ExpeER
Distributed Infrastructure for EXPErimentation in Ecosystem Research

Grant Agreement Number: 262060

SEVENTH FRAMEWORK PROGRAMME

CAPACITIES
INTEGRATING ACTIVITIES: NETWORKS OF RESEARCH INFRASTRUCTURES (RIs)
THEME: ENVIRONMENT AND EARTH SCIENCES

DELIVERABLE D1.4

Deliverable title: Assessment report on research added value of ExpeER infrastructure

Abstract: This report evaluates the research added value generated in the ExpeER-project, reviews the key research and policy needs for European wide ecosystem research facilities and assess the final situation of the project on the ExpeER roadmap (ExpeER deliverable 1.3).

Due date of deliverable: Month 48 Actual submission date: M48

Start date of the project: December 1st, 2010 Duration: 54 months

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Revision N°: V[3]

Dissemination level:

PU Public (must be available on the website)	**[X]**
PP Restricted to other programme participants (including the Commission Services)	**[ ]**
RE Restricted to a group specified by the consortium (including the Commission Services)	**[ ]**
CO Confidential, only for members of the consortium (including the Commission Services)	**[ ]**

ExpeER Ecosystem Research

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Glossary

ANAEE: Analysis and Experimentation on Ecosystems

MCDA: Multi-Criteria Decision Analysis

LTER: Network of Long Term Ecological Research

TA: Transnational Access

WP: Work package, see description of work (DOW) of the ExpeER project

BGU: Ben-Gurion University of the Negev

CNRS: Centre national de la recherche scientifique

DTU: Technical University of Denmark

Juelich: Forschungszentrum Jülich

TUM: Technische Universität München

UA: University of Antwerp

UFZ: Helmholtz Centre for Environmental Research

UL: University of Leeds

Acknowledgements

Responses for a questionnaire survey were essential in building this document. Therefore, Steffen Zacharias (UFZ), Arnon Karnieli (BGU), Ingrid Kögel-Knabner (TUM), Klaus Steenberg Larsen (DTU), Ivan Nijs (UA), Hans De Boeck (UA), Harrie-Jan Hendricks-Franssen (Juelich) are acknowledged in provisioning of valuable opinions and insights which are used in this document.

1. Executive summary

The research added value generated in the ExpeER project is evaluated by 1) describing the improvements in research tools and products, 2) by reviewing the key research and policy needs for European wide ecosystem research facilities and 3) by assessing the final situation of the project on the ExpeER roadmap. These were assessed with a questionnaire survey directed to the ExpeER research work packages and with a revision of the key research deliverables and other ExpeER publications. Finally collected information was considered against the ExpeER RoadMap (ExpeER deliverable 1.3, referred here after as ExpeER Road Map).

ExpeER resulted unquestionable improvements in ecosystem measurement techniques, experimental facilities, modelling tools as well as in upscaling techniques of ecosystem processes. These developments were also widely reported (see the list of publications produced by the ExpeER research WPs). Furthermore, each of the research work packages identified specific issues where further research and improvements are required.

This deliverable also highlights the general requirements for the development of ecosystem research infrastructures. Several issues were identified including e.g. a further support of collaboration in different levels, a more rapid publication of methodological advances, a central coordination of the data collection, availability and model development as well as the active contribution to discussions on the future of the European research landscape.

According to the conducted review and results from the questionnaire, the ExpeER project passed the halfway of the general road map defined for the European ecosystem research infrastructures. The key research needs and necessary infrastructures were clearly identified in the ExpeER together with the methods for selecting existing facilities. Also the European wide research network and facilitation procedures were strengthened in the project. However, in order to achieve the final steps in the ExpeER roadmap, it is required that the ecosystem research infrastructures moves from the project-oriented development to an enduring funded pan-European infrastructure for ecosystem research.

2. Introduction

Background

The ExpeER infrastructure covers an enormous breadth of research domains, from the nanoscale to remote sensing and from fundamental to applied ecosystem science. It thus strongly supports the European strategy for interdisciplinary, long-term environmental research with specific focus on the combination of monitoring and experimentation. The ExpeER research facilities are all involved with research in crucial ecosystem services such as food security, biodiversity, carbon storage, soil structure – and the effects of climate change, land-use change, air pollution and other effects of growing human activities on these. The results from such studies and experiments are therefore crucial for present and future policy makers for making the right choices in order to protect these fundamental ecosystem services.

