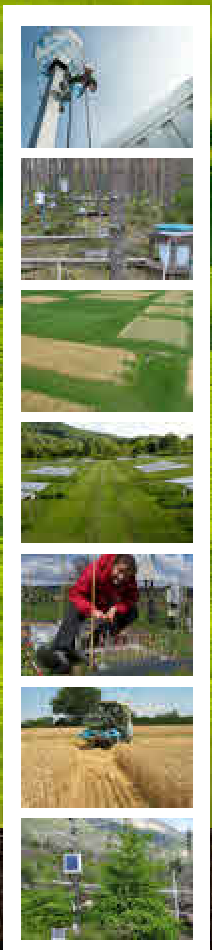
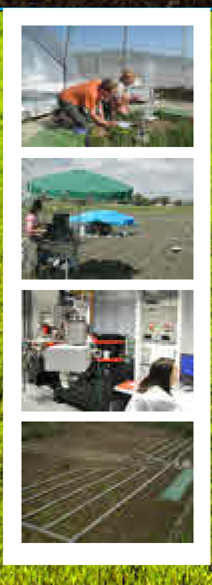


ExpeER

Infrastructures for Experimentation in Ecosystem Research

FINAL RESULTS



CONTENT

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FOREWORD

Ecosystem sustainability and services is a subject of considerable public and scientific interest today. There are many challenges involved in understanding ecosystem changes, and in providing societies with the policy-relevant knowledge base to deal with them. Ecosystems services are threatened by climate change, land-use change, pollution and loss of biodiversity. If ecosystem dynamics are not understood, Europe will not be able to assess the impacts, control the risks or adapt to the changes that will affect these ecosystems. Ultimately, the well-being of humankind is at risk. It is therefore necessary to understand and predict how Europeans ecosystems respond to the current and future changes, in order to propose new approaches to manage them with mitigation and adaptation perspectives. Achieving these goals requires not only to cross the usual boundaries between disciplines but also to implementing state-of-the-art research infrastructures (RIs) and sound integrative approach to help us explain and predict in a coordinated fashion global environmental changes, preparing society for change and as well as increased uncertainty.

In light of this, ExpeER, "Experimentation in Ecosystem Research", provided a unique opportunity to address the major ecological challenges with a more integrated, standardised and statistically rigorous approach. The content of this brochure illustrates how the experimental methods were encouraged by ExpeER, which ensured their advancement and standardization at the European level, and participated to integration targets. Ecosystem function parameters, methods and information management were standardized and disseminated. New experimental methods and analytical approaches were developed and new ecosystem models and modelling toolkit were elaborated. Establishing this common ground, especially through the interaction of ExpeER´s building blocks with related research infrastructures, helped to foster the consolidation and integration of the continental ecosystem research community. The ExpeER Roadmap identified further requirements for the management and the necessary steps towards the successful implementation of a pan-European infrastructure for ecosystem research. The AnaEE project (www.anaee.com), currently in a preparatory phase of the ESFRI road map, as well as the eLTER Horizon2020 project (2015-2019) are perfect examples that illustrate the success story of the ExpeER project.

In this context, our community is dedicated to build a dynamic community, bringing together a diverse range of researchers, funders, policy makers and industries, to showcase the very best from this research infrastructure spectrum. We are convinced that the implementation of these infrastructures will place Europe at the vanguard of continental ecology science.

Dr. Abad Chabbi
ExpeER coordinator.

ExpeER IN A NUTSHELL

ExpeER (Experimentation in Ecosystem Research) is a European project (Dec 2010 - May 2015) which aimed to bring together most of the major observational, experimental, analytical and modelling facilities in ecosystem science in Europe.

By uniting these highly instrumented ecosystem research facilities under the same umbrella and with a common vision, ExpeER contributed to structuring the still fragmented research community on terrestrial ecosystems within the European Research Area. ExpeER improved the quality and performance of these infrastructures and stimulated their international use.

More precisely, ExpeER contributed to the development of a state-of-the-art research infrastructure by:

> enabling collaboration and integration across experimental, observational and modeling approaches in ecosystem research;

> standardizing measurements protocols and data management;

> improving the technology and methodology at play in ExpeER infrastructures through specific research programs on environmental controls;

> developing a "model toolbox" allowing the scientific community within and outside the ExpeER network to access and use more easily major ecosystem models

> developing new modelling approaches for upscaling and interpreting ecological processes;

> hosting research teams within its 30 sites and platforms through a strong program for Transnational Access (121 research visits);

> linking the ExpeER highly instrumented facilities to existing networks of long-term research sites across Europe (*e.g.* LTER-Europe) and with other European and international infrastructures (ICOS, Lifewatch, NEON, TERN);

> initiating partnership for the writing and development of ESFRI preparatory phase projects (AnaEE and eLTER).

19 countries and 30 sites across Europe

See last page of the brochure for the list and location of ExpeER participants.

Picture

Fouth annual meeting in Paris, Sept. 2014. ©INRA, B. Nicolas

ExpeER TYPES OF FACILITIES

Ecotrons

Their principle is to confine ecosystem samples in individual experimental units in order to simultaneously simulate precisely a large range of environmental conditions and to measure accurately ecosystem processes such as fluxes of carbon dioxide, water and isotope fractionation. Platforms at different scales (intact or reconstructed ecosystems, samples from 100 g to 10 tonnes) enable us to address a large range of questions. A minimum of twelve independent units per platform allows the study of interacting factors under replicated conditions.

Highly Instrumented Experimental Sites

They are designed for *in situ* analyses of the responses of ecosystems structures and processes to experimental treatments. Each of the 17 ExpeER experimental sites is characterized by one or more experiments. Ten relates to forest, 8 to croplands and 3 to grasslands. Land use (rotations, cutting regimes, etc.) is the most common experimental treatment (8 sites) followed by precipitation regime (5 sites) and fertilization (5 sites). Temperature is manipulated on 5 sites and plant biodiversity in one site. Processes under study concern the carbon cycle, other greenhouse gases, soil biogeochemistry, soil biology, hydrology and biodiversity.

Highly Instrumented Observational Sites

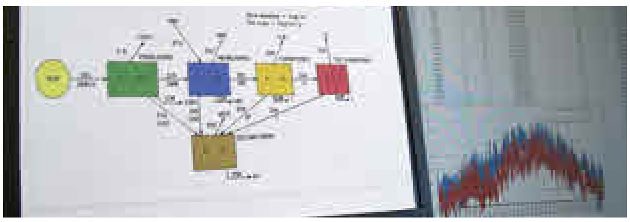
They are designed for long-term monitoring of ecosystems structures and processes. Among the 17 ExpeER observational sites, some are characterized by intensive measurements of ecological processes (*e.g.* many fluxes on a single plot) while others provide access to a large number of plots (up to 300) where less intensive measurements are made of biodiversity and other environmental parameters. This large number of monitored plots across climatic gradients, ecosystem types and land use intensity provides many opportunities to analyse impacts of environmental changes and how they change with time.

Analytical Platforms

They are laboratories equipped with instruments for measuring or developing the measurements of specific parameters in samples. They provide a range of chemistry data (*e.g.* for isotopes, volatile organic compounds and trace gases) that enables in-depth analysis of ecosystem processes.

Modelling Platforms

Developed during the course of ExpeER, they consist of modelling toolkits that will include an integrated parameter library, models of hydrological and biogeochemical dynamics, vegetation dynamics/species interactions as well as evaluation tools for uncertainty estimations.



5 Modelling platform. ©J. Roy

Pictures

1 Montpellier Ecotron. ©J. Roy

2 Negev experimental site. ©H. Rueff

3 Zöbelboden observational site. ©Umweltbundesamt

4 TU Muenchen analytical platform (NanoSIMS). ©C. W. Mueller

ANALYSIS OF THE RESEARCH RESOURCES PROVIDED BY THE ExpeER SITES

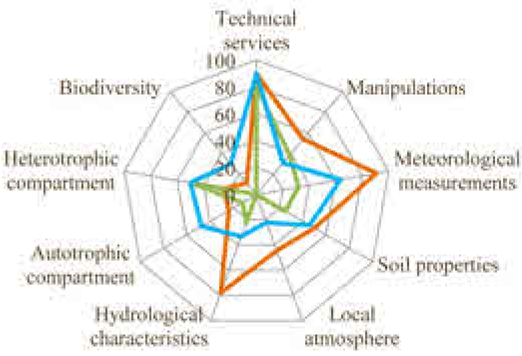
Authors

Helen French,
Andy Macdonald
& Katrin Knoth

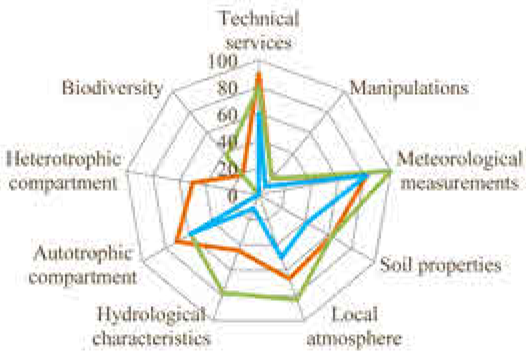
The ExpeER research network is comprised of four types of research infrastructure distributed across 33 facilities within 13 European countries. Most of them (29) are highly instrumented experimental field sites or highly instrumented observational field sites, but ExpeER also includes 2 Ecotrons and 2 Analytical Facilities which provide state of the art controlled environment facilities and analytical equipment for ecosystem research. Questionnaires answered by the sites managers provided information about the ecosystems studied, the research disciplines involved (*e.g.* agronomy, biogeochemistry, hydrology, atmospheric chemistry etc.), the environmental and ecosystem parameters measured and the technical services available in these facilities. The analysis of this information revealed strengths and weaknesses within the network, from which areas for improvement were identified.

The questionnaire responses indicated that the ExpeER sites are located within seven climatic zones, including humid subtropical, oceanic, continental, semiarid, subtropical (dry), subarctic, and highland with annual rainfall and mean annual air temperature ranging from 500 to 2500 mm and from 3 to 17°C, respectively. However, the sites do not cover all ecosystem and climate zones, and forest ecosystems are over represented compared to the other land uses in Europe. The information for each site was divided into 9 categories and synthesised graphically using radial diagrams to help characterise the main focus of research at each site. For illustration, three agricultural and three forest sites have been combined in pictures 1 and 2 respectively. More environment and vegetation parameters are analysed at the agricultural sites (Picture 1) compared with the forest sites, which are mainly observational (no manipulation; Picture 2), In general, many sites have good technical services and conduct a broad range of meteorological and soil measurements, but many were lacking laboratory space for collaborative work. In addition, it was apparent that the extent of the experimental manipulations together with a range of other measurements, including hydrology, local atmosphere and biodiversity, could be expanded. There also appeared to be a bias in favour of studies on autotrophic organisms (mostly plants) compared with heterotrophic communities.

In addition, the frequency with which the different individual parameters were measured at the sites was examined. For illustration, picture 3 shows the number of sites recording data on various categories of organisms. Most sites record the essential meteorological parameters, but hydrological measurements (drainage) at many of the sites are missing, an important component of most ecosystem models. The ability to manipulate climatic factors and other drivers of ecosystem development is shown in picture 4. Many ExpeER sites are largely observational but about 70 manipulations of ecosystem drivers are carried out at some sites. The data indicate that land use, irrigation/drought, soil management (*e.g.* cultivations) and fertiliser/manure applications were the most common experimental treatments imposed at the sites. Less common were manipulations of atmospheric variables, biodiversity, temperature and drainage; no manipulations of ozone, salinity or radiation were conducted *in situ*.



1



2

Pictures

1 Agriculture
Orange: Harz Tereno (Germany)
Blue: Rothamsted (England)
Green: Apelsvoll (Norway)

2 Forest
Orange: Hyytiälä (Finland)
Blue: Hesse (France)
Green: Zöbelboden (Austria)

For climate change research these variables are highly relevant and can truly help validate the estimates of earth responses and feed-back mechanisms. However, considering the European diversity of climate and ecosystems, the manipulation of some important drivers (*e.g.* temperature) is not conducted at enough sites to allow conclusions to be drawn at the continent level.

There is a clear need to further develop the research network established within the ExpeER project. More sites are needed to cover the main ecosystem types under the major climatic conditions of Europe. The Digital Map of European Ecological Regions* comprises about 70 ecoregions. Since a given site will never have the capacity to run all possible mani-pulations of ecosystem drivers, several sites per ecoregion would be needed. A target of around 200 highly instrumented experimental field sites together with a similar number of highly instrumented observational sites would be ideal. While this may be a reasonable target for the observational sites, such a target for experimental sites will require new investments to be achieved.

Besides increasing the number of *in situ* sites, there is also the need to increase the number of experimental treatments at these sites. In particular, the capacity to manipulate several factors simultaneously is needed to understand their interactions. This is crucial since current environmental changes imply simultaneous changes in several factors. In addition, many of the current sites were established to address specific questions and have focused on the associated parameters, but societal challenges and associated scientific questions have changed together with the available scientific technology for measurements, data handling and modelling. Consequently, expanding the number of common measurements made, together with their standardization, is still a challenge.

Ecotron facilities offer a valuable complement to in situ experimentation. They are currently not numerous enough to cover the need of European ecosystem science. New ones are being built, but specialized ones for studying specific systems (*e.g.* manipulation of snow and ice) are still missing. New instruments are becoming available to analyse ecosystem processes, but many of them are very expensive and require highly qualified personnel. New shared open analytical platforms will be the answer to be able to take advantage of these new developments. Model developments and a closer interaction between models and experiments were among the ExpeER objectives, but a much larger effort will be required to integrate and upscale results and to enhance the connections between disciplines.

Note

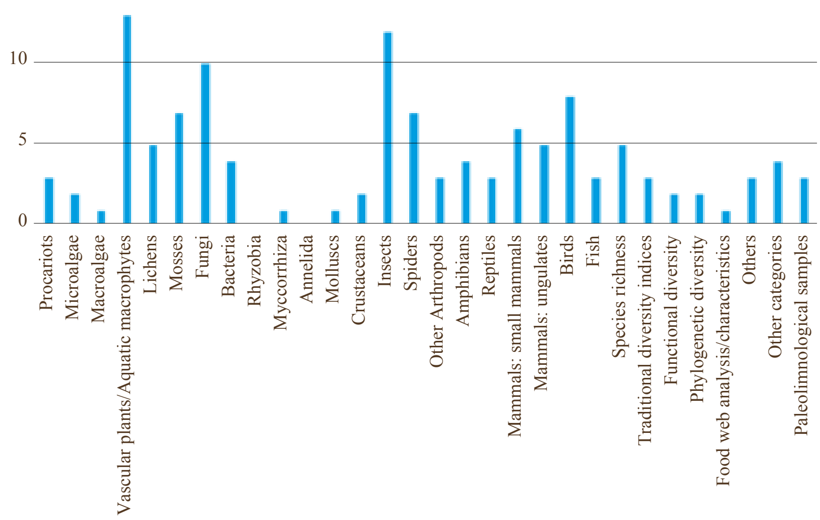
*see http://www.eea.europa.eu/data-and-maps/figures/dmeer-digital-map-of-european-ecological-regions

Pictures

3 Number of ExpeER sites conducting biodiversity measurement on specific categories of organisms (Traditional diversity indices: Shannon, Simpson, etc.; Food web analysis /characteristics: length, connectivity, etc.; Other categories: Zooplancton, Meiofauna, Benthic macroinvertebrate, etc.)

4 Number of ExpeER *in situ* sites manipulating various ecosystem drivers. (Controlled radiation includes light intensity and spectrum treatment).

3



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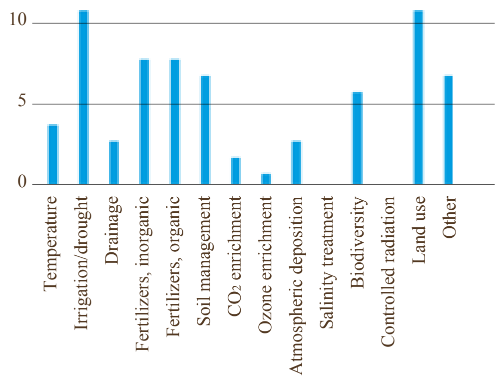


PROTOCOLS FOR STANDARDISED MEASUREMENTS OF ECOSYSTEM PARAMETERS

Author

Les Firbank

The compilation and comparison of research findings across European ecosystem research facilities is often hampered by non-harmonised and non-standard measurement protocols that limit the comparability of datasets of different research sites and infrastructures. Therefore, an important aspect of ExpeER was to develop standardised ecological methods so as to allow findings to be compared and generalised. Our focus was on protocols not currently covered by major international standards.

The approach was to develop a set of parameters that are important to indicate the state of ecosystems. The parameters were chosen according to the following criteria:

- Considered important to ecosystem integrity.
- Common to many ecosystem research sites.
- Protocols are of an intermediate complication level.
- Protocols are easily executed and not too expensive.
- The parameters cover a variety of areas within terrestrial ecosystems.
- Methodologies are not already highly standardised (*e.g.* weather).

ExpeER members were consulted by email to develop first a long list of parameters, and then this list was prioritised. This list was brought to the ExpeER meeting at Leipzig in February 2012, which considered the list against the above criteria and chose a list of 10 parameters, and draft protocols were developed. These were trialled during a training programme, "TEsting and Refining SAmpling Protocols for Ecosystem Research" TERESA-PER, held at CNR, Rome on 27 - 31 August 2012. This course was aimed to inform protocol development, and so was targeted at ExpeER staff.

In 2013, two training courses were held using revised protocols which were targeted at non-ExpeER staff, at CNR - Rome, 20 - 24 May 2013, and VU University - Amsterdam, 26 - 30 August 2013. The courses also covered metadata recording.

Picture

Participants to the TERESA-PER course during the field excursion to the Chiarano test area of the LIFE+ ManFor C.BD. Project.

