and threatens the functioning of ecosystems. One effect is that too much nitrogen stimulates the growth of only a few plants, which outcompete other, often rare, species. As a consequence biodiversity declines. Though this is known to happen in natural and semi-natural grasslands, it has never been shown in forest ecosystems where management is a strong, mostly overriding, determinant of biodiversity. We studied long-term monitoring data from 28 intensively observed forest sites across Europe to analyse temporal trends in plant species cover and diversity. At sites where nitrogen deposition exceeded the critical load, the cover of forest plant species preferring nutrient-poor soils (oligotrophic species) significantly decreased, whereas plant species preferring nutrient-rich soils (eutrophic species) showed an opposite - though weak - trend. These results demonstrate that airborne nitrogen has changed the structure of forest floor vegetation in Europe. Plant species diversity did not decrease significantly within the observed period but the majority of newly established species was found to be eutrophic. Hence we hypothesize that without reducing nitrogen deposition below the critical load forest biodiversity will decline in the future.

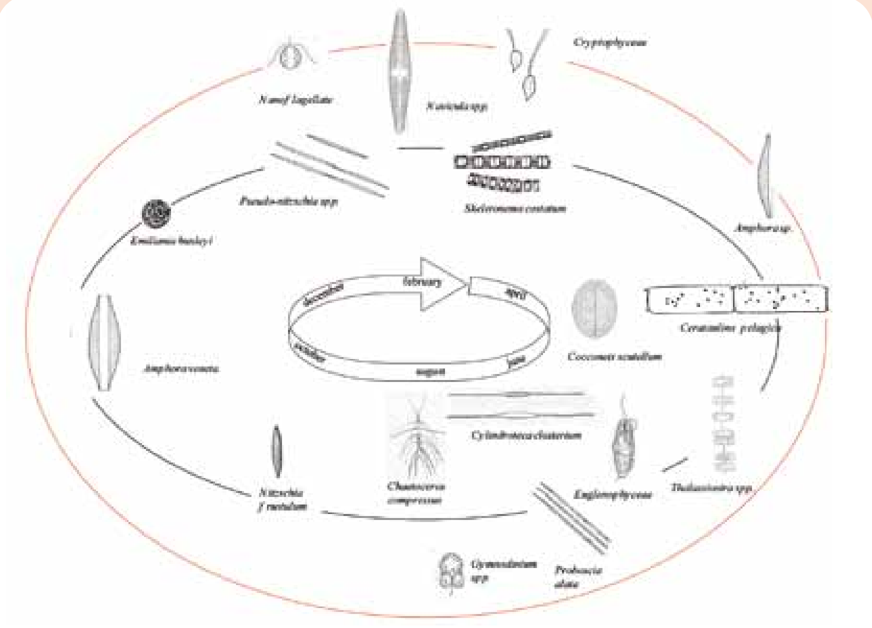
For more information see: Dirnböck, T., Grandin, U., Bernhardt-Römermann, M., Beudert, B., Canullo, R., Forsius, M., Grabner, M.-T., Holmberg, M., Kleemola, S., Lundin, L., Mirtl, M., Neumann, M., Pompei, E., Salemaa, M., Starlinger, F., Staszewski, T., Uziębło, A.K. 2013. Forest floor vegetation response to nitrogen deposition in Europe. Global Change Biology (in press).



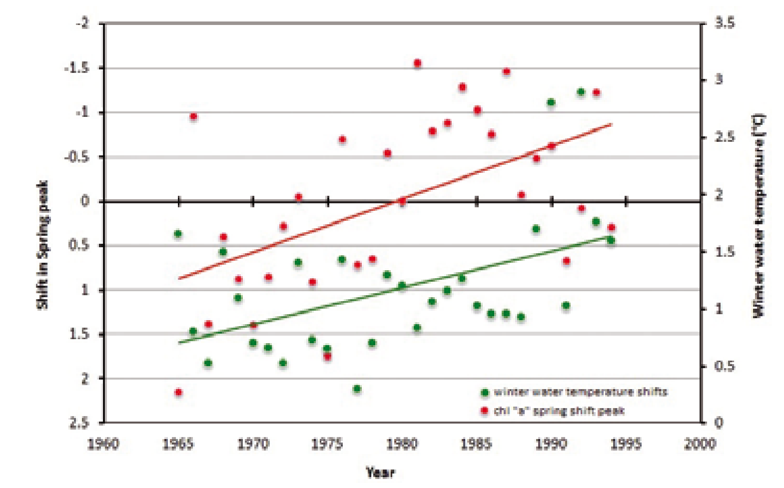
Examples of decreasing oligotrophic species across Europe (Cl_{exc}: Critical load exceedance of Nitrogen).