One the main objective of ExpeER has been to facilitate the development of a multidisciplinary approach to ecosystem research. This objective is supported by improving the research infrastructure performance within EU research community and by developing measurement and upscaling techniques, experimental facilities as well as modeling tools.

Objective

Objective of this report is to evaluate results from the ExpeER research work packages with respect to how they have improved ExpeER facilities, i.e. technical and operational capacity for providing detailed documentation of ecosystem processes and services and outline further needs for improvement. Specific aim is to provide:

i) A synthesized description of improvements of ExpeER tools and products
ii) A review of key research and policy needs for optimised use of European wide ecosystem research facilities
iii) An assessment of the final situation on the ExpeER roadmap

3. Methods and approach

The research added value of the ExpeER was approached 1) by reviewing the results from key research deliverables and other ExpeER publications, 2) by preparing a questionnaire directed to the ExpeER research work packages and 3) by considering both of these based on ExpeER RoadMap.

A questionnaire was prepared in order to evaluate the research added value generated in the ExpeER. The questionnaire was targeted to the corresponding authors of the key research deliverables from WPs 7-10 and respective work package leaders.

The questionnaire had two sections. First one was directed to evaluate the research added value of the project. This section aimed specifically to define how the project has improved the ExpeER research facilities and what further actions would be needed. Second part of the questionnaire was aimed to outline the support of ExpeER-infrastructure to create research added value. This multi-choice section aimed specifically to define how the facilities and services provided by the project have supported the research.

All of the research WP's were covered by the responses from at least one corresponding author of a deliverable or from a work package leader. Altogether six responses were received. The questionnaire is included in Annex 1.

4. Synthesized description of improvements of ExpeER research tools and products

ExpeER research activities are organized into four work packages (WPs 7-10) with the aim of improving the performance of the infrastructures and related services. Work package 7 develops and test new methods to overcome current limitations in understanding ecosystem processes. It involves development of new measurement techniques with regards to soil moisture, structure and metogenomics and canopy activity. The methods range from DNA sequencing techniques up to remote sensing of primary productivity. Work package 8 develops improved techniques to control environmental conditions in experiments (climate warming, CO_2 enrichment) and designs new approaches for experimental ecosystems (miniature scale prototypes and more realistic manipulation studies for climate change impacts on biodiversity). WP9 develops ecosystem models and provides a model toolkit based on three models for the analysis of ecosystem processes (COUP, LPJ-GUESS, JULES). Finally WP10 develops a model-data fusion approach to upscale biogeochemical and ecological processes and study ecosystem responses to environmental changes.

Following sections consider the research added value achieved in ExpeER work packages 7-10 based on the responses from the questionnaire.

Measurement techniques (WP7)

The potential to monitor soil moisture dynamics in high spatial and temporal resolution was tested in ExpeER with a combination of wireless sensor networks and cosmic ray moisture probes (ExpeER deliverable 7.1). The novel combination of these two technologies is a significant development in order to bridge the gap between point and catchment scale measurements. Benefits include measurements of soil moisture at a scale commensurate with modelling needs and reveal the spatial distribution of soil moisture which is critical to identify emergent behavior of catchment scale processes. It was shown that the combination of technologies enabled an improved calibration of the cosmic ray moisture probes. Furthermore, a vertical weighting function was developed that improves the comparison of sensor network data with water content estimates of cosmic ray probes.

Furthermore, the technical performance of sophisticated NanoSIMS (secondary ion mass spectrometry) and AFM (atomic force microscopy) techniques for the investigation of soils at the submicron scale were improved (ExpeER deliverable 7.2). Developed approaches make it possible to characterize the soil structural assemblage with respect to its function as a microbial habitat.

Following issues for further improvements were identified. The quantification of the effect of static and dynamic hydrogen pools on the soil moisture estimation using measurements of background neutrons emitted from soils. Especially the influence of biomass on the detected neutron signal is still poorly quantified. The calibration of soil moisture measurement devices should be continued and integrated with additional scientific probes. The developed methods should be applied to different soil systems and combined with other measurement techniques. The combination of different data sets from microbiology and soil physic-chemistry should be enhanced together with the upscaling of results to larger process scales.