PROTOCOL 1
ABOVE GROUND BIOMASS

Knowledge of the key parameters of the carbon cycle is essential in understanding how ecosystems function. The increase (forests) or harvesting (grasslands/croplands) of biomass over a year is an appropriate estimator of annual net primary production (ANPP). Methods differ between forests and grasslands, but both protocols involve using of random sampling (often stratified) to ensure that the data are representative of the habitat in question. Data are generated in terms of dry mass per unit area by species, with metadata including location and date of sampling.

For forests, the approach is to build allometric relationships between biomass and a parameter easily measured in living trees, *e.g.* tree diameter, and then estimate total biomass in the forest by applying the allometric relationship to the measured parameter values across all trees in the forest (or sampling plots). Estimating the allometric relationship involves harvesting a sample of trees that represent the range of sizes (and, if required, species) in the stand. A number between 5-10 trees gives a manageable set of initial data, though more may be needed if they generate allometric relationships with substantial variation. The tree is cut down, cut into sections and removed so that the entire stem, branches and leaves are collected and weighed separately; subsampling may be required for very large trees.

A subsample is brought to the laboratory for assessment of dry to fresh weight ratio. The Specific Leaf Area (m^2 g^{-1}) can be estimated from samples, and scaled up to give the total leaf area of the tree from the total weight of leaves. The allometric relationship itself is a power relationship of the form

$$\text{Biomass} = a \bullet \text{measured parameter}^{\,b}$$

This relationship varies between species and may depend on site factors such as fertility, climate, management and stand structure. The relationship is usually different for young vs. mature trees.

For grassland and crops, the protocol involves removing all above ground dry matter from the sample areas (usually square quadrats of length 0.5 m or 1 m) for subsequent drying and weighing, after sorting by species. Timing is critical; ideally, harvesting should take place at the yearly maximum of above-ground biomass, but will need to precede any agricultural harvesting. Multiple sample occasions may be needed. Three fractions should be formed: (1) plant material which was dead in the time of clipping; (2) non-photosynthesising living material; and (3) photosynthesising material.

Authors

Giorgio Matteucci & Miklós Kertész

Pictures

1 In-the-field weighting of sample from tree stem during the TERESA-PER course.

2 Practical lesson of biomass sampling in grassland during the SAéPER course in Amsterdam.

PROTOCOL 2
ORGANIC MATTER DECOMPOSITION

Authors

Jutta Stadler
& Mark Frenzel

Decomposition is among the most important biological drivers of carbon sequestration and nutrient cycling and an important ecosystem service. It is influenced by many abiotic and biotic factors as *e.g.* soil temperature and moisture, soil chemistry, litter substrate quality and soil fauna and fungi community composition. As soil fauna structure is very complex and difficult to investigate, the determination of the feeding activity is a surrogate measure of the biological status of the soil. Litter bags as well as bait lamina are a quick and low-cost measure of the soil fauna feeding activity. Both techniques are applicable in all ecosystems including aquatic ecosystems.

Litter bags filled with a standard litter substrate are often used for comparative investigation of decomposer activities in different ecosystems or biogeographic regions. Depending on the research question, leaf litter substrate can be (1) monospecific or polyspecific, contain local (2) natural or (3) cultivated species or (4) invasive or (5) non-local species. Litter bags of 10 x10 cm proved to be a good balance between a reasonable amount of litter and decomposition turnover rate. Litter bags are filled with 2 g dried standard substrate and placed randomly in the litter layer in the field for several weeks or months to allow decomposition. After removing from the field, litter bags are re-weighed. Mesh size of litter bags has an essential influence on the decomposition process as it allows specific decomposers to enter the litter bags. Mesh sizes below 100 µm enable only fungi and bacteria to colonize the bag while litter bags with a mesh size of 1 mm or wider enable additional access of invertebrates as decomposers. Similar to substrate type and substrate quality the selection of mesh size depends on the hypothesis to be tested. The bait lamina method is a quick and comparatively low-cost screening of soil biotic organisms. Soil invertebrates and to a small extent micro-organisms progressively degrade the bait placed in the soil substrate in a very short time span. Although it is difficult to disentangle the effects of fauna and micro-organisms on feeding activity completely, studies have shown that macro-organisms are the main feeders on bait lamina. This is mainly due to the short exposure time of the bait lamina which keeps the influence of micro-organisms small. However, bait consumption is a proxy for the feeding activity of the soil fauna and complements cumulative parameters such as decomposition rate or mass loss of standard litter. The bait lamina strip is a PVC-strip of about 15 cm length, with up to 16 conical holes. The conical holes are filled with a bait mixture that contains fine ground cellulose powder, bran flakes and traces of active coal. Bait lamina strips are plunged in the soil with the uppermost hole positioned just beneath the soil surface. The bait lamina strips are removed when more than 40% of the bait is eaten. When comparing the feeding activity at different study sites, the bait laminas need to be removed at exactly the same time span of exposure at all sites.

In order to account for local variability of decomposer communities, a sampling design with a minimum of five repeats at a single location is recommended.

Picture

Samples of litterbags (upper part of photo) and bait laminas (lower part) for decomposition studies.

PROTOCOL 3
LAND USE AND MANAGEMENT

The need to collect data on land use and management is recognised by all major ecosystem monitoring activities. The major elements are location (which links to other data on topography, climate, etc); land cover (in terms of vegetation, allowing linkage to remotely sensed and other data); manipulations by land managers and scientists (to enable the interpretation of ecological change to external drivers). This protocol ensures that essential contextual data are routinely collected for every spatial unit that is being monitored. It gives a description of the site, and also to provide contextual data on land operations to help interpret (and even help model) ecosystem changes. The protocol ensures that essential data are collected to a basic level; local protocols may exceed these standards (*e.g.* by collecting Level 3 EUNIS data on vegetation type). It is of most value for those sites that are managed by farmers and foresters, as it ensures that data are collected in their activities in a timely and consistent way.

This protocol must be completed at least once a year. As the protocol is not field based, timing is not critical. Some data will not change between years, but should always be checked.

Data are required for each spatial unit on the site that has consistent management (this may be a field, an area of forest managed as a unit, a plot within an experiment, or a chamber within an Ecotron). Required data include: description of the spatial unit; its location and area; biodiversity or landscape protection designations; is the vegetation native, or has it been sown or imported?

Vegetation is characterised using the European EUNIS classification to at least Level 2. Data on inputs of pesticides and fertilizers, other abiotic inputs and removals, should be recorded to the nearest day, and to the available level of accuracy about quantity. Such data may come from the farmer or forester. More precise data will be available for formal experiments, in which case it is probably preferable to refer to the database of the experiment itself using appropriate links.

Data on biotic inputs, thinning and removal, and harvesting, should be recorded to the nearest day, and to the available level of accuracy about quantity. Data on soil operations, nutrient and pesticide inputs, experimental manipulations and other forms of land disturbance and manipulation should likewise be recorded to the nearest day. Such data may come from the farmer or forester. More precise data will be available for formal experiments, in which case it is probably preferable to refer to the database of the experiment itself using appropriate links.

Author

Les Firbank

Picture

Recording of land use in the UK for analysis of land use and management patterns.

PROTOCOL 4
LEAF AREA INDEX

Authors

Giorgio Matteucci
& Miklós Kertész

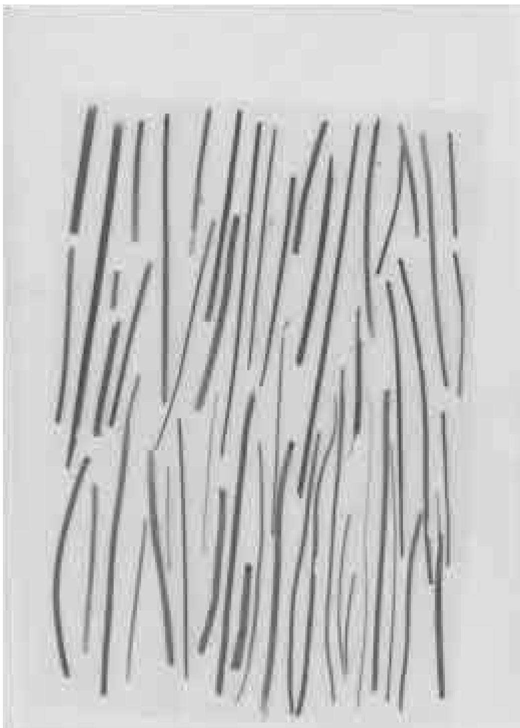
Leaf Area Index (LAI), a basic structural and functional variable of terrestrial ecosystems, is defined as the total one-sided foliage area per unit ground surface area. It regulates a number of ecophysiological processes, such as photosynthesis and evapotranspiration, and is a key variable in various stand- and regional-scale models of Net Primary Production. LAI can be measured directly by harvesting small sample parcels of vegetation in grassland and cropland or by collecting leaves from sample trees to develop allometric relationships between LAI and a more easily measured parameter, such as tree diameter. As direct measurements of LAI can be difficult and time-consuming, indirect procedures based on the measure of light transmission through plant canopies have been developed.

In deciduous forests, Leaf Area Index can be assessed directly by collecting falling leaves by a number of litter traps (funnels), weighing them and assessing the ratio leaf area to weight on a subsample of collected leaves. There should be at least 10 traps per plot in uniform forest, 2-3x as many in stands of variable structure. Traps are made of nets or bags attached to a frame of durable material, with a known area of minimum 0.18 m^2, preferably 0.25 m^2 or larger; they should be at least 0.5 m deep and be clear of the ground to allow drainage. Litterfall should be collected monthly, and more frequently in periods of heavy leaf fall (*e.g.* in autumn or after heavy rain or storms). Dry leaves may need to be soaked before taking area measurements using an LAI meter or scanner; wet leaves may need to be cleaned and flattened. Dry weight should also be taken.

In evergreen forests, falling needles do not equal standing leaf area but are, in the medium-long term and on the average, equal to annual foliage production. Hence, in evergreen forests, direct measurement of LAI can be made using allometric relationships. Needles do not change area after cleaning, but can twist on drying, making preparation difficult.

Indirect methods of assessing LAI of trees involve assessment of light interception, either using the analysis of hemispherical photographs or instruments detecting the fraction of light intercepted by the canopy. Multiple measurements should be taken during the season, to account for phenology, ensuring that LAI is assessed at its maximum (normally in the middle of the growing season).

In grassland and croplands, direct measurements of LAI can be made by harvesting small parcels of vegetation, weighing the harvested biomass and measuring the ratio of leaf area to weight on a subsample of collected material.



Picture

Sample of grass prepared to be scanned for leaf area estimation (SAPER course in Amserdam).

PROTOCOL 5
SOIL MESOFAUNAL DIVERSITY

There is a need for an index that describes soil quality, based on the community composition. Yet soil quality monitoring is often inaccessible to land managers because the measurement systems are too complex, too expensive or both (Herrick 2000). The application of biological indicators is often limited by lack of expertise in identifying soil fauna. Therefore, here we propose a simplified eco-morphological index that does not require the classification of organisms to species level. The QBS-ar index (*Qualità Biologica del Suolo*) is based on the following concept: the higher the soil quality, the higher the number of microarthropod groups morphologically well adapted to this soil habitat. Microarthropods (smaller than 2 mm) are considered mesofauna, contrary to larger arthropods (macrofauna), nematodes, bacteria, fungi and algae. QBS-ar has been tested in several sites across Italy for testing the effects of forest cutting, grazing, trampling, industrial activities, emissions, agriculture, heavy metals and other anthropogenic affects.

Soil organisms are separated into biological forms according to their morphological adaptation to soil environments; each of these forms is associated with a score named the EMI (eco-morphological index), which ranges from 1 to 20 in proportion to the degree of adaptation. The QBS-ar index value is obtained from the sum of the EMI of all collected groups. If in a group, biological forms with different EMI scores are present, the higher value (more adapted to the soil form) is selected to represent the group in the QBS-ar calculation. This choice is based on the consideration that the examined soil is able to support well-adapted and consequently more vulnerable biological forms. Parisi *et al.* 2005 provides tables to easily calculate the index.

The protocol should be completed at the same time of year (spring or autumn) annually in stable soils, more frequently in arable systems. It is recommended that the samples will be taken from two soil depths, or if only one is taken, then is taken from a wetting front. Three soil cores, 10 cm deep, should be taken and any litter removed. The samples should be transported in polyethylene bags and placed in a Berlese-Tüllgren funnel within 24 hours, in which the soil organisms fall from the bottom of the sample into a solution of 75% alcohol and 25% glycerine by volume. The extracted specimens are observed under a stereomicroscope and identified at different taxonomic levels: classes for miriapoda (Diplopoda, Chilopoda, Symphyla, Pauropoda) and orders for insects, chelicerata and crustacea. Collembola are subdivided according to a simple key. The organisms belonging to each biological taxon are counted in order to estimate their density at the sampled depth (0-10 cm) and to relate the number of individuals and the sample area to 1 m^2 of the surface (ind/m^2).

Each taxonomic unit is given a score named the EMI (eco-morphological index), which ranges from 1 to 20 in proportion to the degree of adaptation. The QBS-ar index value is obtained from the sum of the EMI of all collected groups. If in a group, in which biological forms with different EMI scores are present, the higher value (more adapted to the soil form) is selected to represent the group in the QBS-ar calculation.

Authors

Amélie Joseph,
Elli Groner
& Cristina Menta

Pictures

1 Digging up the soil extracts to be taken to the lab for the soil mesofauna.

2 The Berlese-Tüllgren funnels in the laboratory extracting the mesofauna from the soil, using heat.

PROTOCOL 6
SOIL ORGANIC MATTER
CARBON AND NITROGEN STOCKS

Author

Carsten W. Müller

This protocol explains how to collect samples for soil carbon (C) and nitrogen (N) stock information and the determination of the soil bulk density. By obtaining these data, it will be possible to relate stand biomass, soil microbial biomass, root mass, etc. to reliable information about the C and N content and especially C and N stocks in soil.

The number and selection of sample sites depends on the heterogeneity and area of the site. At a minimum, three composite locations could be used, and replicated points should be analysed. For soil mapping using geostatistical approaches, far more samples are required (often > 100), *e.g.* using a nested grid design. At each location, the sampling point consists of a soil pit for soil morphology and bulk density evaluations, whereas the composite sample (C and N content, pH or CEC etc.) is taken from eight points around the central soil pit. In mineral soils, steel rings of 100 cm³ are usually used to sample a known volume. The sampling points should be re-locatable for re-sampling, every 5 years in the absence of human management, annually in managed conditions, ideally in early spring before soil amendments are added.

The samples for C and N analysis can be taken using a shovel or spatula, taking care not to mix soil material of different horizons or layers. They are promptly air dried, sieved over a sieve of 2 mm mesh size and homogenized. For referencing the obtained C and N contents, a drying of soil aliquots at 105°C for 24 h is crucial. The method most commonly used to analyse C and N concentrations, and thus organic matter content, is lab-based dry combustion using an elemental analyzer. When the pH exceeds 7, a parallel carbonate destruction and inorganic carbon quantification is required, either by combustion of the organic C at 450° for at least 4 hours, or by acid treatment using *e.g.* HCl.

Bulk density is crucial for all determinations of element stocks, including C, N and soil nutrients. A known soil volume is taken to the lab and dried at 105°C for at least 24 h until constant weight. The bulk density is calculated from the dry weight and volume. For the determination of the volume and weight of the organic layer, a "counting frame" (*e.g.* square frame 20x20 cm) is used to remove the total organic layer material within the frame before drying and weighing. Bulk density accounts by definition only for the fine earth (< 2 mm), and so the influence of larger particles must be removed. After the weighing of the dry soil, the soil has to be sieved over a sieve of 2 mm mesh size, and the larger particles must be weighed, and these are assumed to have a medium density of 2.65 g cm³.

Picture

Taking volumetric soil samples using stainless steel rings for bulk soil, C and N determination at regular depth increments in the subsoil of a Podzolic Cambisol under European beech (DFG research unit, FOR 1806).

PROTOCOL 7
GREENHOUSE GAS EMISSIONS FROM SOILS

Soils can act as both sources and sinks of Greenhouse Gases (GHGs). This protocol addresses the measurement of the efflux of the greenhouse gases CO_2 N_2O and CH_4 from soils using chambers that rest on the soil surface. Here the two most common methods in current use are presented, but technologies are developing rapidly.

The location of sampling points depends on the research objectives, with a suggested minimum of three replicate locations per experimental plot or stratified/grid sampling scheme of an area; they should be linked to an automatic multi-chamber measuring system. Positions should be re-locatable. If only heterotrophic soil respiration is to be measured, autotrophic fluxes from rhizosphere and root respiration must be excluded by inserting a cylinder deep into the soil well before sampling starts. Trace gas fluxes exhibit a high degree of temporal variability. Temperature, rainfall and photosynthesis control trace gas emissions in natural undisturbed ecosystems, whereas in managed agricultural systems fertilization, tillage and harvest are additional drivers. While one should ideally estimate the diurnal, weekly and monthly variability, resource limits often require measuring at a particular time of day every 15 days, with additional measurements following potential flux peaks *e.g.* rainfall, snow melt, litterfall and agricultural activities. Soil temperature data can be used to interpolate values.

There are currently two types of chamber used, the Non-Steady-State Through-Flow System (NSS_TFS, also referred as closed dynamic chamber) and the Non-Steady-State Non-Through-Flow closed system (NSS_NTFS, also called closed static chamber). Both types have a lid and are open to the soil surface, located on a collar fixed into the soil to maintain an airtight seal. In the dynamic chamber, air is circulated constantly between the chamber headspace and the analyser. The dynamic chamber is capable of higher precision, but requires an operator and a power supply. Static chambers are preferred when only occasional measurements are required; N_2O and CH_4 fluxes are normally measured collecting gas samples to be analyzed later in the laboratory, while CO_2 is often measured using low cost CO_2 IRGAs (Infrared Gas Analyzer). Data are required on detailed chamber design and operation in order to estimate GHG emissions from detected levels of the gases. Chambers need regular maintenance and calibration.