BOX 6. ***Is the timing of the growing season ("phenology") of plant species changing?***

Recorded changes in the seasonal timing of plant and animal species (phenology) has been proposed as tool to monitor systematically the state of the ecosystems and to detect changes triggered by perturbation of the environmental conditions. This study addressed the aquatic ecosystems (marine, transitional and freshwaters) and their microalgal component (the so called "phytoplankton"). The main aims were to: (i) identify critical phenological signals at LTER sites; (ii) identify relations with ecological drivers (nutrients, physical/chemical parameters, climate indices); (iii) compare changes in these signals across different aquatic sites; (iv) estimate the impacts on the life cycle events in phytoplankton population due to climate changes. A total of 30 LTER sites (15 freshwater, 6 marine and 9 transitional) were considered. The conclusions of the study pointed out that: (i) the LTER sites are good sentinels for identify phenological changes; (ii) the trends for most of the LTER sites are showing an anticipation of the spring peak; (iii) an increase in water temperature is the main factor for the difference in the phenology pattern across sites.



Seasonal timing (phenology) of microscopic algae (phytoplankton): the "phytoplankton calendar" (example from the LTER site "Lagoon of Venice"; Bernardi Aubry et al, Scientia Marina, 77-1, 2013).



Relationship between the spring peak of phytoplankton growth (chlorophyll) and water temperature (example from Lake Galten - Sweden)

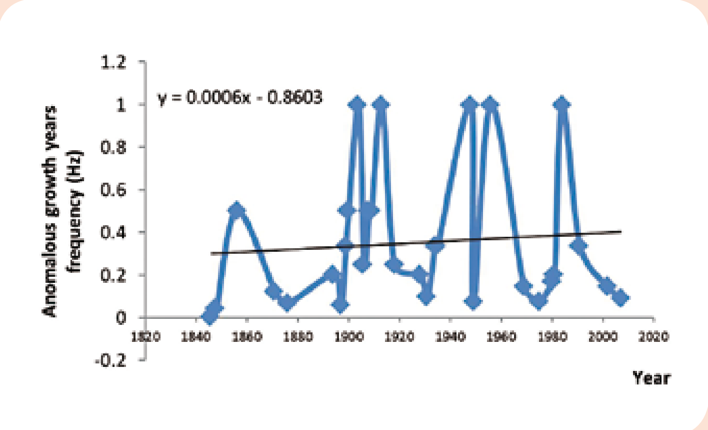
BOX 7. ***Is tree-ring chronology changing due to past human and natural disturbances?***

Similar patterns of tree physiological growth follow related natural and anthropogenic disturbances, within a given area and time period.

The growth response indicates the stability and/or the adaptation capabilities of the trees. Tree rings are a very inexpensive and straightforward data source, which is available wherever and whenever trees of a suitable age occur, or where adequate preserved wood samples are available for the purpose of such analysis.

The main conclusion of the study suggests a slow, but steady higher frequency and amplitude of the pointer years, denoting the cumulative incidence of natural and anthropogenic disturbances, and acting as a warning signal.

In fact, translated into a sound wave, this signal would have a higher and higher pitch, in close connection to the increasingly frequent disturbances.



Increasing frequency of anomalous growth years for spruce trees in Bucegi LTER site (Romania)

Frequency of anomalous growth translated into music: higher pitch (frequency) sound wave on a music stave

Can LTER be connected to the space?

One of our tasks in EnvEurope was to initiate collaboration between LTER-Europe and the remote sensing activities related to environmental monitoring, specifically with Copernicus.

At the European level, Copernicus (formerly Global Monitoring for Environment and Security - GMES), is a EU strategic programme that receives major observational inputs from satellites in the earth observation domain.

Most of our efforts were devoted to understanding the opportunities of a two-way collaboration with the Copernicus programme, to provide an assessment of in situ data usability and to test applicability of large scale remote sensing products for long-term ecosystem monitoring in Europe.

We carried out a survey to determine if the *in situ* requirements provided by the Copernicus *in situ* component (the GISC project) could be fulfilled by the LTER community.

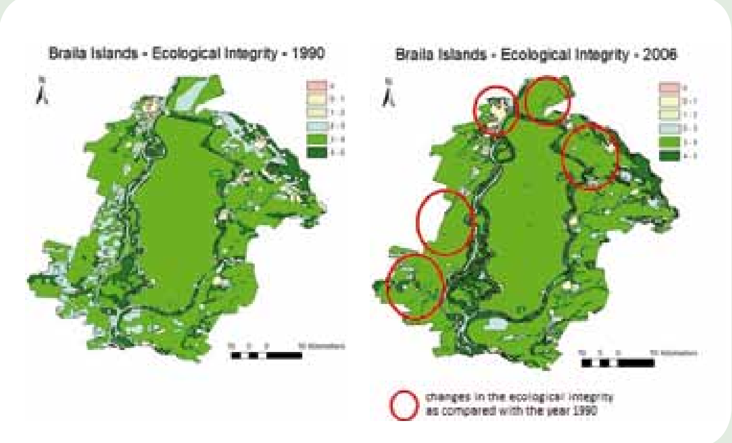
We also wanted to assess whether there was scope for further cooperation following EnvEurope. During the time frame of EnvEurope, most partners had established formal contact and cooperation with Copernicus representatives in their own countries.

An example of interaction between LTER data and Copernicus products was developed within EnvEurope in the crucial context of Ecosystem Services (ESS) and of Ecosystem Integrity (EI) (**BOX 8**).