Experimental facilities (WP 8)

Improved techniques and methods for experimental warming were developed and presented in three scientific articles. A first study (De Boeck et al. 2012a) investigating potential artefacts related to warming with passive open-top chambers and climate-controlled greenhouses (with suggestions how to deal with them). A second study quantified a side effect of warming with infrared heaters, namely increased water loss (De Boeck et al. 2012b). Also an infrared heating system of experimental facilities was developed, based on a theoretical paper (De Boeck & Nijs 2011). A complete on-site test will still be conducted within ExpeER, and if successful, the new infrastructure should allow other researchers to adopt a similar way of regulating infrared heaters with significantly improved realism.

The new generation biodiversity and climate change experiments were formulated in two scientific articles. The first is a perspectives study on ‘choices and pitfalls in global change experiments’ (De Boeck et al. 2014). It discusses approaches of manipulation experiments that deal with global change, as artefacts and inherent limitations can lead to misinterpretations. Technical and non-technical solutions or workarounds are proposed when available, and limitations in interpreting and extrapolating experimental results are outlined. The paper is currently under review (August 2014), and should attract broad attention when published. Also a protocol for two aspects of biodiversity research was developed. The first is aimed toward investigating species richness - ecosystem functioning relationships using the natural variation in species richness at the microsite scale. The second is a quick method for characterizing species interactions in multispecies systems in the field, and is the focus a paper currently under review. These two techniques could contribute significantly to biodiversity research and community ecology.

Methodological advances are suggested quasi-continuously, also outside of ExpeER. The overview paper ‘Choices and pitfalls in global change experiments’ highlights the most pressing issues in global change ecology and offers solutions and workarounds where possible. However, it also stresses that the diversity of experimental approaches holds value in itself, as long as the limitations of each study are clearly defined. ExpeER WP8 has offered several technical (e.g. temperature and CO_2 control) and non-technical (e.g. general set-up of experiments) solutions for experimental ecosystem research. However, some issues will remain and in order to keep these from distorting conclusions, acknowledging and quantification of artifacts is the key in development of experimental approaches.

Modelling tools (WP9)

The modelling toolbox developed in ExpeER provides a tool for improved operational capacity of the experiments facilities. Modeling toolbox facilitates a significantly easier access to three different ecosystem models and thus increased scientific output of the data obtained at each experiment. The model toolbox includes software, documentation, parameter setting and support for three ecosystem models (COUP, LPJ-GUESS and JULES). These can be used to simulate soil water and heat processes in many types of soils (COUP), interactions between climate, atmospheric burdens of trace gases and vegetation, biogeochemical cycles and trace gas exchange (LPJ-GUESS) and the fluxes of carbon, water, energy and momentum between the land surface and the atmosphere (JULES).

The main challenge in the creation of the modeling toolbox is the actual accessibility of high-quality driver and verification data from the experimental sites in order to be able to apply the ecosystem models. This underlines the need for further integration of experiments and modelling in future research.

Upscaling techniques (WP10)

Research on upscaling of biogeochemical fluxes was conducted by research groups from CNRS (France) and Julich (Germany). This was further supported by University of Helsinki with studies on the usability of remote sensing images to improve estimates of large-scale water, CO_2 and N_2O fluxes. Two frameworks for upscaling of biodiversity were developed and are already implemented; a sampling-based statistical approach (Leeds) and an approach based on wavelet analysis (UFZ). Results for upscaling of biogeochemical fluxes and biodiversity with new monitoring strategies were linked. Uncertainty estimates of the upscaling methods were used directly to estimate data value and the need for additional monitoring stations. Main support for the ExpeER research infrastructure from these works includes the information on the value of different data sources as well as the determination of how much certain data really improve the prediction capacity (i.e., of water and carbon dioxide fluxes). These are crucially important for the equipment of future research sites and monitoring strategies.

For the future improvements upscaling techniques additional measurement types to further constrain carbon balance, e.g. frequent monitoring of carbon pools over long time periods, or estimation of aboveground and below-ground (living) biomass, or better and more frequent respiration measurements are required. Also further improvement of land surface models, especially concerning the representation of soil respiration and also higher quality of remote sensing data to effectively combine it with *in situ* measurements are required.