Authors

Gemini Delle Vedove,
Carlo Grignani
& Chiara Bertora

Pictures

1 Steel anchor and automated closed chamber on a bare soil.

2 Closing a chamber to sample N_2O and CH_4 in a rice crop. The chamber is equipped with a fan, vent valve and sampling port.

3 Withdrawing of gas sample for chromatographic analysis from a closed chamber.

INTEROPERABILITY FOR LONG TERM EXPERIMENTAL & OBSERVATIONAL DATA

Author

Johannes Peterseil

Websites

*www.anaee.com
*www.lter-europe.net
*www.enveurope.eu

Note

**see data.lter-europe.net/deims

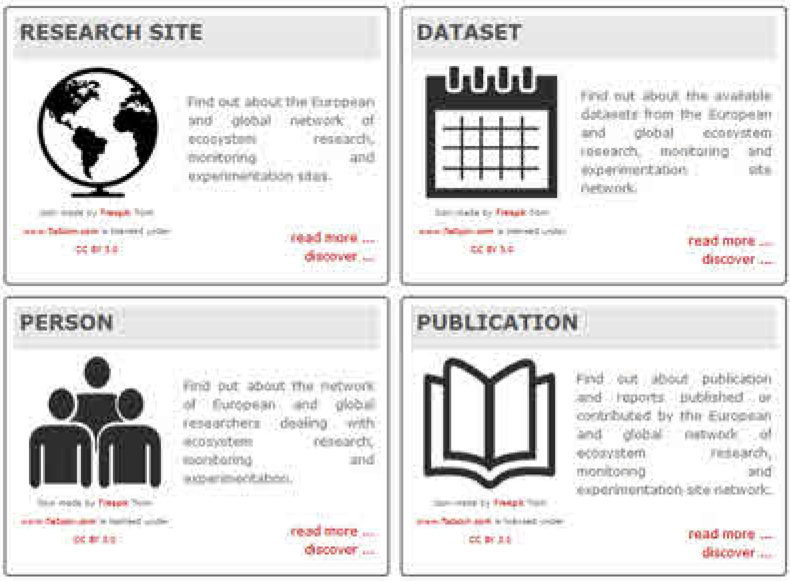
Picture

Information models addressed within DEIMS.

Addressing challenges for long term data management

In order to provide improved knowledge for the environmental management and to support the development and implementation of targeted and evidence based environmental policies at European scale, information on the status and trends of ecosystems as well as on the underlying processes is needed. To enable this, a broad variety of data is generated by research sites and communities adding up to a common data pool used to analyse the effects of drivers and pressures along European scale environmental gradients and experimental treatments. Nevertheless, a number of challenges still need to be addressed when integrating these data. Despite harmonisation efforts by various research infrastructure initiatives and networks, a lot of data heterogeneity still exists between different scientific domains and research infrastructures. In addition to the variety of disciplines involved, data management still show a high level of diversity - ranging from single data centres to distributed data management centres at single institutes or within research groups. Also different data formats, descriptions or reference lists are used by the different communities.

The ExpeER project addressed a number of these challenges and thus contributed to the development and establishment of common services for European scale Research Infrastructures (*e.g.* AnaEE, LTER Europe). Common and harmonised methods for data generation, management, documentation, and sharing are needed in order to build a shared data and knowledge base. This can only be reached through an integrative approach addressing common objectives and research topics, providing sufficient resources and including the relevant disciplines.



So for instance, providing a complete documentation of information resources (*e.g.* dataset or research sites) and putting them into a semantic context were the main results of ExpeER. A common structure and semantic framework for the description of data and research infrastructure elements are crucial for future usage and integration of information.

Sharing knowledge and data

One of the challenges still hampering the integration and reuse of data and information is missing meta-information. An attempt to solve this was the development of the DEIMS Research Site and Dataset Registry**, a metadata portal to document and exchange information on the network of observation and experimental sites as well as their related datasets and persons. Building on existing work from US LTER and EnvEurope, DEIMS was extended within ExpeER to cover the needs of both, the experimental and the observational communities. DEIMS was designed to provide an easy way to manage, discover and access meta-information of ecological data. Thus providing a one-stop shop for a range of information needed to use existing data.

DEIMS focuses on four types of information resources: (1) the Research site or experimental facilities, as the main location of data generation, (2) the Dataset, as the main result of the experiments and observation, (3) the Person, as the main context for the data generation, and (4) the Publication, as a product. All information models are interlinked within DEIMS and can be discovered.

The metadata models are based on well-established standards (e.g. ISO19115 and EML for datasets) or community best practises (*e.g.* research site from LTER Europe) and were specialised using community requirements. The resulting community profiles are used to resulting community profiles are used to document and discover the information.

By the use of standard service interfaces (like Catalogue Service Web (CSW) or metadata harvesting) linkage of metadata from the European long term observation and experimental domain with other communities, *e.g.* DataOne, is possible.

Using a common language

In order to enable the analysis of data resulting from the different research and experimental sites an extensive documentation as well as a common understanding of the data structure and content is needed. A common semantic can also be described as the "common language" used by the different data providers and generators having a set on agreed terms and concepts describing the data.

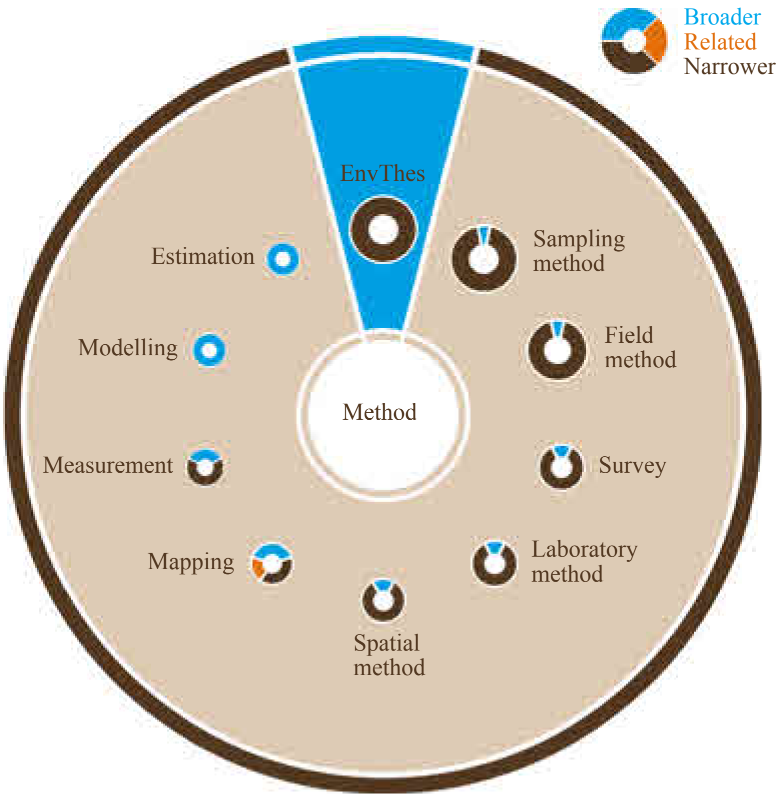
Within ExpeER a controlled vocabulary was established to provide keywords for the documentation of datasets on the one side and to create a base vocabulary for describing data structure and content (*e.g.* observed entities, observed properties, observation methods, or units) in a harmonised manner on the other. This thesaurus needs to cover terms and concepts from the relevant domains ranging from ecological experiments, agricultural practices, and ecological monitoring. The semantic work in ExpeER was based on existing efforts in this field extending EnvThes***, a thesaurus for long term ecological observation started by the EnvEurope project, to include the experimental ecosystem domain. EnvThes has been created as extension of already existing US-LTER controlled vocabulary including the QUDT ontology (NASA Sweet Ontology - Units), the EUNIS habitats, and the INSPIRE spatial data themes. Within ExpeER special focus was laid defining concepts of experimental treatments, agricultural practices and observed parameters resulting finally in a total of about 2.000 concepts in EnvThes.

The semantic work resulted also in the restructuring of the top level hierarchy of EnvThes following the recommendations of the OGC Observation & Monitoring data model thus allowing for a clearer connection between elements of datasets (*e.g.* columns) and concepts within the thesaurus (*e.g.* observed property). Using the SPARQL (SPARQL Protocol and RDF Query Language) to query linked information sources (*e.g.* datasets exposed by D2RQ linked with a thesaurus) via the web semantic integrated data sources can be produced. This needs the implementation and use of the controlled vocabulary in the data management framework.

The development of the controlled vocabulary EnvThes is a community effort, driven by their needs which might change in future. Therefore continuous developments and adaptations by the community are necessary. In order to ensure the flexibility and extensibility within the related communities a simple governance model has been established defining working bodies (*e.g.* contributor, editorial team, or technical coordinator) as well as workflows for the proposal of terms and concepts.

Note

***see http://vocabs.lter-europe.net/EnvThes Dev



Picture

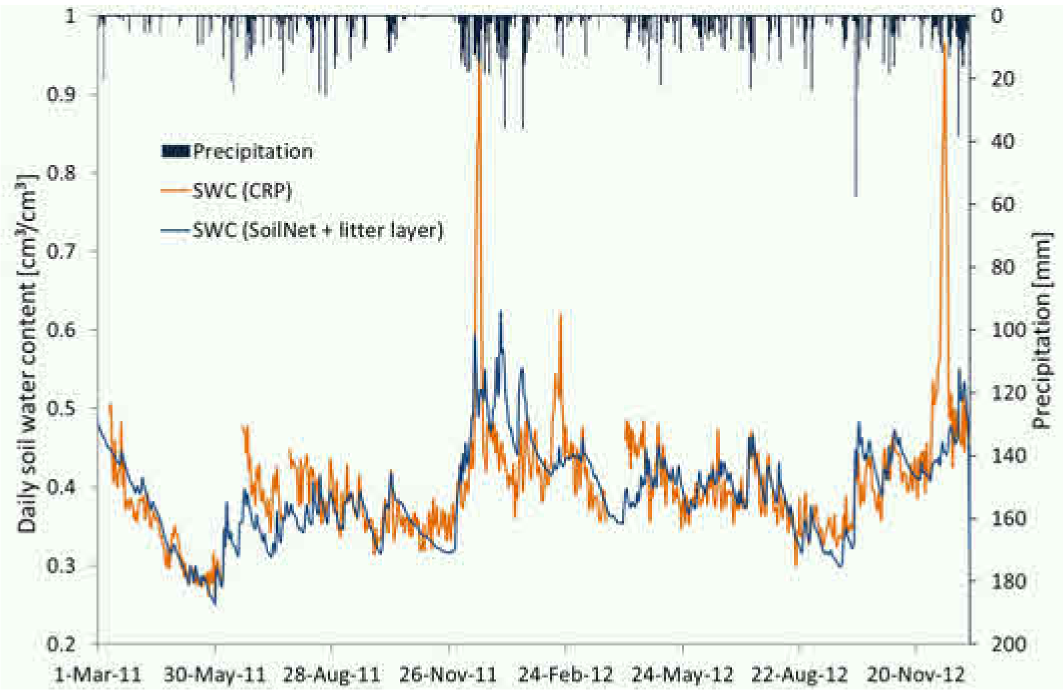
Relations of the top level concept "method" within EnvThes.

NEW SENSOR TECHNOLOGIES FOR INTEGRATED OBSERVATION OF SOIL MOISTURE AT THE FIELD SCALE AND LANDSCAPE SCALE

Author
Steffen Zacharias

Soil moisture is a key state variable for the terrestrial environment that determines both the storage and the generation of runoff processes. Hence, adequate knowledge of soil moisture distribution is a fundamental precondition for improving model predictions. The monitoring of storage, movement, and quality of water at the landscape scale is of critical importance to practical applications such as agricultural production, water resources management, as well as flood, drought and climate change predictions. An adequate investigation of land surface processes requires the inclusion of soil moisture information averaged at a scale that is relevant and representative for the terrestrial processes (physical-chemical, biological). High resolution mapping of functional soil properties and monitoring of processes and dynamics are an indispensable prerequisite for the theoretical understanding of the links between soil properties, water flow and ecological processes.

Emerging sensor technologies and novel measurement concepts allow a better assessment of soil moisture and an improved analysis of the complex feedback mechanisms between different environmental compartments. Geophysical measurement techniques offer the opportunity for collecting information about the spatial and temporal variation of soil properties covering a wide range of scales. Wireless sensor network technologies create new possibilities to observe soil moisture dynamics at the field scale in high resolution both in space and time. Another emerging technology, cosmic-ray neutron probes (CRP), can be used to monitor soil moisture content near the surface covering a footprint of tens of hectares. This makes the technology unrivaled in providing representative data for environmental models at the hectometer scale. Within ExpeER all three groups of technologies were tested and the potentials for an improved assessment of soil moisture dynamics at the field scale were tested.

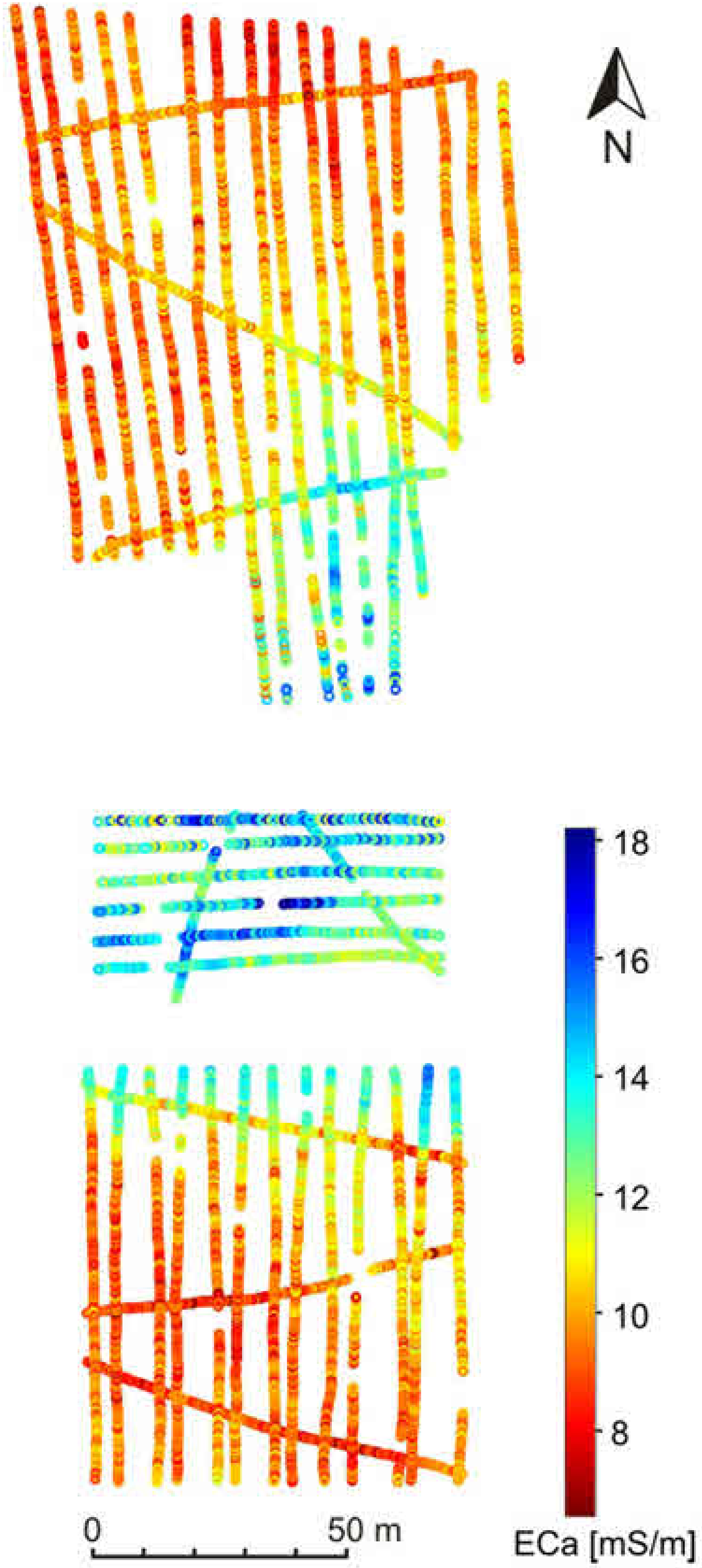


Picture

Time series of weighted average soil water content (wireless soil moisture sensor network SoilNet) and soil water content derived from CRP measurements using a calibration option that considers simulated water dynamics of the litter layer (Bogena *et al.*, 2013).

The technologies were applied, implemented and combined in different long-term observation sites in Germany and France. For the first time CRPs were operated in a humid forest ecosystem. Since the accuracy of the of the CRP measurements is affected by any source of hydrogen within the support volume of the device, such ecosystems are less favorable for the CRP (Cosmic Ray Soil Moisture Probe) application. Carbohydrates in the soil organic matter, water in the belowground and aboveground biomass, and the presence of a litter layer exhibiting highly dynamic water content complicates the interpretation of the CRP signal. It could be shown, that the inclusion of the water content of litter layers improves the sensor calibration. Furthermore, a newly developed vertical weighting function enables the comparison of wireless sensor network data and CRP soil water content estimates. The results were published in Bogena *et al.* (2013).