BOX 8. ***How can LTER site knowledge be connected with remote sensing data in order to make quick assessments of Ecosystem Integrity (EI) and Ecosystem Services (ESS)?***

The approach to this question encompassed four challenges, to: (i) ensure support for the EU biodiversity strategy about assessment of ESS throughout Europe, (ii) provide a homogeneous and (iii) cross-domain data base for LTER sites and (iv) make use of a publicly available product based on satellite data, the CORINE land cover/ land use maps of Europe (CLC, available for 1990, 2000, 2006). We combined CLC data of individual sites with a matrix of ranked contributions of each CLC class to ESS and EI.

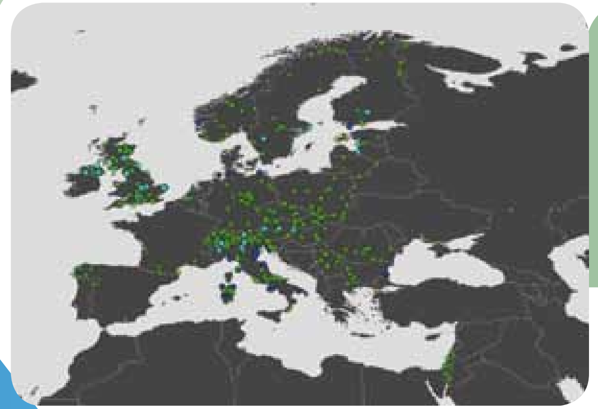
Thereby we could produce spatially explicit site maps showing the ESS value of occurring CLC categories and the changes taken place from 1990, 2000 and 2006. Moreover, the basic matrix with ranking values was adjusted by local knowledge of LTER site managers. This is a starting point for a pan-European assessment of ESS and EI at the landscape scale



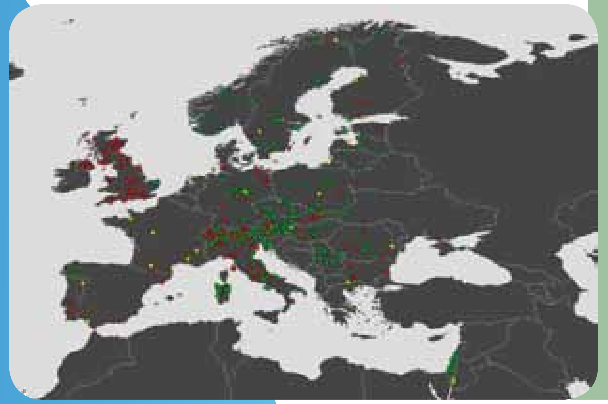
Changes in EI through time: example from Braila Islands (Romania, Danube River)

Is there "LIFE after LIFE+"? The living heritage of EnvEurope

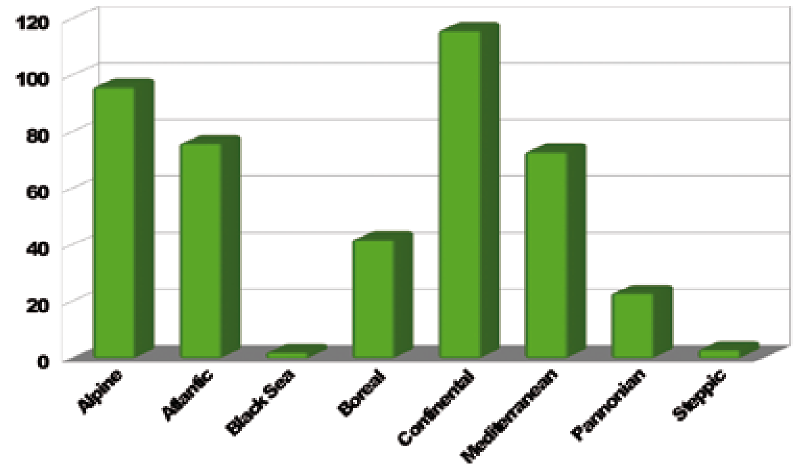
In building a site network for biodiversity and ecosystem research since 2004, LTER-Europe has identified a set of requirements in the field of cross-site workflows, network design, tools for information management, harmonization and standardization. The LIFE+ project EnvEurope has successfully tackled these requirements within its runtime (2010-2013). The tasks of EnvEurope were planned with the clear aim to enhance LTER-Europe. With its successful completion, EnvEurope leaves a network that is arguably in a much better state that it was four years previously. It is more integrated, more active and has greater capacity to deliver and support vital research. The products of EnvEurope represent, for LTER-Europe, the entry point for the next phase in designing the European research infrastructure landscape in the field of biodiversity and ecosystem research. LTER-Europe, with its highly instrumented observational sites and socio-ecological research platforms, is now ready to cooperate and integrate with both large scale monitoring schemes (including remote sensing) and experimental approaches.



LTER sites: terrestrial (green dots), continental waters (light blue dots), transitional and marine waters (blue dots)



LTER site typologies: Platforms (observation region up to 10,000 km²: yellow dots) and sites (observation region up to 10,000 ha). Complex sites (red dots) include more ecosystem types; simple sites (green dots) include only one



Distribution of LTER sites among the main European biogeographical regions

CONSORTIUM

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