5. Review of key research and policy needs - European wide ecosystem research facilities

The protection of biodiversity, habitats and ecosystem functions are keys for the sustainable supply of goods and services to human societies. Ecosystems provide vital goods and services, such as food, carbon sequestration and water regulation that underpin ecosystem functionality, economic activities, social well-being and quality of life (MA 2005, TEEB 2010, Ehrlich et al. 2012). Biodiversity plays a key role in the structure and dynamics of ecosystems, and is essential for maintaining basic ecosystem processes and supporting ecosystem functions (Cardinale *et al*. 2012, Naeem *et al.* 2012). Both biodiversity and ecosystem functions are affected by many pressures such as climate change, land use, pollution, over-exploitation of natural resources and invasive alien species, providing a major challenge for the sustainable management of the key ecosystem services (Schröter *et al.* 2005, Mooney *et al.* 2009, Forsius *et al.* 2013, Pereira *et al.* 2013). Efforts have also been made to define ‘planetary boundaries’ for the major impacts and changes (Rockström *et al.* 2009). Nonetheless, the losses of biodiversity and ecosystem services continue more rapidly than ever (MA 2005, Pereira *et al.* 2010, Ehrlich *et al.* 2012).

Several major intergovernmental environmental science and policy processes at both regional and global scales have therefore been established to deal with these problems, and require Information based on ecosystem research. Key ones at the global scale are the IPCC (Intergovernmental Panel on Climate Change) and the recently established IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). Major scientific assessments are conducted under the framework of these bodies and require up-to-date knowledge on both past and present ecosystem impacts, as well as their future developments.

At the European scale main policy needs relate to the implementation of EU climate change policies and climate change adaptation strategies (http://ec.europa.eu/clima/policies/brief/eu/index_en.htm). Also the EU biodiversity strategy and work under the EU No Net Loss of Biodiversity initiative (http://ec.europa.eu/environment/nature/biodiversity/nnl/index_en.htm) require scientific information on changes in biodiversity and ecosystem services. Furthermore, development of air pollution strategies needs information on long-term ecosystem impacts and their future scenarios (EU directive on National Emission Ceilings, UNECE Convention on Long-Range Transboundary Air Pollution). The implementation of the Water Framework Directive (WFD) is heavily based on assessment of ecosystem data (http://ec.europa.eu/environment/water/water-framework/index_en.html).

The maintenance of sustainable provision levels of ecosystem services has also become a major concern at the national level, and several extensive assessments have been conducted (e.g. UK NEA 2011) and additional ones are presently under work. The above mentioned policy processes require work at the national scale as well. Major assessments on ecosystem services have also been conducted at the European scale (Maes et al. 2013), and additional work in this field is currently ongoing.

In the above context, the European-scale ExpeER ecosystem research facilities provide infrastructure for studying the biogeochemical and ecological processes of ecosystems and how these respond to environmental changes. Major research fields include at least:

- Soils and their potential for sustainable agriculture, soils as productive factor in bioeconomy
- Understanding and adapting to extreme climate events
- Understanding and adapting to ecosystem regime shifts that occur at tipping points
- Explaining and linking ecological responses at different scales, from the microsite to the landscape level
- Development of new technologies to monitor ecosystem processes
- Assessment of net carbon balances
- Carbon trading
- Impact of climate change on biogeochemical fluxes
- Climate change adaptation and mitigation

Therefore, the ExpeER infrastructure should be further developed in order to enable the adaptation and mitigation to the threats ecosystems currently are facing. The following recommendations were highlighted in the questionnaire responses related to the further research and policy needs within ExpeER:

- The collaboration between researchers, research groups and research facilities should be further supported and enhanced. Further development of the transnational access (TA) sites network should be supported in order to preserve the link between the instrumental facilities networking across Europe. Methodological advances in ecosystem science should be published rapidly and presented at major scientific conferences. This would stimulate other researchers to adopt improvements or build upon them. Simple techniques and approaches that do not require extensive advanced knowledge or specialized technical skills should be preferred. Furthermore, focus should be directed on the artefacts associated with accepted methodology, quantify them in order to know the important ones, and actively search for solutions rather than accepting artefacts as inevitable.

- A central, European-wide organ to coordinate data collection, availability and model development would be desirable. Data accessibility over internet and in real-time would improve data value for the research community. Furthermore, it should be noted that at many facilities only part of the data is collected. For a more complete picture it would be good if more observatories cover many different types for different terrestrial compartments.