By applying a wireless soil moisture sensor network at a grassland site, the suitability of such a technique to highlight significant events, for which critical hydrological processes like preferential flow or surface runoff occur, could be shown. By applying advanced statistical techniques, the large datasets generated by such networks could be analyzed in order to identify and describe the relevant hydrological dynamics, patterns and states at the field scale. At the same site repeated mobile electromagnetic induction (EMI) measurements were carried out. By providing dense information in a fast and non-invasive way this technology proved to be a powerful tool for digital soil mapping. It could be shown, that a reliable soil mapping application needs to account for the hydrological state in order to prevent misinterpretation of the data. First results of this work are published in Martini *et al.* (2015).



Picture

Spatial map of soil bulk electrical conductivity (ECa) measured using an EMI device. The spatial pattern of ECa was found to be very consistent over different measurement dates at the hillslope scale (Martini *et al.*, 2015), while a more detailed analysis of the patterns revealed significant variability of patterns at the smaller scale.

NANOSIMS TO UNRAVEL MICRO-SCALE SOIL PROCESSES

Authors

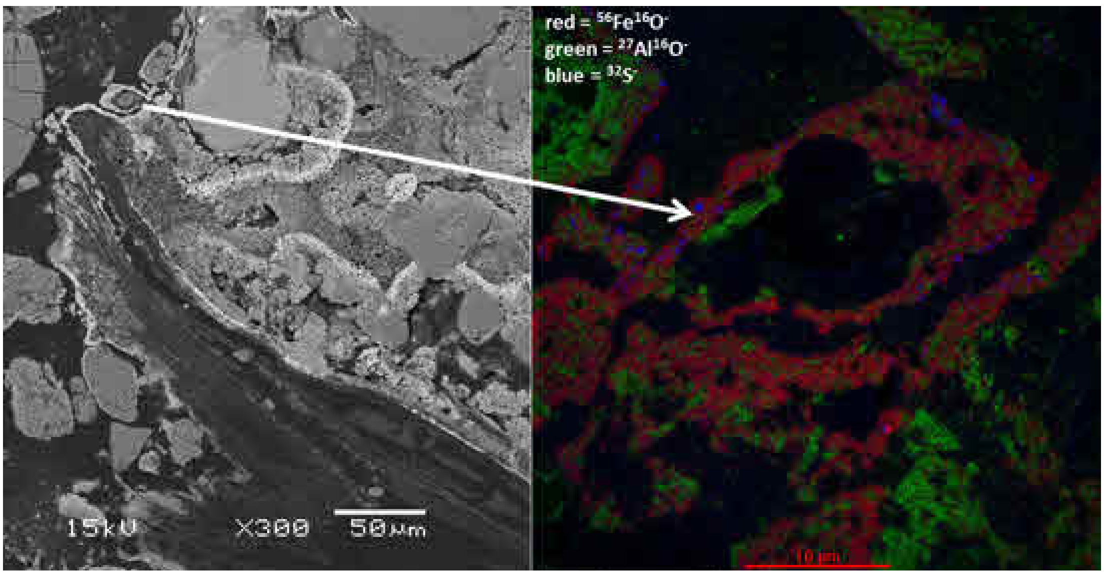
Carsten W. Mueller, Cornelia Rumpel & Ingrid Kögel-Knabner

Soil organic matter plays a vital role for a range of soil functions, especially the distribution and composition of organic matter at the micro-scale can influence soil wettability and thus affect soil hydrology. Moreover, microbial processes influencing organic matter composition and soil C storage are strongly dependent on water availability. The molecular complexity of soil organic matter is extraordinary, and the metabolic products of higher plants and the diverse soil microbial community are mixed together in a three-dimensional inorganic soil matrix. An essential step to overcome this obstacle is the identification of intact molecular structures in soils. To investigate the evolution and composition of submicron-sized organo-mineral associations on single particles and insoil aggregates it is crucial to test novel micro-analytical techniques allowing the simultaneous analysis of the spatial distribution of elements involved in stabilization processes of soil organic matter (for example C, N, Si, Al and Fe). This is a major step forward in the understanding of soil formation with significant implications for our conceptual understanding of the soil C and N cycles, structural stability and sorptive properties. This is also a vital prerequisite to understand processes at larger scales up to the ecosystem level. The establishment of the NanoSIMS facility at TU Muenchen for such soil analyses is a major step forward in securing state-of-the-art analytical techniques for elucidating the composition of soil and its reactive interface.

Until today, the NanoSIMS technique has been mainly applied in the field of material science, cosmochemistry, geology, mineralogy and biology. In the field of soil science, the possible applications of NanoSIMS for the study of biogeochemical processes were reviewed by Mueller *et al.* (2013). They described the great potential of submicron studies of soil samples with a special emphasize on the potential for the study of soil organic matter dynamics.

The availability of the NanoSIMS microprobe at TU Muenchen adapted to soil science and related environmental research was also considered as an initiative for further international activities and collaborative efforts for soil science and related disciplines. The technique was intended to add a new dimension to tackle research questions in several coordinated research efforts, stimulating the collaboration between soil chemists, microbiologists but also plant physiologists.

The high sensitivity and lateral resolution of the NanoSIMS instrument can only adequately be used with appropriate sample preparation. In particular topography, out gassing and charging effects are of major concern to achieve highly precise analyses. Two different sample preparation techniques (1) wet deposition and (2) the sectioning of epoxy resin embedded samples were developed. Wet deposition is used for primary soil particles, *i.e.* mineral particles and particulate organic matter. The epoxy resin embedding technique is used for intact soil



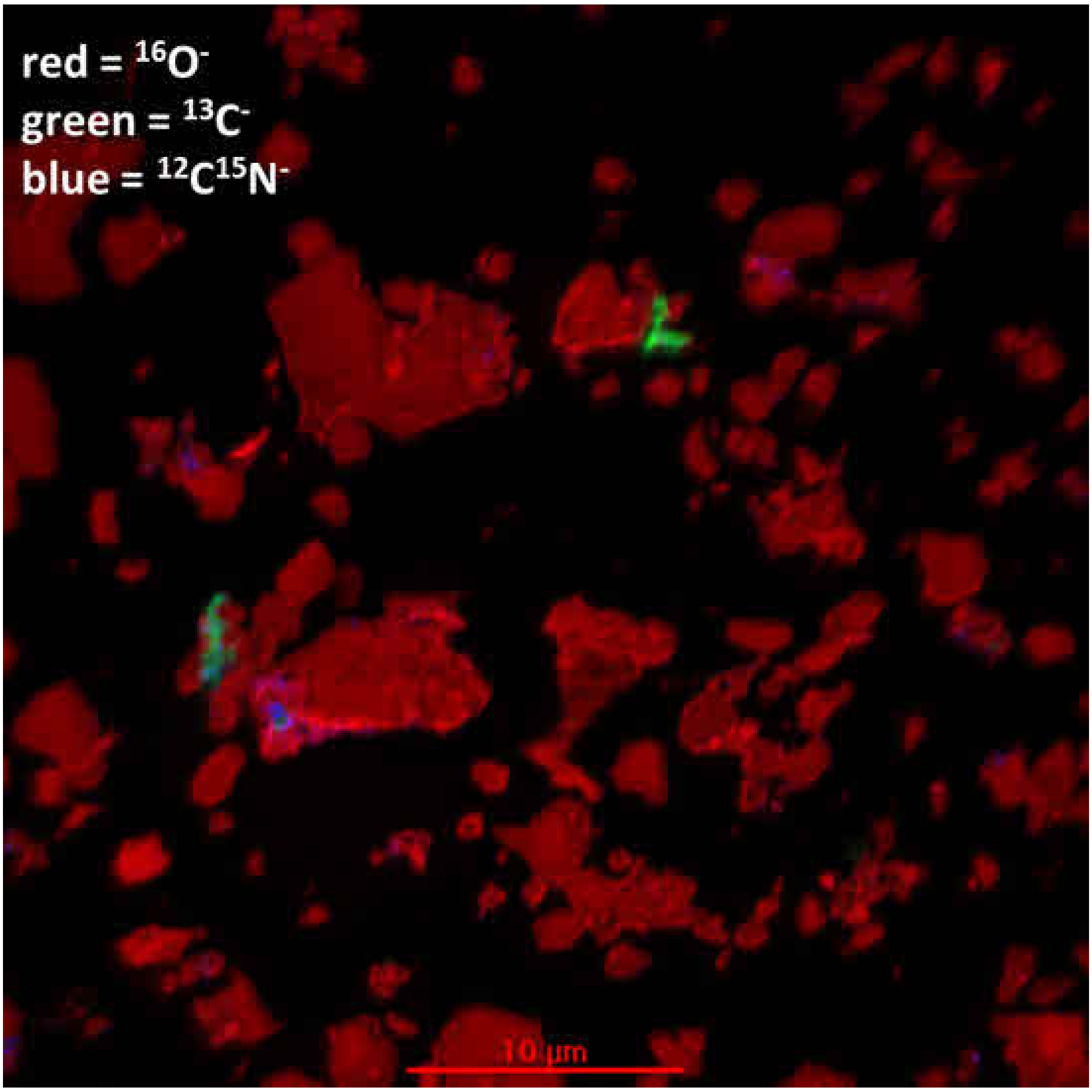
Picture

Coordinate transformation in combination of different microscopic techniques (intact iron rich soil core, embedded in Araldite 502). Left image shows a SEM micrograph of iron oxide rich sphere, composite image of 3 secondary ion species on the right illustrate the correlation between iron layers (56Fe16O-), clay minerals (27Al16O-) and Sulphur (32S-). (Mueller, unpublished data).

aggregates up to intact soil core sections (see also Picture 1). Both techniques allow the production of samples that meet the requirements of the instrument, i.e. vacuum stability at < 10-9 mbar, flat and polished surface and sample sizes fitting exactly into the sample holders.

The wet deposition technique was used for a study on the fate of freshly added 13C and 15N labelled litter in an incubated soil. By using NanoSIMS we were able to demonstrate that the labelled organic matter was recovered mainly at spots were already inherited soil organic matter was located on soil micro-aggregates (Picture 2). It was also possible to show that organic matter was heterogeneously distributed on clustered soil structures at the micro-scale (Vogel *et al.* 2014), whereas the high lateral resolution was demonstrated on goethite needles covered with extracellular polymeric substances (Liu *et al.* 2013).

The influence of potentially contrasting hydrology in different depths of the soil profile on SOM stabilization processes at nanoscale was studied using an in situ incubation experiment at INRA Lusignan. Analyses of a specific density fraction using NanoSIMS and electron microscopy indicated contrasting composition of organic matter associated to metal oxides at different soil depths (Rumpel *et al.* 2015). This points to differential microbial functioning at distinct depths of the soil profile, which may to some extent be the result of contrasting hydrology. The combination of field experiments using well equipped research infrastuctures with highly sophisticated analytical techniques, such as NanoSIMS thus seems to be a promising avenue to understand soil processes under *in situ* conditions.



Picture

The image represents the possibility of the NanoSIMS technique to locate fresh organic matter (13C and 15N derived from labelled litter) as associated with soil micro-aggregates (Vogel *et al.* 2014). The 16O-distribution indicates minerals in micro-aggregate structures.

METABARCODING TO ASSESS MICROBIAL RESPONSE TO ENVIRONMENTAL CHANGE

Authors

Joe Jenkins
& Gail Taylor

Microbial communities within the soil are responsible for driving nutrient cycles. Bacteria and fungi break down soil organic matter, recycling nutrients back into the soil, whilst carrying out essential biogeochemical processes such as nitrogen fixation and phosphorous mobilisation. Previous work has indicated that bacterial community diversity and structure are driven by a combination of factors, including pH, soil moisture and vegetation type. Environmental changes associated with climate change will lead to shifts in these driving variables (such as decreased soil moisture due to drought, or increased soil pH through biochar application). In ExpeER, we therefore aimed to determine whether new technologies could be utilised to measure changes in microbial community structures, and the abundances of individual genera.

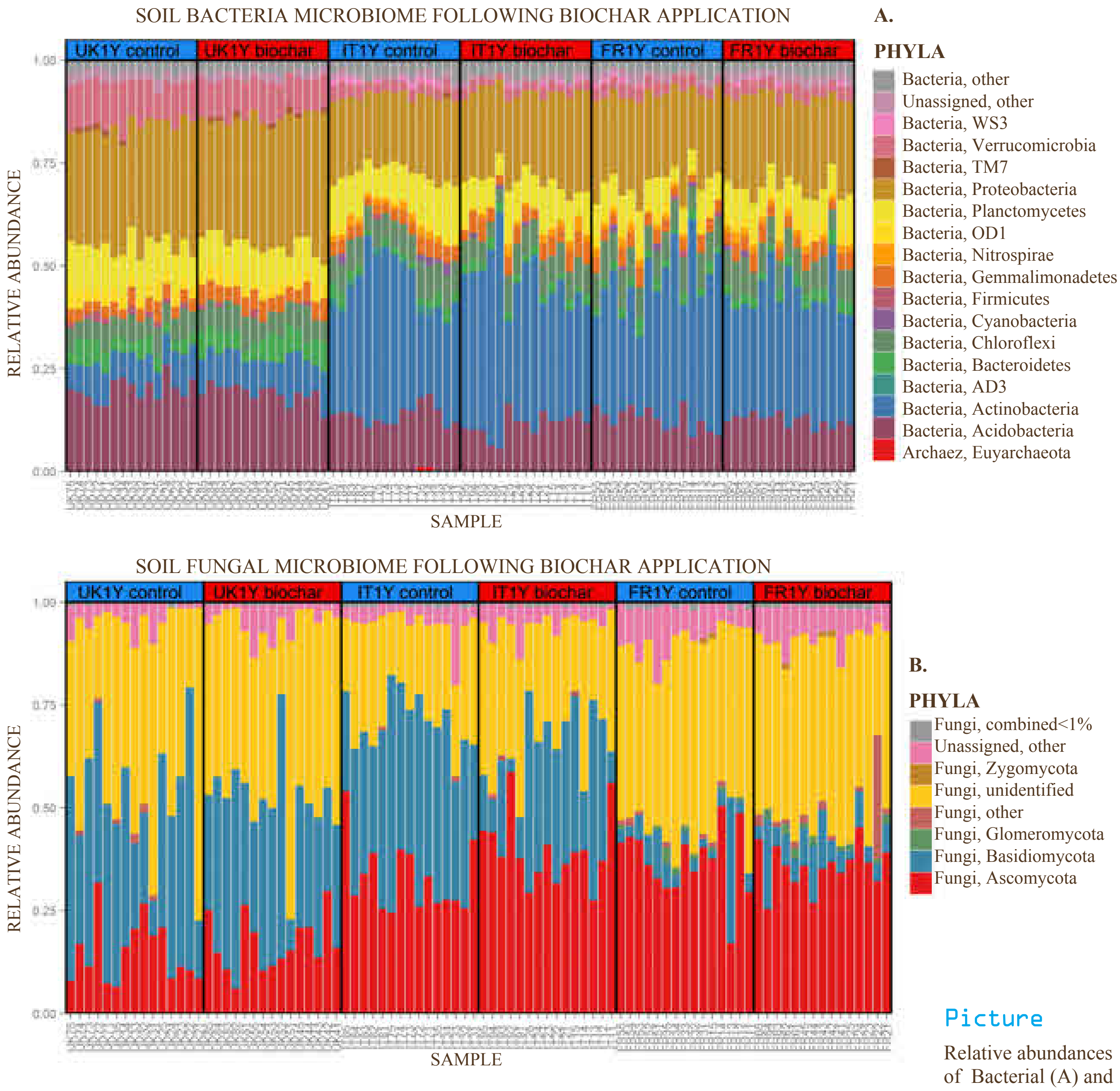
Previously, changes in bacterial and fungal community structure could only be assessed in very broad terms, looking at changes in the abundances of phyla present. DNA sequencing technologies have rapidly improved in recent years, leading to reductions in cost and increased data yield and we have captured these advances as part of the project ExpeER. The greater availability of sequence data has enabled the use of metabarcoding to assess changes in microbial diversity. Metabarcoding utilises regions of genes which are specific to individual taxa, which enables the identities and abundances of taxa present within a sample to be detected through sequencing. Specifically, we chose to use the internal transcribed spacer (ITS) region and the 16s ribosomal RNA subunit (16srRNA) region, which can be used to identify fungi and bacterial taxa respectively. This method is particularly powerful in that it also detects the abundances of taxa which have not been formally identified.

We utilised high throughput metabarcoding to assess the changes in microbial diversity in response to environmental change manipulations experiments. Soil samples were collected from sites treated either with drought or biochar, with paired controls. Total DNA was then extracted from these samples, prior to amplification with 16S or ITS specific primers. The resulting amplicons were then sequenced using high throughput Illumina technologies, generating datasets representing the taxonomic identities and abundances of bacteria and fungi in each sample. By using the QIIME bioinformatics pipeline, we were able to effectively survey the proportional abundances of bacteria and fungi within samples, and compare the results by treatment. These methods enable general comparisons of communities, determining whether treatments have similar taxa in comparable proportions. Additionally, use of further bioinformatic methods such as STAMP enabled us to determine precisely which taxa changed in abundance due to treatment. By combining this information with existing functional profiles of cultured taxa, it is possible to propose the likely functional implications of taxonomic shifts.

Using these methods we successfully detected significant differences between bacterial and fungal communities in soils treated with biochar, when compared with controls, with a shift to oligotrophic taxa after biochar application (see picture next page). This illustrates the potential for metabarcoding methods to further unravel environmentally driven microbial community change.

Picture

Collection of soil samples prior to DNA extraction and metabarcoding.



Picture

Relative abundances of Bacterial (A) and Fungal phyla (B) at three European biochar sites as detected using metabarcoding, for control soil (blue) and soil treated with biochar (red), modified from Jenkins *et al.* (2016, submitted).

> We compared the effects of a standardised biochar application at three European field sites, in the UK, FR and IT. The UK field site consisted of *Salix sp.* short rotation coppice (SRC) for bioenergy in the south of England, whilst the IT site comprised of SRC Populus in northern Italy. The FR site was agricultural grass-land.