- Active contribution to ongoing discussions on the future of the European research landscape should be conducted. Some ecosystem research facilities involved in ExpeER will presumably become part of AnaEE project (see the blueprint at www.AnaEE.com) but many will not. There is an urgent need in Europe to co-ordinate the research activities in this large number of high-quality existing experimental facilities which will not be future AnaEE sites. The only way to ensure such coordination is that the EU Commission takes this into account in the future calls.

6. Assessment of the final situation on the ExpeER roadmap

A roadmap for European ecosystem research infrastructure (ExpeER deliverable D 1.3) outlines the necessary steps towards the successful implementation of a pan-European infrastructure for ecosystem research (Fig. 1).

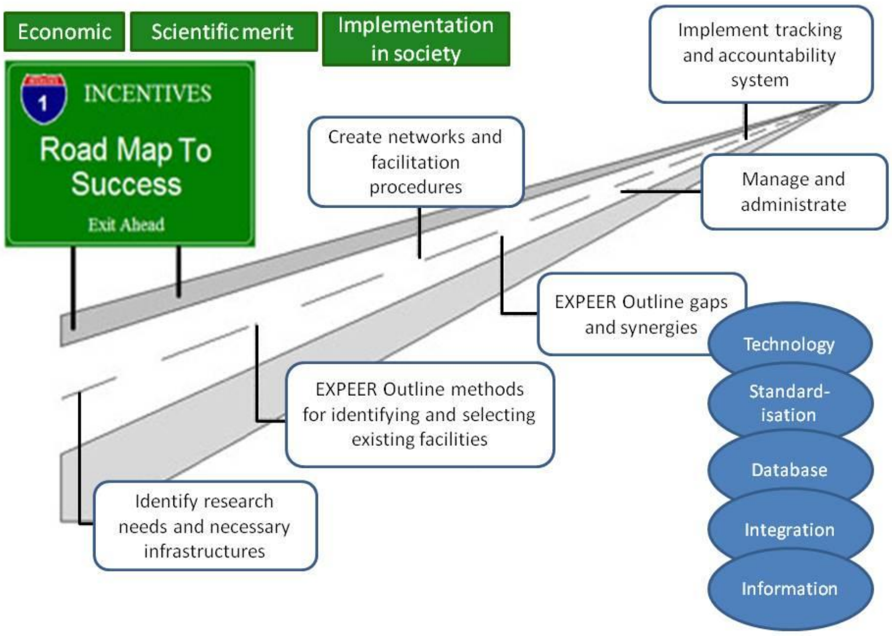

Figure 1. Necessary steps towards a successful implementation of pan-European infrastructure for ecosystem research. Contributions by the ExpeER project in blue and incentives necessary in green (Figure from ExpeER deliverable D 1.3)

The results from the questionnaire indicate that the increased and rationalized collaboration between researchers produced the main benefit from ExpeER infrastructures (Fig. 2). The possibility to use and access multiple ExpeER research facilities was considered nearly as beneficial.

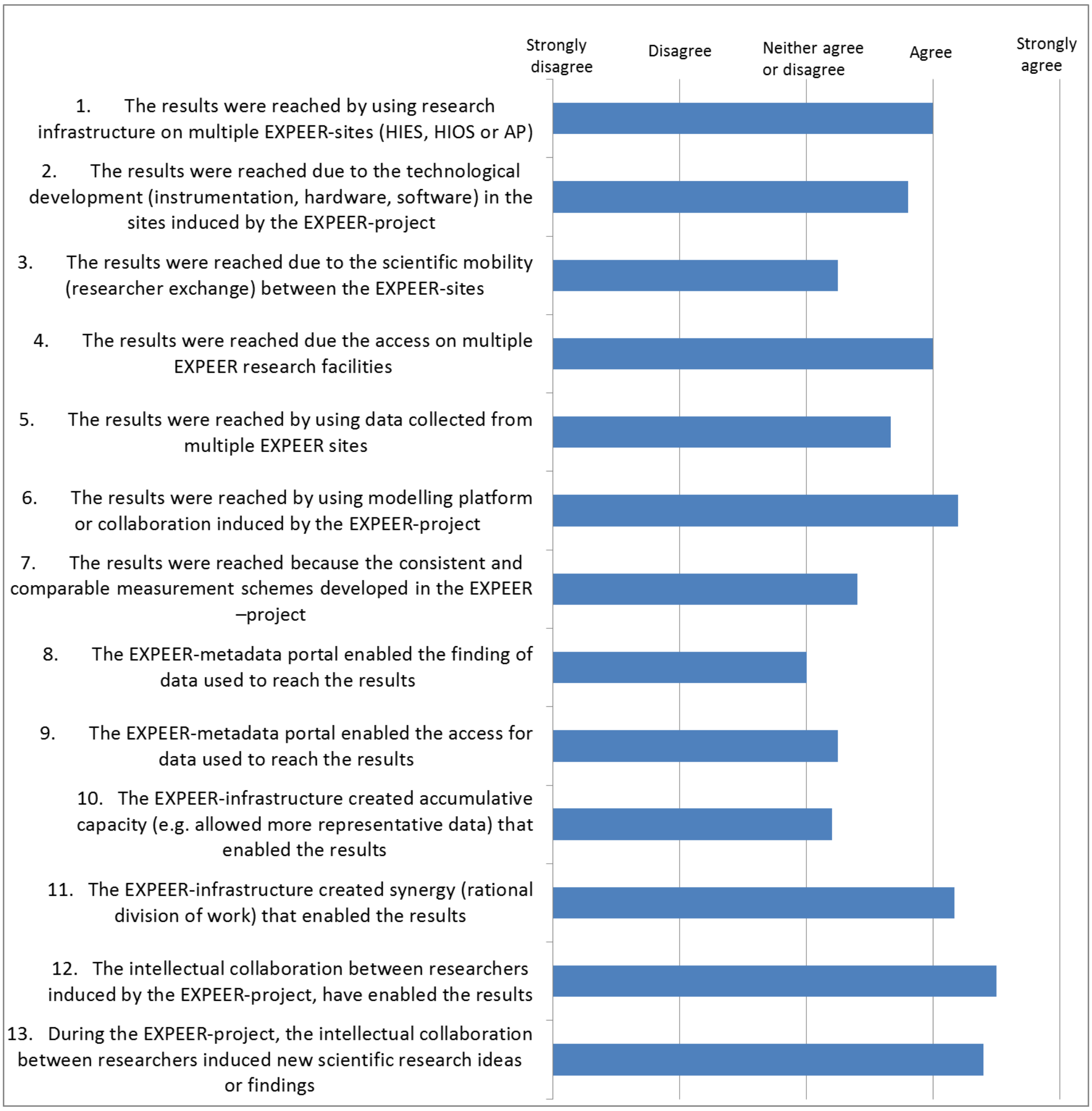

Figure 2. Evaluation of the support of ExpeER-infrastructure for research added value. Results are presented as average values from the results of 6 questionnaire replies.

Below the main steps in the ExpeER road map are considered in respect to ExpeER achievements.

1. Identifying research needs and necessary infrastructures

ExpeER-project brought together the major observational, experimental, analytical and modelling facilities in ecosystem science in Europe. The collaboration between high quality researchers concentrated the key areas for further research. The ExpeER infrastructure was identified particularly relevant to the following general research areas:

1) Ecosystem structure function and dynamics

2) Relationships between biodiversity detentions and ecosystem functions

3) Up-scaling and downscaling of ecosystems dynamics

4) The effect of climate changes on ecosystem structure function and dynamics

5) The effect of land use changes on ecosystem structure function and dynamics

6) Ecosystem modelling

7) The integration of field and earth observation data for ecosystem modelling

This first step in the road map can be considered passed, since ExpeER provided a more concentrated agreement on key research needs. However, ExpeER did not produce a formalized framework for up-keeping and updating these needs. Such framework could direct conducted research and infrastructures involved.

2. Outline methods for identifying and selecting existing facilities

The ExpeER road map outlined a method for comparing existing facilities, finding gaps and synergies as well as scopes for investments in the future. A ranking of facilities based on their technical capacity and scientific performance (number of publications, number of visits, annual investments, etc.) can be used to provide suggestions for the future developments (see. Fig. 16 in the ExpeER Road map -document). Furthermore, a method based on Multi Criteria Decision Analysis (MCDA) will be applied on forthcoming ANEAA-project (http://www.anaee.com/index.php/). Thus, a formalized method for identifying and selecting existing facilities together with creation of synergies and outlining gaps was created within ExpeER.