We compared the effects of biochar on microbial community profiles at each site, in order to determine whether there were standardised effects of biochar application on microbial soil community structure.

Results are presented in the picture below: Bacterial and fungal communities differed at the level of phylum by site, with samples collected in FR and IT being dominated by Actinobacteria (30-40%), Acidobacteria (10-20%) and Proteobacteria (20-25%), whilst the UK site was dominated by Proteobacteria (25-35%), Acidobacteria (16-25%) and Verru-comicrobia (8-12%). Further analysis of differential abundance showed significant enrichment of Gemmatimonadetes and Acidobacteria in the UK biochar samples after treatment. Samples from IT displayed enriched abun-dance of the Rhizobiales, a Proteobacteria known to play a role in nitrogen cycling.

Fungal diversity differed between sites, and also exhibited significant differences at the community level between treated and untreated samples. STAMP analysis revealed a significant difference in only IT samples, where an enrichment of Chaetothyriaceae occurred. Therefore, it appears that whilst biochar significantly effects certain bacterial taxa, its effect on fungi is at a community scale, causing small changes in fungal abundance which are not significant individually, but cause a cumulative effect.

These results provide novel insight into the effects of biochar treatment on microbial community response in field scenarios.

IMPROVEMENT OF THE INFRARED HEATING TECHNIQUE

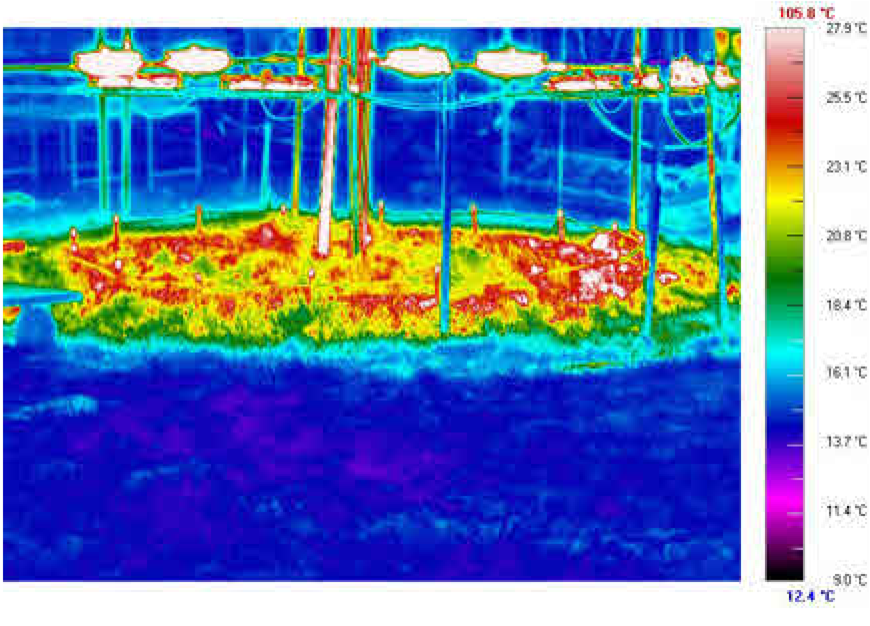
Authors

Ivan Nijs
& Hans De Boeck

For studying climate change impacts, there are several ways to warm vegetation. Currently, only one of those can both operate in free-air conditions and provide a custom, easily adjustable temperature increase: infrared heating. Because the heaters warm the surface (tissues, soil) directly, significantly less energy is required than if the air would have to be heated. This makes it possible to use this technique outside, hence avoiding artefacts that mark other warming techniques relying on enclosing ecosystems (greenhouses, open top chambers). The research group Plant and Vegetation Ecology at the University of Antwerp has been at the forefront of developing and perfecting the infrared heating technique.

One of the recent improvements should resolve two main problems scientists face when using infrared heating. The first is that meteorological and climatological data and scenarios consider air temperatures, not canopy temperatures. This renders it more difficult to choose the level of (canopy) warming, as the relationship between air and canopy temperatures is not linear or constant. The second problem is that current control methods for infrared heating usually maintain a constant temperature difference between warmed and control plots. This implies that any responses of the vegetation in the warmed plots which themselves modify canopy temperature are filtered out. For example, increase of canopy temperature in response to drier conditions owing to decreasing transpiration cannot be expressed if canopy temperature is increased by a fixed amount. A new method developed by De Boeck & Nijs promises to remedy both issues, and follows three steps based on energy balance calculations: (1) determine the canopy conductance of the reference (unwarmed) plot; (2) calculate a theoretical canopy temperature associated with given (target) air temperature; (3) compute the energy output of the infrared heaters required to achieve said theoretical canopy temperature. To apply this in the field, a number of sensors (wind speed, air and canopy temperature, net radiation, etc.) are installed, with a custom program modulating the output of the infrared heaters. The researcher then just needs to input the desired increase in air temperature, and the regulation makes sure that the heating is applied both precisely and realistically.

Another improvement was made in quantifying the extent to which infrared heating increases transpiration, a phenomenon caused by the increase of both the gradient and the conductance for water vapour. Results suggest a 12-15% increase in transpiration under infrared heaters for a 1 °C warming (De Boeck *et al.* 2012). The excess water loss underneath infrared heaters reported upon here could be compensated by increasing irrigation or applying newly developed techniques for increasing air humidity in the field, thereby increasing the appeal of infrared heaters further.



Picture

Thermal image of plot warmed by infrared heaters during testing.

IMPROVING LYSIMETER BOUNDARY LAYER CONDITIONS FOR GLOBAL CHANGE STUDIES

Understanding how climate change, *i.e.* changes in precipitation and temperature, is affecting ecosystem carbon, nitrogen and water fluxes and quantifying ecosystem feedbacks remains one of the major challenges in ecosystem research. The Karlsruhe Institute of Technology has addressed this challenge by translocating intact soil cores or lysimeters of reasonable size (diameter 1.12 m, depth 1.2 m) - taken from grassland ecosystems - along a temperature and rainfall gradient in the Ammer catchment, Bavaria, Germany. Fluxes of water, heat, nutrients and gaseous emissions will be followed over a period of about 10 years, allowing an assessment of how grassland ecosystems respond to different climate change scenarios.

However, using lysimeters for climate change studies results in problems of discontinuity. When soil cores are taken from the field thesoil is disconnected at the base and the sides. Consequently, boundary conditions, relating to soil water and heat exchange, are disturbed, especially those at the lower boundary condition. In recent years the use of suction cups together with reference tensiometers in nearby undisturbed soil - have significantly improved simulations of the lower boundary condition and associated soil water fluxes. Implementing this approach now provides an opportunity to obtain realistic simulations of vertical soil water transport and associated leaching of nutrients. This is at least true for soil lysimeters taken from sites were lateral water transport is of minor importance. However, the heat transfer problem, created by enclosing the soil in a lysimeter apparatus and disconnecting it from it's environment has not been yet been overcome. Within ExpeER we experimented with radiation reflection shields at the lysimeter top rim, insulation of the lysimeter body and heat transfer device (water bath) at the bottom of the lysimeter (see picture).

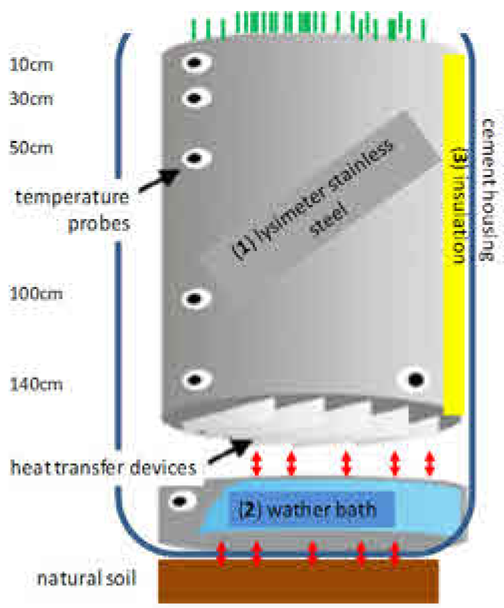
For the topsoil (first 10 cm) temperature differences between lysimeter grassland soils and adjacent grassland soils could be up to 4°C in summer, with heat effects diminishing towards the center of the lysimeter. This indicates that reflection shields at the top rim were not effective and that the exposure of the stainless steel lysimeter rim should be avoided, *e.g.* by inserting lysimeters in a homogenous landuse such as grassland. Insulation of the main lysimeter body did not improve the heat transfer problem. However, fixing a metal plate to the bottom of the lysimeter and dipping it into a water bath, diminished the heat transfer problem for the lower boundary condition significantly.

Experiments are still on-going, but findings have already resulted in a new lysimeter design for global change studies.

Authors

Ralf Kiese &
Klaus Butterbach-Bahl

Pictures



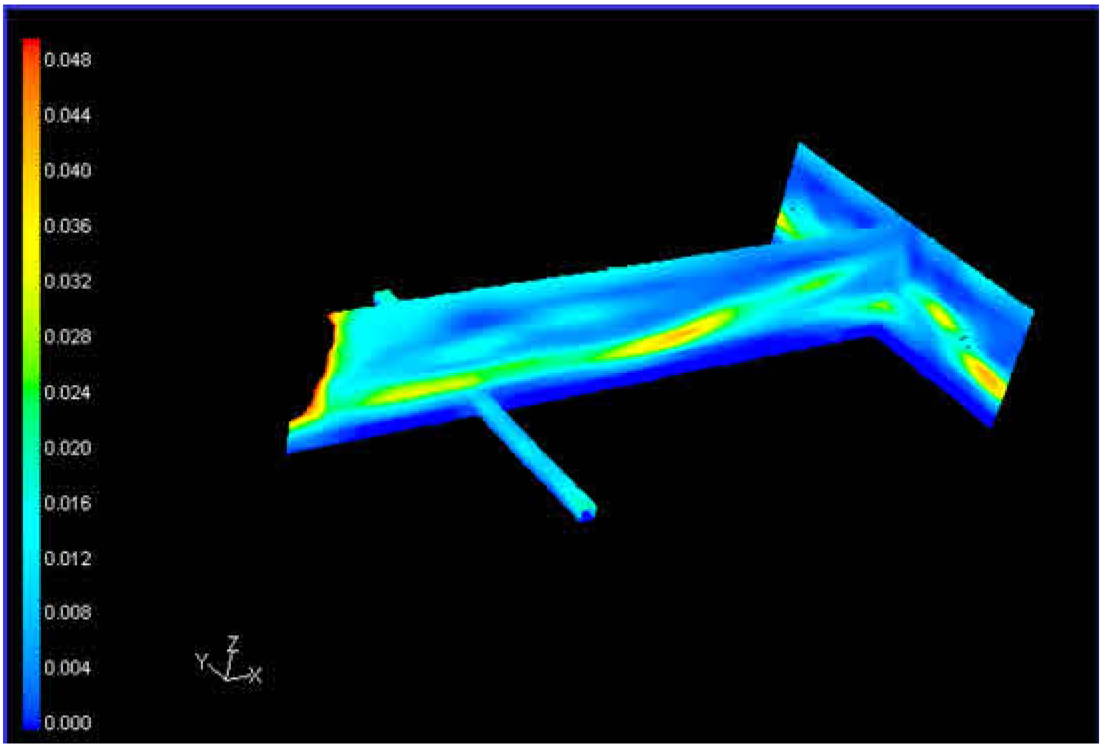
1 Scheme of the experimental lysimeters tested in three configurations: (1) the stainless steel lysimeter alone, (2) with a water bath to control the bottom temperature and (3) with a side insulation to limit horizontal heat exchange.

2 TERENO Fendt experimental site with an robot system to measure soil N_2O, CH_4 and CO_2 emissions. Here the rim of the lysimeter is protected against the heat load of the incident radiations. ©Ralf Kiese, KIT, IMK-IFU

CO_2 INJECTION IN FACE SYSTEMS

The ExpeER Project enabled the testing of a novel FACE system based on improved technology for the control of atmospheric CO_2 concentration in an otherwise undisturbed, open environment. The concept of FACE (Free Air CO_2 Enrichment) is to expose plants growing in the field to the levels of atmospheric CO_2 concentration that are expected in the near future. The technology is not entirely novel, but thanks to ExpeER, major improvements and simplifications have been made in the apparatus required to control the release of pure-CO_2 from an array of horizontal pipes equipped with a series of tiny nozzles. The pressure created by the CO_2 inside the pipes enables the creation of a so called shockwave effect when the CO_2 is vented out of the jets. The speed of the gas at the releasing points easily reaches sonic velocity and this favors a rapid mixture between the CO_2 vented and the surrounding air. In this way, a few centimeters distance from the jets, the atmospheric concentration of CO_2 is brought down to a few thousand parts per million. And from that point onwards, atmospheric turbulence causes further dilution. The possibility to maintain reasonably constant levels of CO_2 concentrations in the vicinity of the plants finally depends on the capability of the FACE system to modify the fraction of CO_2 released by adjusting the pressure inside the pipes, as a function of wind speed and turbulence using a classical PID algorithm (Proportional-Integral-Differential).

Author
Franco Miglietta



Pictures

1 Views of the FACE prototype used by ExpeER to upgrade and improve the infrastructure. Fiorenzuola d'Arda, Piacenza, Italy.

2 An example of gas dispersion simulations made using a CFD (Computational Fluid Dynamics) approach. The simulations enable us to predict how the CO_2 released by the FACE array is distributed over the experimental plots, depending on the forcing variables.

TRADEOFFS BETWEEN REPLICABILITY AND REPRODUCIBILITY IN MICROCOSM MODEL SYSTEMS

In ecology, experimental approaches involving simplified ecosystem models (microcosms/ pots) are often use to inform global ecological problems. Despite oversimplification of ecological complexity, microcosms are used due to ease of replication, accurate control of environmental variables and precise manipulation of the parameters under investigation. A high standardization of biotic and abiotic parameters is sought to make the experiments more replicable (*i.e.* to produce the same results in identical conditions).

Several recent studies however, are now pointing out that thorough standardization, typically assumed to increase the statistical power and replicability, might be responsible for generating results only valid for the narrow conditions of the experiment (local truth) and are lacking external validity (reproducibility). The emerging hypothesis is that the reproducibility crisis is caused by exaggerated and oversimplified standardization within laboratories which removes the sources of biological and environmental variations which would enlarge the external validity of experiments.

In ecological research, the fact that many processes are context dependent (changing through time and space) has often been put forward as an excuse to not repeat experiments. The idea of adding systematic and controlled variation/heterogeneity in studies with ecological systems is in stark contrast to the usual microcosm approach. To date, we have no quantification of the extent to which standardization can reduce the reproducibility of microcosm findings. While there are trade-offs between replicability and reproducibility (see Picture 1), we are lacking knowledge of how much controlled systematic heterogenization is necessary to increase the external validity of ecological microcosm experiments.

To address this knowledge gap we repeated the same experiment in twelve European laboratories to (1) test the overarching hypothesis that the reproducibility of results between laboratories increases when controlled systematic heterogenization (both biological and environmental) is incorporated in the experiment and (2) to analyze which level of heterogenization (biological and/or environmental) is needed to achieve a detectable increase of reproducibility.

The experiment aimed at quantifying the well-known legume-grass facilitation effect by comparing communities of the model species *Brachypodium distachyon* (grass) and *Medicago truncatula* (legume). The following two treatments were established:

(1) *B. distachyon* with or without *M. truncatula* in microcosms (2 levels) crossed with (2) a controlled systematic variation of heterogeneity (6 levels of heterogeneity). The introduced heterogeneity was within or between pots and concerned the abiotic environment (more or less patches of sand in the soil, see picture 2) and the biotic material (one to three lines/varieties for each of the two plant species).

The measured response variables included biomass production, leaf nitrogen content, evapotranspiration, litter decomposition and the expression of genes related to nitrate transport in *B. distachyon* roots. Results are currently being analyzed.

Authors

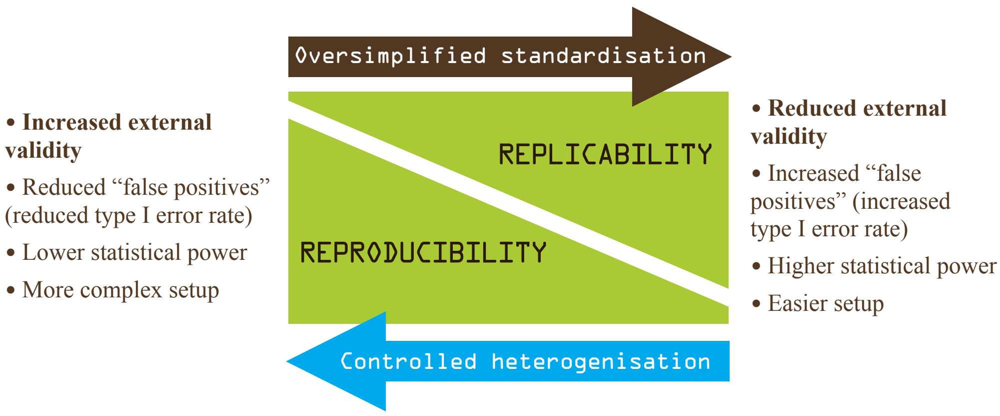
Alexandru Milcu
& Jacques Roy

Pictures

1 Trade-offs between replicability and reproducibility.

2 Cross section of a pot showing one patch of sand. There were treatments with 0, 3 or 6 such patches per pot.

TRADE-OFFS BETWEEN REPLICABILITY AND REPRODUCIBILITY



DEVELOPING ECOSYSTEM MODELS AND A MODELLING TOOLBOX

Author

Klaus Steenberg Larsen

A modelling workspace (the "Modelling Toolbox") has been developed within ExpeER to provide easier access to simulation and evaluation tools, allowing users to test hypotheses, extrapolate outputs, and visualise and understand results arising from their ecosystem experiments. The Toolbox is constructed around three whole-ecosystem models, which can be used to simulate ecosystem functioning and processes in response to experimental manipulation of forcing functions ranging from climate variables to land use management practices. These models (COUP, LPJ-GUESS and JULES) were selected to cover a range of spatial scales and process detail in their simulated outputs (Table).