3. Create network and facilitation procedures

According to the results presented in Figure 2, the services provided by ExpeER in order to enhance the research, such as scientific mobility programs, metadata and data discovery services were considered less useful when compared with other claims. Result indicates that procedures to support networking and further facilitation of the sites still require further work. Similarly the ExpeER Road Map identified further requirements for the managing and administration of pan-European infrastructure for ecosystem research facilities. These included 1) Systems for effective sharing of data to ensure availability, this implies safe systems for data storage (metadatabase), consistency of data including data format, and incentives for making sure new data are included in sharing systems, 2) Incentives for continuous technological upgrade of selected facilities, 3) Coordinated funding mechanisms between EU and individual nations and 4) Funding and administrative mechanisms which promote international collaboration at the distributed research infrastructure.

The last step in the ExpeER road map that is the implementation of tracking and accountability system, likely requires that the ExpeER research infrastructure moves from the project-oriented development to an enduring funded pan-European infrastructure for ecosystem research. In this context, the links between the ExpeER elements and other existing/planned major European research infrastructures of the ESFRI process (European Strategy Forum on Research Infrastructures, http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri) need to be identified.

7. Concluding remarks

Discussion in different platforms and projects (ESFRI-Env, ENVRI, ExpeER), have identified a general need for a hierarchy of integrated infrastructure components, covering experimental and observational ecosystem research (Figure 3). Such a hierarchy should operate at multiple scales from the experimental plot up to the landscape level and should provide platforms for both natural science and socio-ecological research on ecosystem services under global change. The central part in Figure 3 represents the requirement of complementary and interoperable in-situ networks for standardized large scale monitoring (e.g. ICOS), natural and socio-ecological systems research (e.g. LTER, INTERACT) and experimentation (e.g. AnaEE, INCREASE). These in-situ infrastructures provide data for the infrastructures dealing with modelling, data analysis and workflow automatization (LifeWatch, IS-ENES) supporting system understanding, predictions and decision-making. Modelling and analyses feed their parameter requirements back to the data generating platforms. All RIs should make use of generic supporting e-infrastructures such as EUDAT (bottom). Scientific and other user communities (top) will benefit from the RIs.

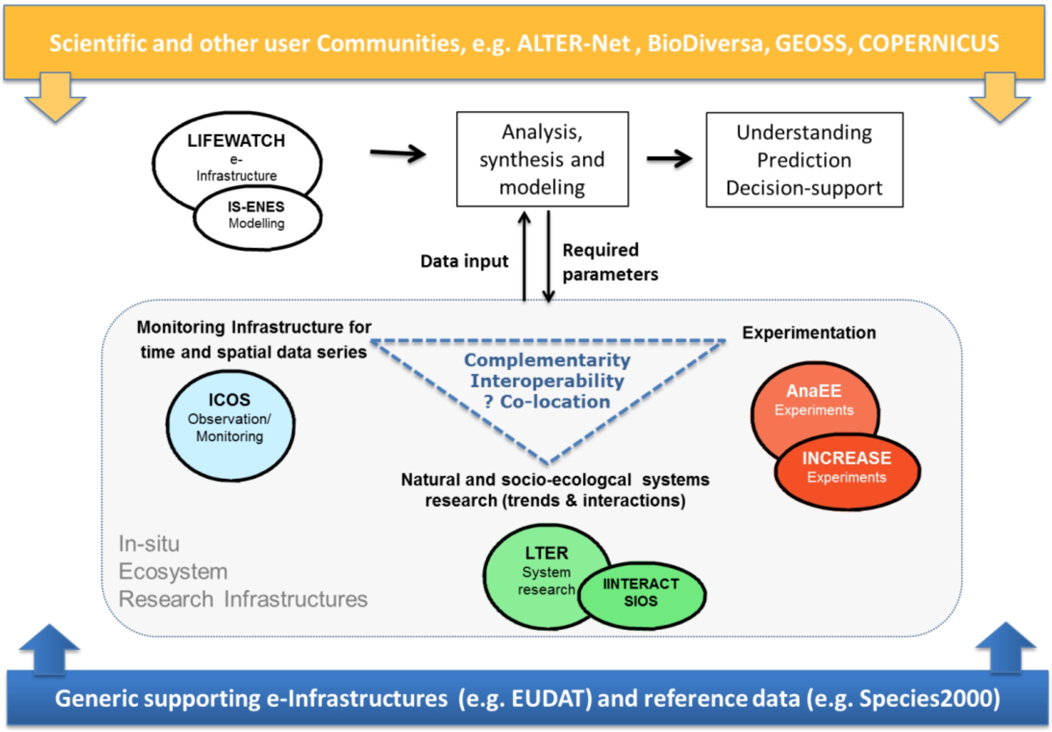

Figure 3. Interaction of in-situ ecosystem and biodiversity RIs (central part) with supporting services (bottom, blue) and user communities (top, orange). [from: ESFRI Environmental Expert Group start-up meeting for the ESFRI 2030 roadmap, 22 May 2014, Paris]

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ExpeER
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9. Appendices

Annex I: Questionnaire on the research added value of ExpeER project

This questionnaire aims to the synthetized evaluation of the research added value generated in the ExpeER work packages 7-10. Collected information will be used in an assessment on the research added value created in the ExpeER project (ExpeER WP1/Task 1.4).

Target group

Corresponding authors of the key research deliverables from WPs 7-10 and work package leaders.

About the questionnaire

We kindly ask you to answer the questions corresponding to the specific deliverable you are involved with or the aspect of work package you are leading.

This questionnaire has two sections:

1) Research added value of ExpeER
   Specifically how the deliverable/task has improved the ExpeER research facilities and what further actions would be needed. This section is more time consuming. It includes 6 questions in which we ask you to consider in the respect of the deliverable you are corresponding or as a work package leader.

2) Support of ExpeER-infrastructure for research added value
   Specifically how the deliverable/task has utilized the current facilities of ExpeER. This section is a short multi-choice questionnaire

Estimated answer time for the questionnaire is 25 minutes.

We ask you to return your answers by 1st of July to saku.anttila@ymparisto.fi .

Contacts

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Section 1: Research added value of ExpeER

Please identify the deliverable of the word package you are involved with
[Name of the deliverable you are corresponding <u>or</u> work package you are leading]
1. How has your work improved the technical and operational capacity of the ExpeER infrastructure?
[Free text]
2. What are the main remaining needs for further technical/operational improvements in your sector of work?
[Free text]
3. What key research and policy needs can you identify where the ExpeER infrastructure is particularly relevant (both present and future)?
[Free text]
4. Can you suggest ways on how to implement the improvements of ExpeER into the wider research community?
[Free text]
5. Do you have any further suggestions on how to improve or coordinate European ecosystem research facilities?
[Free text]
6. Please provide list of reports and publications produced as part of the work of your deliverable/task
[list of publications/reports]

ExpeER Ecosystem Research

Section 2: Support of ExpeER-infrastructure for the research added value

Please evaluate the following claims accordingly to relevancy with options 1-6 (defined below) on how they have advanced the research presented in the deliverable you are corresponding or in the work package you are leading

Options for all questions:
1 Strongly disagree, **2** Disagree, **3** Neither agree or disagree, **4** Agree, **5** Strongly agree,
6 Not relevant

Question	Option (1-6)
1. The results were reached by using research infrastructure on multiple ExpeER-sites (HIES, HIOS or AP)	
2. The results were reached due to the technological development (instrumentation, hardware, software) in the sites induced by the ExpeER-project	
3. The results were reached due to the scientific mobility (researcher exchange) between the ExpeER-sites	
4. The results were reached due the access on multiple ExpeER research facilities	
5. The results were reached by using data collected from multiple ExpeER sites	
6. The results were reached by using modelling platform or collaboration induced by the ExpeER-project	
7. The results were reached because the consistent and comparable measurement schemes developed in the ExpeER –project	
8. The ExpeER-metadata portal enabled the finding of data used to reach the results	
9. The ExpeER-metadata portal enabled the access for data used to reach the results	
10. The ExpeER-infrastructure created accumulative capacity (e.g. allowed more representative data) that enabled the results	
11. The ExpeER-infrastructure created synergy (rational division of work) that enabled the results	
12. The intellectual collaboration between researchers induced by the ExpeER-project, have enabled the results	
13. During the ExpeER-project, the intellectual collaboration between researchers induced new scientific research ideas or findings	