The Modelling Toolbox itself is web-based and offers a menu-driven series of options to access information about each of the three models and guidance on how to download or access executable versions and standard parameter sets for each of the models. Toolbox users can access guidelines and information to aid in selecting and implementing an appropriate model (or models) to examine questions or applications relevant to a particular experimental site. The Toolbox provides example outputs consisting of simulation results and intra-model comparisons for a series of applications using all three models to simulate ecosystem responses: (1) to experimental manipulations at five selected ExpeER sites; and (2) to climate change scenarios along North-South and East-West transects in Europe.

As part of the Modelling Toolbox, model applications were performed for all ExpeER sites using a set of standard parameters from globally available databases. These standard parameter sets were derived at the scale of the European transects study and provide for an easy first application of each model for any ExpeER site. The standard parameter sets have been applied to each of the sites with each of the models and the simulation results are available from the Toolbox homepage. The standard parameters can be accessed by contacting the model communities directly (links provided at the Modelling Toolbox homepage).

The Modelling Toolbox offers a user-friendly environment to assist users with the development of simulation capabilities for their site. For example, as a tutorial for modelling at any ExpeER site, a user can be guided to download the appropriate model, run initial applications for the site, and compare the results to the outputs available in the Toolbox. Comparing across the models at a site and utilizing the Toolbox's guidelines for each model, the user can then identify the refinements to the standard parameter sets that would be needed to fine-tune the preliminary parameters sets for the site, thus improving the utility of the models for examining questions related to that particular site.

Table

Summary of whole-ecosystem models in the WP9 Modelling Toolbox.

	COUP	LPJ-GUESS	JULES
PURPOSE/ FEATURES	Quantification of basic hydrological and biological processes in the soil-plant-atmosphere system. The model simulates soil water and heat processes in many types of soils.	Dynamic global vegetation model for simulation of interactions between climate, atmospheric burdens of trace gases and vegetation, biogeochemical cycles and trace gas exchange.	Process-based model that simulates the fluxes of carbon, water, energy and momentum between the land surface and the atmosphere.
SCALE/ SPATIAL UNIT	Spatial resolution: plot. However model can be run in distributed mode representing any region.	10 minutes (Europe) or 0.5 degree (globe). May also be applied at stand or plot scale.	Typically 1km for the UK or 0.5 degree (globe) but may also be applied at stand or plot scale.

Using the Modelling Toolbox

The Modelling Toolbox offers user selectable details about the models available, giving summaries of the characteristics and specific features of each model. The Toolbox offers assistance in model selection which provides considerations to take into account and guidance documents for each model. The Toolbox maintains a library of past simulations that can be accessed as exemplars and/or tutorials in the application of each model. A video tutorial is available for users, which describe how to use the Toolbox. Guests can access the website and browse the features available. Other video tutorials are available at the model homepages, *e.g.* for the CoupModel*. Selected output from gridded applications of all three models using global datasets are available in the Toolbox for North-South and East-West transects across Europe including all grid elements containing ExpeER sites (pictures). In addition, five ExpeER sites have been modelled using all three models and local detailed site data as exemplars of how the Toolbox can be applied to other ExpeER sites. The Modelling Toolbox is available at: **http://michaelmi.nateko.lu.se/**

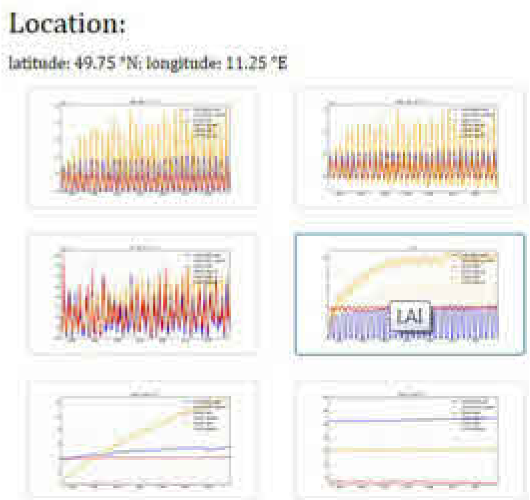
Ex. of Toolbox as a resource for projects at ExpeER sites

The Modelling Toolbox has been used as a resource in a project examining differences in water balance between grassland and forest watersheds using long term data and two different models. The project "Water balance in grassland and forest watersheds" was carried out as part of ExpeER: https://www.kth.se/en/abe/inst/2.12732/grupper/biogeofysik/research/water-balance-1.507367

The site in this study is the Plynlimon ExpeER site in the UK. The models used are the Coup Model (in the Toolbox) and HBV (an external hydrological model not currently supported on the Toolbox). This application serves as an exemplar for the synergies between the ExpeER network and externals research interests that can be stimulated and developed using the Modelling Toolbox.

Note

*www.coupmodel.com



Pictures

1 Toolbox webpage showing gridded transect applications of the three models available in the Toolbox.

2 Toolbox webpage showing gridded ExpeER site applications of three models available in the Toolbox.

UPSCALING ECOSYSTEM FLUXES AND STOCKS BY DATA ASSIMILATION

Authors

Natasha McBean
& Philippe Peylin

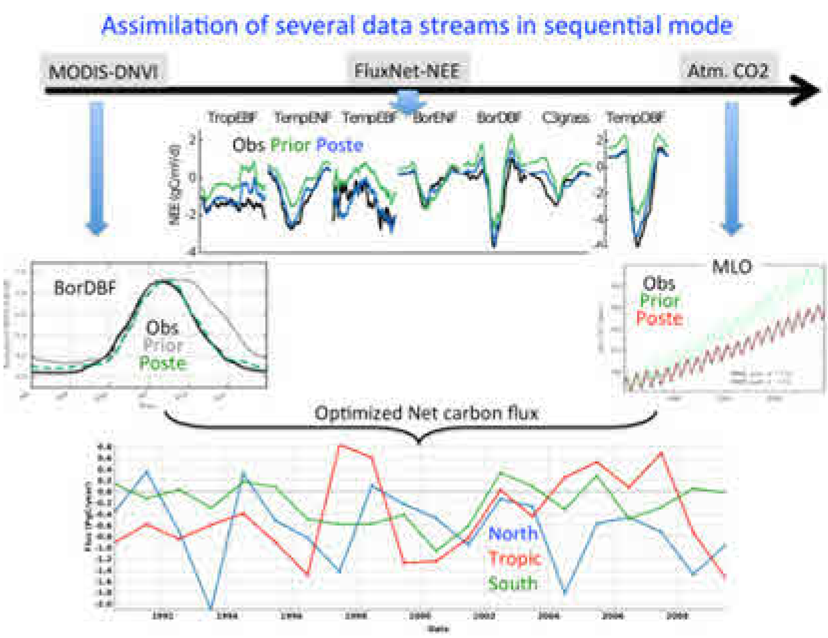
A data assimilation system to upscale ecosystem carbon and water fluxes as well as ecosystem carbon stocks has been developed at LSCE, based on the ORCHIDEE land surface model. The system allows optimizing the main parameters of the ORCHIDEE model controlling the transfer of carbon, water and energy in the soil-plant-atmosphere continuum, using various data sources (*e.g. in situ* flux measurements, satellite products, atmospheric CO_2 measurements, carbon inventory data, *etc.*). The aim of the assimilation procedure is to minimize a misfit function that measures the mismatch between (1) the model outputs and the various data streams, and (2) a priori knowledge of the parameter values, taking into account uncertainty of both components in a statistically robust framework. In this way, we combine our current understanding of the system (models) with the most up-to-date, detailed process information (observations), in order to provide the best estimate of the variables being studied. Given this information, the ORCHIDEE Data Assimilation Systems allow the derivation of optimized posterior model parameter values and uncertainties. These uncertainties can be propagated through to any model state variable.

Once the model has been calibrated with in-situ or satellite data at given sites the optimized model can be run at larger spatial scale and for future condition, to provide up-scaled carbon and water budgets. The optimized ORCHIDEE model will ultimately be used to diagnose the response of the terrestrial biosphere to climate, management and land use changes.

Several applications have been performed within many projects including ExpeER. The picture provides an example with the assimilation of MODIS-NDVI data, FluxNet measurements at more than 70 sites and atmospheric CO_2 concentrations at 70 stations. The optimized ORCHIDEE model can then be used to estimate the net carbon fluxes between the atmosphere and the ecosystems. For instance, the North (> 30°N), Tropic, and South (< 30°S) mean C fluxes indicate a similar mean C sink between the tropical and the temperate/northern ecosystems, with significant year to year variations.

Within ExpeER, a first attempt was made to assimilate the observations from manipulative experiments such as those conducted at Brandbjerg, a shrubland site in Denmark (drought, warming and CO_2 fertilization experiments). The optimization is crucial to reduce current uncertainty in model prediction of the carbon budget of terrestrial ecosystems, in particular under future climate changes.

More information on the system design and the contributors as well as on the results obtained with the optimization of ORCHIDEE can be found under: **http://orchidas.lsce.ipsl.fr/**



Picture

The step-wise ORCHIDEE carbon cycle multi-data streams assimilation system: MODIS-NDVI, FluxNet carbon and water fluxes, and atmospheric CO_2 data are assimilated sequentially in order to optimize key model parameters. Model-data fits are illustrated for each data stream as well as the resulting upscaled carbon fluxes for North, Tropic, and South regions simulated with the optimized model.

ASSESSING PHOTOSYNTHETIC PRODUCTION WITH THE PHOTOCHEMICAL REFLECTANCE INDEX

Ecosystem carbon and water fluxes can be measured from towers installed on top of plant canopies using the so called eddy covariance techniques. However, these measurements are restricted to certain points across the planet where such towers exist (in the order of 400-450) and they are not homogeneously distributed. To understand how carbon balances vary over large landscapes we need different approaches. Satellite images are promising tools to upscale these flux tower measurements to the landscape and regional levels because they provide a continuous coverage across space and time. For example, the MODIS satellites used in this study acquire for each point on the globe about two images every day.

Satellites have been extensively used to estimate the photosynthetic production of terrestrial ecosystems for obvious reasons. When light reaches a plant canopy it can be absorbed by plants and other components or it can be reflected back to the atmosphere. Therefore, the intensity and spectral properties of the reflected light carry information on how much energy has been absorbed by plants. Variations in light absorption across space can then be associated to variations in photosynthetic capacity and carbon fluxes. For example, a satellite pixel corresponding to an arid area will show less greenness compared to a pixel in the middle of a forest, and so photosynthetic capacity and carbon fluxes can be predicted with the help of greenness data, a relationship that is currently exploited by existing global models. However, the relationship is complicated when plants undergo certain stresses, as drought and cold stresses, and especially in evergreen forests. Although evergreen plants remain green throughout the year, their photosynthetic capacity is drastically reduced in response to stress. For example, a green Spruce forest does not present significant levels of photosynthesis during the cold winter months. This is because, under stress, absorbed energy is not used in photosynthesis but harmlessly dissipated as heat in the leaf. To do so, plants use a protective mechanism that involves carotenoid pigments.

Fortunately, these tiny changes in carotenoid pigments are registered in the reflectance spectra and can be measured from remotely sensed data *via* the Photochemical Reflectance Index (PRI), for example using MODIS data.

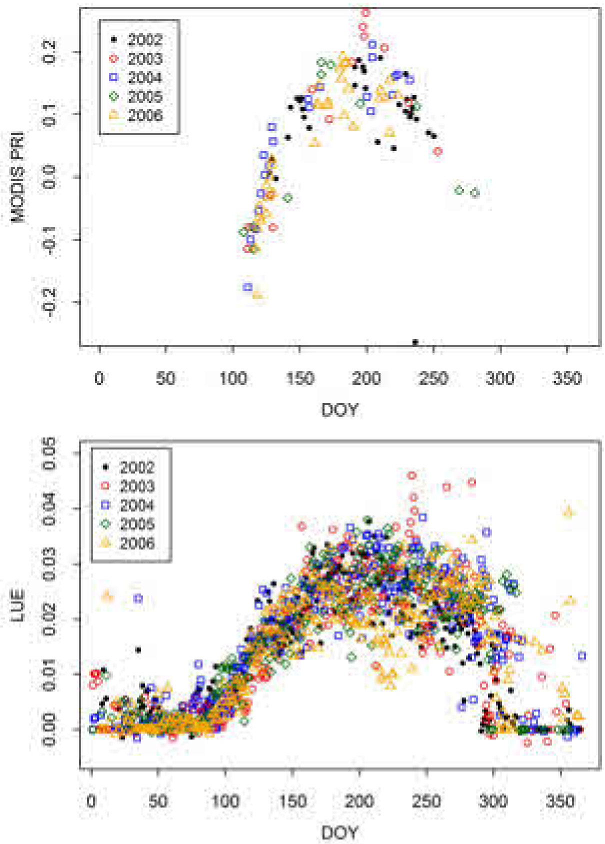
We assessed how PRI and canopy greenness based measurements can be combined to estimate the production of an evergreen Scots pine forest in Hyytiälä Finland. We found that MODIS PRI was well related to the photosynthetic light use efficiency of forests over several years (see picture). However, the relationship presented some inconsistencies: we found a strong relationship between PRI and LUE at the leaf and satellite pixel level, but a weaker relationship when measurements were performed from a tower, suggesting that factors such as sun elevation and sensor view geometry need to be taken into account and properly corrected. Overall, the PRI clearly conveys additional information on top of that presented by greenness indices and we believe it will help to better constrain the photosynthetic production in the globe, especially for ecosystems under cold or drought stress.

Authors

Albert Porcar-Castell,
Nea Kuusinen,
Jaana Back
& Frank Berninger

Picture

(A) The time course of the photochemical reflectance index (unitless) plotted against the day of year (DOY) for different years at Hyytiälä field station. (B) the efficiency of the photosynthesis to convert light into biomass as measured by the Light Use Efficiency (LUE) estimated at low light.

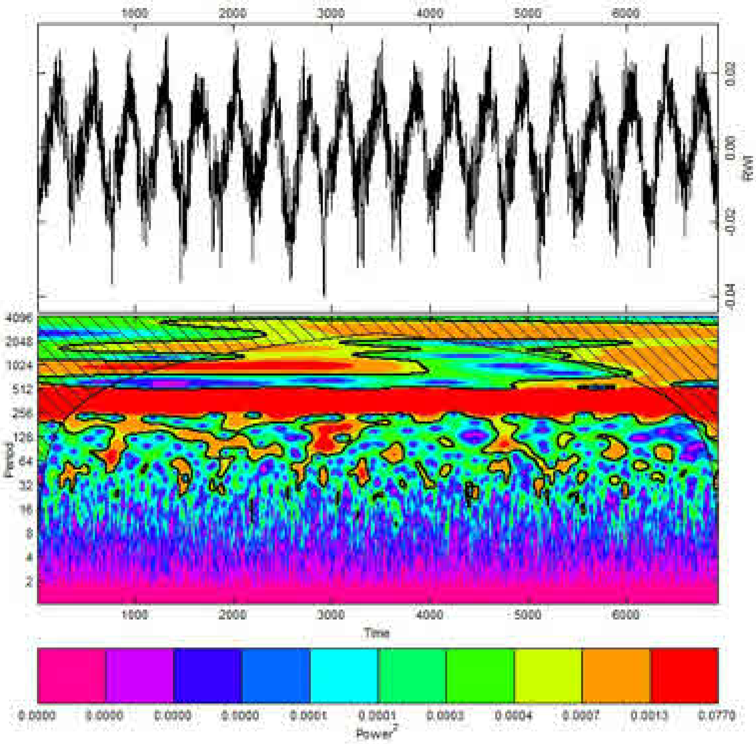


WAVELET ANALYSIS IN CONTEXT OF BIODIVERSITY

Authors

Gudrun Carl
& Ingolf Kühn

ExpeER examined ecological responses to environmental change. Many of these responses are highly scale dependent, as are many environmental variables themselves. In the presence of strong scale-dependence, a linear approach will not be able to extract information on when coupling between an environmental factor and an ecological response occurs. Instead, scale-dependent analyses of coupling between two time series would be needed for a systematic investigation of periods when, *e.g.*, temperature has a potential influence on plant growing. Wavelet analysis has been proved to be a suitable mean to quantify temporal structure as a function of both time and scale, *i.e.* period. A function that describes a multi-scale process can be described using combinations of wavelets. A wavelet is an oscillating function whose amplitude diminishes to zero within a certain time interval. Any function can be produced by a combination of wavelets, which can be visualised to reveal behaviours at the selected time scales; knowledge of the wavelet coefficients gives perfect knowledge of the original function.



Once calculated, the wavelet coefficients are powerful tools for relating environmental change to ecological response. In ExpeER, wavelets are used to relate vegetation phenology to changing weather patterns. In particular, the focus in the study was on the seasonal activities of a temperate deciduous forest in relation to temperature as their main driver. The newly developed method "phase difference analysis" reported here provides a framework for detecting couplings and phase shifts between two series, especially identifying scale-dependent cross-phase coupling of bivariate time series (Carl *et al.* 2013). It allows, in particular, the calculation of scale-dependent decompositions of time series, the calculation of seasonal phases, and the calculation of phase differences between seasonal phases of different time series. The procedure itself includes the following three steps: calculation of (1) scale-dependent decompositions of time series, (2) phase shifts of seasonal components in relation to the annual cycle, and (3) inter-annual phase differences between seasonal phases of different time series.

The model is applied to air temperature data and remote sensing phenology data of a beech forest in Germany. The study revealed that certain seasonal changes in amplitude and phase with respect to the normal annual rhythm of temperature and beech phenology are coupled, time-delayed components, which are characterized by a time shift of about one year (Carl *et al.* 2013).

Picture

Wavelet power spectrum for daily air temperature for a period of 19 years. The upper panel shows the standardized tempera-ture as a function of time (in days). The lower panel displays its power spectrum detecting the annual cycle as dominant period (wide red band).

MODEL DATA FUSION TECHNIQUES TO IMPROVE CLM4.5 CARBON FLUX PREDICTIONS FOR THE RUR-CATCHMENT IN CENTRAL EUROPE

Land surface models such as CLM4.5 are subject to multiple error sources and uncertainties. Besides model structural deficits, also model parameter and initial states are uncertainty sources in these models, leading to considerable uncertainties in the simulated carbon fluxes and pools (Piao *et al.*, Glob Change Biol, 2013; Kuppel *et al.*, Biogeosciences Discuss, 2012). Biogeochemical fluxes and their interactions simulated by LSMs are of high complexity and nonlinearity. Estimating unknown states and parameters of such models requires therefore Monte Carlo (MC) simulation methods. When applying MC methods the model is executed multiple times with different parameter and/or initial state values that are sampled randomly from prior distributions. Model-data fusion methods can help to decrease and quantify uncertainties in model parameters and/or states and enhance the consistency of modeled fluxes and measured data. Model-data fusion methods most commonly used in the past for parameter and/or state estimation of LSMs are sequential data assimilation methods (*e.g.* Kuppel *et al.*, 2012) like Ensemble Kalman Filter (EnKF) or Monte Carlo based parameter estimation methods. To improve the consistency of modeled net ecosystem exchange of CO_2 (NEE) for the central-European Rur-catchment and improve our understanding of model behavior, we applied the DiffeRential Evolution Adaptive Metropolis (DREAM) which is based on the Markov chain Monte Carlo (MCMC) technique. The main focus of our work was on estimating eight carbon flux relevant CLM4.5 parameters with DREAM using measured NEE via eddy covariance (EC).

The DREAM algorithm is a MCMC-based method which can effectively sample high-dimensional and multi-modal target distributions. It is based on Bayesian theorem which formulates how the posterior distribution of states and parameters is obtained from the prior distribution, and given incorporation of new knowledge in the form of measurements. MCMC methods estimate these posterior distributions with a limited number of assumptions, and are also suitable for arbitrary, complex probability density functions like the mentioned multimodal ones. However, needed computation times are extremely high and often prohibitive. Further advantages of DREAM are that it can condition simultaneously to a complete historical time series of measurement data and can generate multiple solutions to the problem, which allows estimating the uncertainty of the calculated parameters and states.

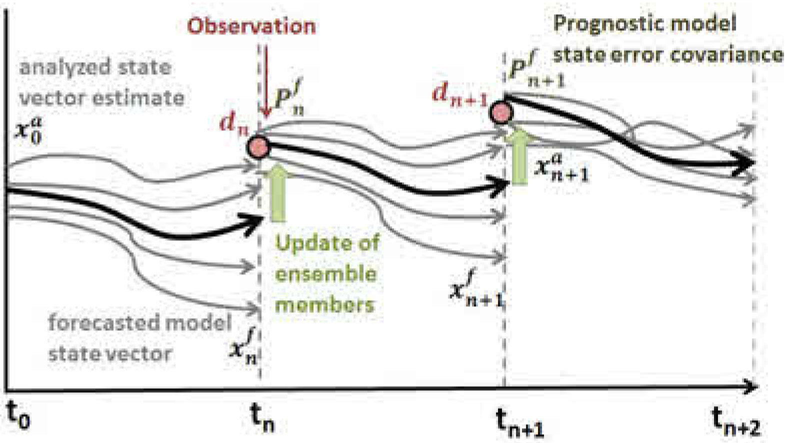
MCMC methods are not efficient for land surface models with many unknown states and parameters. Therefore DREAM is used to estimate parameters and states (and their uncertainty) at a few number of selected sites where many data are available. Next, the ecosystem parameters estimated at those sites are used in the distributed model for those grid cells with the same vegetation type as at the selected sites. Predictions with land surface models can be further improved with sequential data assimilation techniques such as the EnKF. Model predictions are now additionally conditioned to exhaustive information (*e.g.*, LAI), available for all grid cells, from remote sensing.

Authors

Hanna Post,
Harrie-Jan Hendricks Franssen
& Harry Vereecken

Picture

Schematic of the data assimilation procedure with the ensemble Kalman Filter (EnKF).



The picture illustrates exemplary how an EnKF with four ensemble members evolves in time. Starting at time point t_0, the model ensemble (with perturbed initial model states and/or parameters and/or atmospheric input data) evolves in time following different trajectories. The ensemble mean denoted with the black solid line is considered as best estimate. Whenever observation data are available, the forecasted vector of model states (or parameters) is updated. Observations with a high uncertainty will update the model ensemble to a lower extent than observations with a low uncertainty.

TRANSNATIONAL ACCESS PROGRAM

Authors

Cristina Martinez
Alberto Mattedi
& Franco Miglietta

By offering access to 29 state-of-the-art research infrastructures across Europe and joining on-going experiments and measurements, initiating new ones, and using existing databases, the ExpeER call for Transnational Access (TA) proposals provided a unique opportunity for research teams and individuals to access some of Europe's major research infrastructures focused on ecosystem research. The services offered by the TA program went beyond those available at the national scale, thus encouraging greater collaboration amongst Europe's top researchers to fill existing knowledge gaps.

This program was launched in June 2011 and remained continuously open until 31st January, 2015.

The TA program was open to researchers, post-docs, PhD students and technicians from EU-member and Associated countries (see the eligibility criteria).

Proposals could be submitted via the ExpeER website (2-6 months before the intended visit) in a two-step process (see the application procedure): pre-application (short proposal) to check applicant eligibility and project feasibility with the site to be visited, followed by submission of a full application. The TA selection process gave priority to collaborative projects that promoted the transfer and advancement of scientific results, methods and technologies. ExpeER also offered "fast track" transnational access applications to researchers interested in visiting one or more TA sites for a brief period (max. 5 days).

TA users were offered financial support to contribute to subsistence and travel expenses incurred during TA visits. Travel expenses were covered, as well as daily subsistence costs (*i.e.* accommodation and meals; by country specific per diem rates).

At the close of the call, the ExpeER Coordination Team had received 93 full applications, of which 13 were deemed ineligible to receive financial support following review. In addition, 28 "fast track" applications were received, of which 2 did not pass the evaluation stage. In total, 106 TA projects were accepted and took place during the entire time in which the call was open (45 months).

At the launch of the call, the TA network comprised 33 state-of-the-art research infrastructures across Europe. During the course of the project, 4 sites withdrew from the program for varying reasons, thus leaving 29 sites on offer to TA users.

The most visited sites (in terms of number of TA days delivered) were: Höglwald Forest, Germany (6 visits; 205 TA days), Hyytiala, Finland (10 visits; 172 TA days), Montpellier Ecotron, France (9 visits; 158 TA days), and Negev, Israel (12 visits; 156 TA days). Conversely, four TA sites had no applications/visits take place.

A total of 1617 TA days were used, with the average length of TA visits being 15 days, and the average TA user reimbursement was 2570 €. The rate at which TA applications were received grew steadily as the project progressed. In the first twelve months of the call being opened (June 2011 to June 2012), just 14 visits took place (totalling 167 TA days). As the project's visibility grew, so did the number of applications and TA visits, with 32 TA visits (517 TA days) between July 2012 and June 2013, 30 TA visits (525 TA days) between July 2013 and June 2014, and 33 TA visits (408 TA days) between July 2014 and March 2015.

TRANSNATIONAL ACCESS STATISTICS

BETWEEN JUNE 2011 AND JANUARY 2015, **106 PROJECTS WERE ACCEPTED**.

PROJECTS BY ECOSYSTEM TYPE:

FOREST	63%
AGRICULTURE	17%
PEATLAND	11%
GRASSLAND	8%
COAST	1%

AVERAGE GRANT AWARDED: 2570,55€
(Min: 364.95€ - Max: 9702,88€)

AVERAGE DURATION: 15 days
(Min: 2 days - Max: 90 days)

TA VISITORS' AGE:
< 30: 17%
31-50: 58%
> 50: 25%

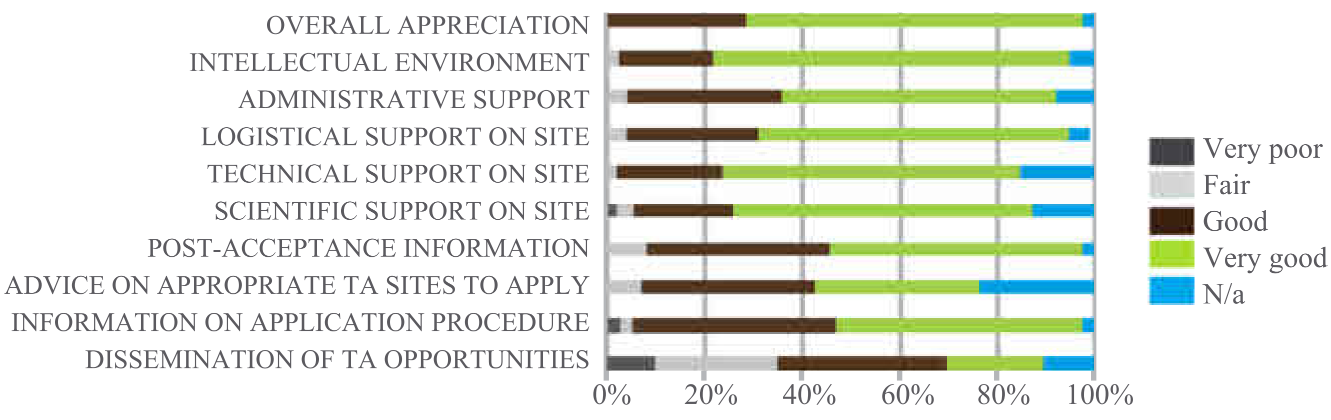
TYPE OF VISITORS' INSTITUTION:
University: 68%
Public research organisation: 31%
Industrial and/or profit private organisation: 1%

TA VISITORS' STATUS:
Experimented researcher: 48%
Post-doctoral: 29%
Post-graduate: 22%
Technician: 1%

TA VISITORS' ORIGIN

GERMANY	15%
SPAIN	10%
ITALY	10%
THE NETHERLANDS	9%
UK	7%
ISRAEL	6%
DENMARK	6%
CZECH REPUBLIC	6%
ESTONIA	5%
AUSTRIA	5%
PORTUGAL	4%
POLAND	4%
FINLAND	4%
BELGIUM	3%
SWITZERLAND	2%
GREECE	2%
TURKEY	1%
ROMANIA	1%
NORWAY	1%
FRANCE	1%
NEW ZEALAND	1%

TA VISITORS' SATISFACTION



LIST OF TA PROJECTS

Note

FT = "fast track" project (maximum 5 days visit)

P = regular project (more than 5 days visits)

SOILS (INCL. SOIL RESPIRATION, ORGANIC MATTER, SOIL C, BIOCHAR...)

FT1 - Carbon and water relations of grassland ecosystems at Park Grass.
TA user: I. Kohler and H. Schnyder (TU Munchen, Germany)
ExpeER TA site: Rothamsted, UK

FT4 - Relationship between soil biodiversity and soil functioning and the effect of soil management.
TA user: J. Faber *et al.* (Alterra, Wageningen, The Netherlands)
ExpeER TA site: Lusignan, France

FT14 - Impact of CO_2 fixation by phosphoenolpyruvate carboxylase (PEPc) on carbon isotope composition of root-respired CO_2 in a C3 plant.
TA user: F Badeck (CRA - GPG, Italy)
ExpeER TA site: Montpellier ECOTRON, France

FT17 - Oxygen as missing link to respiratory quotient: measurement tests in the ECOTRON large scale lysimeters.
TA user: M. Kazda (Ulm University, Germany)
ExpeER TA site: Montpellier ECOTRON, France

FT18 - Distribution of soil organic matter in deep soil layers under maize cultivation.
TA user: T. Lehtinen (Austrian Agency for Health and Food Safety (AGES), Austria)
ExpeER TA site: Tetto Frati, Italy

FT25 - Identification of soil organic carbon thresholds for sustained soil functions in agroecosystems.
TA user: L. Munkholm (Aarhus University, Denmark)
ExpeER TA site: Rothamsted, UK

P1 - Extremes event effects on grassland soil respiration.
TA user: A. Augusti (CNR-IBAF, Italy)
ExpeER TA site: Montpellier ECOTRON, France

P5 - Detection of shoot/root markers in SOM after land use change.
TA user: C. Arbelo-Rodriguez (University of La Laguna, Spain)
ExpeER TA site: Biogeochemistry Lab, France

P10 - Characterisation of organo-mineral associations in soil by NanoSIMS.
TA user: T. Rennert (TU Munchen, Germany)
ExpeER TA site: Moor House, UK

P15 - Carbon and water relations of grassland on the Park Grass Experiment.
TA user: H. Schnyder (TU Munchen, Germany)
ExpeER TA site: Rothamsted, UK

P16 - Response of fine roots to soil warming.
TA user: W. Borken (University of Bayreuth, Germany)
ExpeER TA site: Achenkirch, Austria

P18 - Linking soil organic carbon pools with measured fractions.
TA user: M. Herbst (IBG-3 Agrosphere, Jülich, Germany)
ExpeER TA site: Rothamsted, UK

P20 - Determination of the biological soil quality of biochar fields.
TA user: N. Ameloot (Ghent University, Belgium)
ExpeER TA site: Beano, Italy

P36 - Measuring and modelling soil CO_2 concentrations, production and diffusion.
TA user: M. Herndl (AREC Raumberg-Gumpenstein, Austria)
ExpeER TA site: Hyytiala, Finland / Hesse, France

P41 - Response of nitrogen turnover to soil warming.
TA user: W. Borken (University of Bayreuth, Germany)
ExpeER TA site: Achenkirch, Austria

P49 - Tillage operations and soil movement: Implications for long-term experiments.
TA user: K. Van Oost (Earth & Life Institute/UCL, Belgium)
ExpeER TA site: Rothamsted, UK

P53 - Coupled biochar-soil changes under continuous cultivation.
TA user: E. Graber (Volcani Center, ARO, Israel)
ExpeER TA site: Beano, Italy

P60 Ectomycorrhizal short-root acclimation to soil warming.
TA user: I. Ostonen (University of Tartu, Estonia)
ExpeER TA site: Achenkirch, Austria

P65 - Soil organic carbon changes under different forest regimes.
TA user: T. Chiti (University of Tuscia, Italy)
ExpeER TA site: Höglwald Forest, Germany

P66 - Changes in soil enzyme activity and microbial DNA pool as a result of biochar.
TA user: A. Jaiswal (Dept of Plant Pathology, ARO, Israel)
ExpeER TA site: Beano, Italy

P67 - Microclimate *versus* plant effects on relationships between soil CO_2 concentrations and efflux.
TA user: D. Reinthaler (Institute of Ecology, University of Innsbruck, Austria)
ExpeER TA site: Montpellier ECOTRON, France

P78 - Impact of agricultural practices on SOM stabilisation on a molecular level.
TA user: M. Panettieri (IRNAS-CSIC Spain)
ExpeER TA site: Biogeochemistry Lab, France / Lusignan, France

P85 - Contribution of belowground biomass carbon to stable soil organic matter pool.
TA user: A. Vanderhasselt (Ghent University, Belgium)
ExpeER TA site: Tetto Frati, Italy

P89 - Oxygen as missing link to respiratory quotient: measurement tests in the ECOTRON large scale lysimeters.
TA user: M. Kazda (Ulm University, Germany)
ExpeER TA site: Montpellier ECOTRON, France

P90 - Phosphoenolpyruvate carboxylase (PEPc) and d13C of root-respired CO_2.
TA user: F. Badeck (CRA - GPG, Italy)
ExpeER TA site: Montpellier ECOTRON, France

P93 - C and N dynamics in an amended soil-plant system.
TA user: M. Bustamante Muñoz (Miguel Hernández University, Spain)
ExpeER TA site: Biogeochemistry Lab, France

LAND USE/LAND USE CHANGE/CLIMATE CHANGE (INCL. ECOSYSTEM SERVICE...)

P2 - Land use and land use change Beano.
TA user: C. Pöplau (vTI, Germany)
ExpeER TA site: Beano, Italy

P42 - Better animal farming.
TA user: M. Bleken (Norwegian University of Life Sciences, Norway)
ExpeER TA site: Tetto Frati, Italy

P46 - Effect of the clean development mechanism on dryland afforestation.
TA user: H. Rueff (Oxford University, UK)
ExpeER TA site: Negev, Israel

P56 - Shrub-tree interactions in peat bogs.
TA user: J. Limpens (Wageningen University, The Netherlands)
ExpeER TA site: Hyytiala, Finland

P75 - Ecosystem service and dis-service analysis of rain fed and runoff harvesting afforestation.
TA user: J. Dick (Natural Environment Research Council, CEH Edinburgh, UK)
ExpeER TA site: Negev, Israel

P76 - Forest re-initiation.
TA user: R. Bace (Czech University of Life Sciences Prague, Czech Republic)
ExpeER TA site: Tatra Windstorm, Slovakia

P79 - Spatiotemporal vegetation signals of global change.
TA user: P. Rodriguez-Gonzalez (Universidade de Lisboa, Portugal)
ExpeER TA site: Donana, Spain

REMOTE SENSING (INCL. REFLECTANCE, PRI, HYPERSPECTRAL, UAV...)

FT13 - Changes in leaf inclination angle distribution with height for European deciduous broadleaf tree species.
TA user: J. Pisek (Tartu Observatory, Toravere, Estonia)
ExpeER TA site: Hesse, France

FT19 - Mapping forest background reflectance in an arid region using multi-angle remote sensing data.
TA user: J. Pisek (Tartu Observatory, Toravere, Estonia)
ExpeER TA site: Negev, Israel

P7 - Remote sensing of surface fluxes.
TA user: M. Garcia (University of Copenhagen, Denmark)
ExpeER TA site: Donana, Spain

P19 - Phenological and primary production studies by remote sensing.
TA user: C. Glässer (Martin Luther University, Germany)
ExpeER TA site: Negev, Israel

P23 - Remote sensing of forest canopy cover in the Negev LTER with RapidEye.
TA user: I. Ozdemir (Suleyman Demirel University, Turkey)
ExpeER TA site: Negev, Israel

P24 - Ground and space measurements and modeling of soil albedo.
TA user: J. Cierniewski (Adam Mickiwicz University, Poznan, Poland)
ExpeER TA site: Negev, Israel

P27 - Exploration of relationship between vegetation-soil parameters and hyperspectral data.
TA user: C. Salbach (Helmholtz Centre Potsdam GFZ, Germany)
ExpeER TA site: Negev, Israel

P29 - Scintillometry under advective conditions in a semi-arid ecosystem.
TA user: H. de Bruin (Emeritus Wageningen University, The Netherlands)
ExpeER TA site: Negev, Israel

P30 - Assessing ecosystem function by soil quality with hyperspectral remote sensing.
TA user: T. Paz-kagan (Ben-Gurion University, Israel)
ExpeER TA site: Harz/Central German Lowland, Germany

P45 - Surface fluxes in semi arid environment.
TA user: E. Ceschia (CESBIO, France)
ExpeER TA site: Negev, Israel

P58 - Unmanned aerial vehicles (UAV) for grassland and crop monitoring.
TA user: S. Von Bueren (Massey University, New Zealand)
ExpeER TA site: Eifel, Germany

P62 - Radiative properties of organic-rich soils at the microwave L-band.
TA user: S. Bircher (Copenhagen University, Denmark)
ExpeER TA site: Eifel, Germany

P70 - Using the photochemical reflectance index (PRI) as proxy of seasonal variation in biogenic volatile organic compounds (VOCs) emission capacity.
TA user: J. Penuelas (CREAF/Universitat Autonoma de Barcelona, Spain)
ExpeER TA site: Hyytiala, Finland

P86 - Prior spectral knowledge for ecosystem service monitoring and understanding.
TA user: A. Baraldi (Universita' degli Studi di Napoli Federico II, Italy)
ExpeER TA site: Negev, Israel

NITROGEN (INCL. DEPOSITION, GAS EMISSIONS...)

FT5 - Effects of long term addition of reduced and oxidised nitrogen on dinitrogen fixation and uptake of phosphorus and potassium by Sphagnum - microbe associations in peatlands.
TA user: E. van den Elzen (Radboud University Nijmegen, the Netherlands)
ExpeER TA site: Whim, UK

FT6 - Effects of long term addition of reduced and oxidised nitrogen on the amino acid composition and nitrogen assimilation of *Sphagnum capillifolium* at Whim bog.
TA user: L. van den Berg (Radboud University Nijmegen, the Netherlands)
ExpeER TA site: Whim, UK

FT9 - The relation between physiological responses of *Sphagnum capillifolium* and nitrogen losses to the ground water due to elevated atmospheric nitrogen deposition.
TA user: L. van den Berg (Radboud University Nijmegen, the Netherlands)
ExpeER TA site: Whim, UK

FT10 - Nitrogen cycling in a peat land: the effect of different forms and loads of nitrogen deposition on N_2, NO and N_2O losses to the atmosphere.
TA user: E. van den Elzen (Radboud University Nijmegen, the Netherlands)
ExpeER TA site: Whim, UK

P11 - Long-term effects of Nitrogen deposition in lichen ecophysiology.
TA user: S. Munzi (University of Lisbon, Portugal)
ExpeER TA site: Whim, UK

P26 - Nitrogen gas emissions from contrasting soil environments.
TA user: J. Christiansen (CENPERM, University of Copenhagen, Denmark)
ExpeER TA site: Klausenleopoldsdorf, Austria

P39 - Examining cellular and enzymatic activity and proteomics in nitrogen-treated lichens.
TA user: S. Munzi (University of Lisbon, Portugal)
ExpeER TA site: Whim, UK

P43 - Gaseous nitrogen loss from biological soil crusts in deserts.
TA user: B. Weber (University of Kaiserslautern, Germany)
ExpeER TA site: Negev, Israel

P48 - Effects of residue management on NH_3 losses in multi-plot trial.
TA user: A. Pacholski (Kiel University, Germany)
ExpeER TA site: Tetto Frati, Italy

P52 - Inter- and intra-specific differences in decomposition of *Sphagnum* litter under exposure to reactive nitrogen compounds.
TA user: S. Manninen (University of Helsinki, Finland)
ExpeER TA site: Whim, UK

P64 - Wintertime emission of nitric oxide from soil.
TA user: U. Skiba (Natural Environment Research Council, CEH Edinburgh, UK)
ExpeER TA site: Höglwald Forest, Germany

P77 - Relationships between soil N_2O and NO emission under freeze-thawing events.
TA user: U. Skiba (Natural Environment Research Council, CEH Edinburgh, UK)
ExpeER TA site: Höglwald Forest, Germany

P80 - Decomposition of *Sphagnum* litter under exposure to reactive nitrogen compounds.
TA user: S. Manninen (University of Helsinki, Finland)
ExpeER TA site: Whim, UK

P88 - Gradient measurements of NO concentration in soil pore space.
TA user: U. Skiba (Natural Environment Research Council, CEH Edinburgh, UK)
ExpeER TA site: Höglwald Forest, Germany

BIODIVERSITY (INCL. NEMATODES, DIPTERA, BUTTERFLIES, HOVERFLIES, LIZARDS, GODWITS...)

FT11 - Testing the importance of the optimal canopy nitrogen distribution hypothesis for plant diversity effects in the field.
TA user: D. Bachmann (ETH Zurich Institute of Agricultural Sciences, Switzerland)
ExpeER TA site: Jena, Germany

FT24 - Groundwater invertebrate drift at karst springs: a tool for assessing karst biodiversity and community dynamics.
TA user: T. Di Lorenzo (CNR-ISE, Italy)
ExpeER TA site: Zöbelboden, Austria

FT29 - Legacy effects of crop management on pest suppressiveness of soils.
TA user: H. Hokkanen (University of Helsinki, Finland)
ExpeER TA site: Jena, Germany

P3 - Nematodes the molecular way: molecular bar-coding to detect, identify and quantify soil dwelling nematodes.
TA user: G. De Deyn (Wageningen University, Netherlands)
ExpeER TA site: Jena, Germany

P14 - Biodiversity and ecology of forest-associated *Diptera*.
TA user: G. Stahls (Finnish Museum of Natural History/Uni of Helsinki, Finland)
ExpeER TA site: Fruska Gora, Serbia

P28 - *Syrphidae* (*Diptera*) as bioindicators.
TA user: A. Ricarte-Sabater (National Museums Scotland)
ExpeER TA site: Fruska Gora, Serbia

P33 - Improving Doñana's contribution to Butterfly Conservation Europe.
TA user: I. Wynhoff (Museu Granollers / Ciències Naturals, The Netherlands)
ExpeER TA site: Donana, Spain

P34 - Modeling the current and future hoverfly distribution.
TA user: A. Kaloveloni (University of the Aegean, Greece)
ExpeER TA site: Fruska Gora, Serbia

P37 - Impact of summer drought and plant diversity on free-living soil nematodes.
TA user: M. Ciobanu (Inst. of Biological Research, Romania)
ExpeER TA site: Jena, Germany

P54 - Genetic status of eumerus: conservatIon implications.
TA user: A. Chroni (University of the Aegean, Greece)
ExpeER TA site: Fruska Gora, Serbia

P57 - Steps towards the conservation of hoverflies (Dipt.: *Syrphidae*).
TA user: A. Ricarte-Sabater (University of Alicante (CIBIO Research Institute), Spain)
ExpeER TA site: Fruska Gora, Serbia

P61 - LIZARUN: functional and physiological divergence in lizards.
TA user: A. Kaliontzopoulou (CIBIO/InBio, University of Porto, Portugal)
ExpeER TA site: Donana, Spain

P63 - Habitat use by a threatened long-distance migrant the Black-tailed Godwit.
TA user: T. Piersma (University of Groningen, CEES, Germany)
ExpeER TA site: Donana, Spain

P84 - Land use impact on soil quality using soil arthropods in the Negev.
TA user: C. Menta (University of Parma, Italy)
ExpeER TA site: Negev, Israel

HYDROLOGY (INCL. SOIL WATER RETENTION, WATER FLUXES...)

FT15 - 3-D monitoring of simulated rainfall infiltration in natural soils.
TA user: A. Arato (Politecnico di Torino, Italy)
ExpeER TA site: Harz/Central German Lowland, Germany

FT16 - Simulation of water and snow dynamics at the Schäfertal catchment.
TA user: M. Bitelli (University of Bologna, Italy)
ExpeER TA site: Harz/Central German Lowland, Germany

FT23 - Investigating the impacts of deforestation on hydrological and sediment connectivity in the Wüstebach catchment, Germany.
TA user: R. Pöppl (University of Vienna, Austria)
ExpeER TA site: Eifel, Germany

FT27 - Development of a regional hydrological and biogeochemical model.
TA user: A. Hartmann (Institute for Geo- and Environmental Natural Sciences, Germany)
ExpeER TA site: Zöbelboden, Austria

P4 - Water limitation of canopy and understorey in a maritime pine forest.
TA user: T. Rau (UFZ, Germany)
ExpeER TA site: Ecosylve, France

P8 - Hydraulic parameterization for MuSICA.
TA user: T. Klein (The Weizmann Institute of Science, Israel)
ExpeER TA site: Ecosylve, France

P35 - Influence of biodiversity on soil water flow.
TA user: M. Guderle (Friedrich-Schiller-University Jena, Germany)
ExpeER TA site: Montpellier ECOTRON, France

P50 - Hydrological and biogeochemical modeling using LTER data.
TA user: A. Hartmann (Institute for Geo- and Environmental Natural Sciences, Germany)
ExpeER TA site: Zöbelboden, Austria

P59 - Circadian regulation of leaf water fluxes.
TA user: J. Ferrio-Diaz (AGROTECNIO Center, University Lleida, Spain)
ExpeER TA site: Montpellier ECOTRON, France

VOCS (INCL. DEPOSITION, TEMPERATURE, PRESSURE...)

FT2 - Developing the methods for online biogenic volative organic compound (BVOC) measurements from boreal ecosystems.
TA user: M. Portillo-Estrada (Estonian University of Life Sciences, Estonia)
ExpeER TA site: Hyytiala, Finland

FT8 - Biogenic volative organic compound (BVOC) measurements in a boreal forest using PTR-MS.
TA user: D. Materic (The Open University, UK) ExpeER TA site: Hyytiala, Finland

P6 - Exchange of trace gases from polluted and marine air masses with the biosphere at Castelporziano.
TA user: D. Hauser (University of Innsbruck, Austria)
ExpeER TA site: Roma-Lecceto, Italy

P44 - Ecophysiological responses of urban trees to drought condition.
TA user: A. Pryzbysz (Warsaw University of Life Sciences, Poland)
ExpeER TA site: MEL, Bologna, Italy

P51 - Partitioning of ozone deposition into stomatal and non-stomatal sinks.
TA user: J. Muller (University of Manchester, UK)
ExpeER TA site: Roma-Lecceto, Italy

P68 - Effects of salinity on the leaf physiology and VOC emission of two contrasting grapefruit varieties.
TA user: I. Paudel (Agriculture Research Organization, Israel)
ExpeER TA site: MEL, Bologna, Italy

P71 - Response of isoprene emission and photosynthetic apparatus to urban stresses in sweet gum (*Liquidambar styraciflua L.*).
TA user: A. Pryzbysz (Warsaw University of Life Sciences, Poland)
ExpeER TA site: MEL, Bologna, Italy

FLUXES (INCL. CO_2, GREENHOUSE GASES, GAS EMISSIONS...)

FT12 - Carbonyl sulfide (COS) as a new tracer for photosynthesis.
TA user: D. Yakir (Weizmann Institute of Science, Israel)
ExpeER TA site: Hyytiala, Finland

FT21 - Xylem CO_2 fluxes derived from wood respiration in drought-stressed trees.
TA user: R. Salomon-Moreno (UPM, Madrid, Spain)
ExpeER TA site: Puechabon, France

P21 - Fluxes of greenhouse gases from tree stems and the influence of tree species composition.
TA user: A. Rubio (UPM, Madrid, Spain)
ExpeER TA site: Höglwald Forest, Germany

P38 - Nitrous oxide (N_2O) and methane (CH_4) emissions from *Pinus sylvestris* and *Populus tremula*.
TA user: K. Machacova (CzechGlobe - Global Change Research Centre, Czech Republic)
ExpeER TA site: Hyytiala, Finland

P73 - Methane (CH_4) and nitrous oxide (N_2O) emissions from different tree species of boreal upland forest.
TA user: K. Machacova (CzechGlobe - Global Change Research Centre, Czech Republic)
ExpeER TA site: Hyytiala, Finland

P83 - Methane (CH_4) and nitrous oxide (N_2O) emissions from stems of pine, spruce and birchtrees.
TA user: K. Machacova (CzechGlobe - Global Change Research Centre, Czech Republic)
ExpeER TA site: Hyytiala, Finland

P92 - Methane (CH_4) and nitrous oxide (N_2O) fluxes from boreal tree species.
TA user: K. Machacova (CzechGlobe - Global Change Research Centre, Czech Republic)
ExpeER TA site: Hyytiala, Finland

PLANT PHYSIOLOGY (INCL. TREE BIOCHEMISTRY, PLANT METABOLISM...)

FT7 - Vertical profiles of foliage clumping in Mediterranean evergreen forest.
TA user: J. Pisek (Tartu Observatory, Toravere, Estonia)
ExpeER TA site: Roma-Lecceto, Italy

FT20 - Long-term drought manipulation effects on tree biochemistry.
TA user: J. Rodrgiuez-Calcerrada (UPM, Madrid, Spain)
ExpeER TA site: Puechabon, France

FT22 - Genetic variability in tillering response of durum wheat to assimilate availability modulated by PPFD. TILLER.
TA user: F. Rizzi (CRA - GPG, Italy)
ExpeER TA site: Montpellier ECOTRON, France

FT26 - Climate change impact on tree growth.
TA user: P. Bombi (CNR-IBAF, Italy)
ExpeER TA sites : Hesse, France / Achenkirch, Austria / Klausenleopoldsdorf, Austria / Therwil, Switzerland / Hoglwald Forest, Germany / Eifel, Germany

P12 - Spruce seedlings recruitment.
TA user: M. Weiser (Charles University in Prague, Czech Republic)
ExpeER TA site: Tatra Windstorm, Slovakia

P40 - Compost effect on plant metabolism in stress conditions.
TA user: M. Bustamante Muñoz (CEBAS-CSIC, Spain)
ExpeER TA site: MEL, Bologna, Italy

P74 - Holm oak phenology and relationships with acorn production.
TA user: M. Carbonero (Andalusian Institute of Agricultural Research and Training, Spain)
ExpeER TA site: Puechabon, France

P82 - Stable carbon isotopic composition of aquatic plants organic matter in relation to salinity gradient.
TA user: E. Pronin (Adam Mickiewicz University, Pozna, Poland)
ExpeER TA site: Biogeochemistry Lab, France

PUBLICATIONS

Onset of photosynthesis in spring speeds up monoterpene synthesis and leads to emission bursts. Aalto J., Porcar-Castell A., Atherton J., Kolari P., Pohja T., Hari P., Nikinmaa E., Petäjä T. and Bäck J. (2015) **Plant, Cell & Environment** Accepted.

Continuous VOC flux measurements on boreal forest floor. Aaltonen H., Aalto J., Kolari P., Pihlatie M., Pumpanen J., Kulmala M., Nikinmaa E., Vesala T., Bäck J. (2013) **Plant and Soil** 369: 241–256, DOI 10.1007/s11104-012-1553-4.

C mineralization and microbial activity in four biochar field experiments several years after incorporation. Ameloot N., Sleutel S., Case S. D.C., Alberti G., McNamara N. P., Zavalloni C., Vervisch B., Delle Vedove G., De Neve S. (2014). **Soil Biology & Biochemistry** 78 pp. 195-203.

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Spatio-temporal drivers of soil and ecosystem carbon fluxes at field scale in a temperate mountainous grassland in Germany. Borchard N., Schirrmann M., von Hebel C., Schmidt M., Baatz R., Firbank L., Vereecken H. & Herbst M. (2015) **Agriculture, Ecosystems and Environment** 211 84-93

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Effect of grasses and a legume grown in monoculture or mixture on soil organic matter and phosphorus forms. Crème A., Rumpel C., Gastal F., Mora M.-L., Chabbi A. (2016) **Plant and Soil** In press.

Quantification of excess water loss in plant canopies warmed with infrared heating. De Boeck H.J., Kimball B.A., Miglietta F., Nijs I. (2012) **Global Change Biology** 18: 2860–2868.

Leaf temperatures in glasshouses and open-top chambers. De Boeck H. J., De Groote T., Nijs I., (2012b) **New Phytologist** 194(4): 1155-1164

Choices and pitfalls in global change experiments. De Boeck H.J., Vicca S., Roy J., Nijs I., Milcu A., Kreyling J., Jentsch A., Campioli M., Chabbi A., Callaghan T., Beierkuhnlein C, Beier C. (2015) **BioScience.** 65(9), 922-931.

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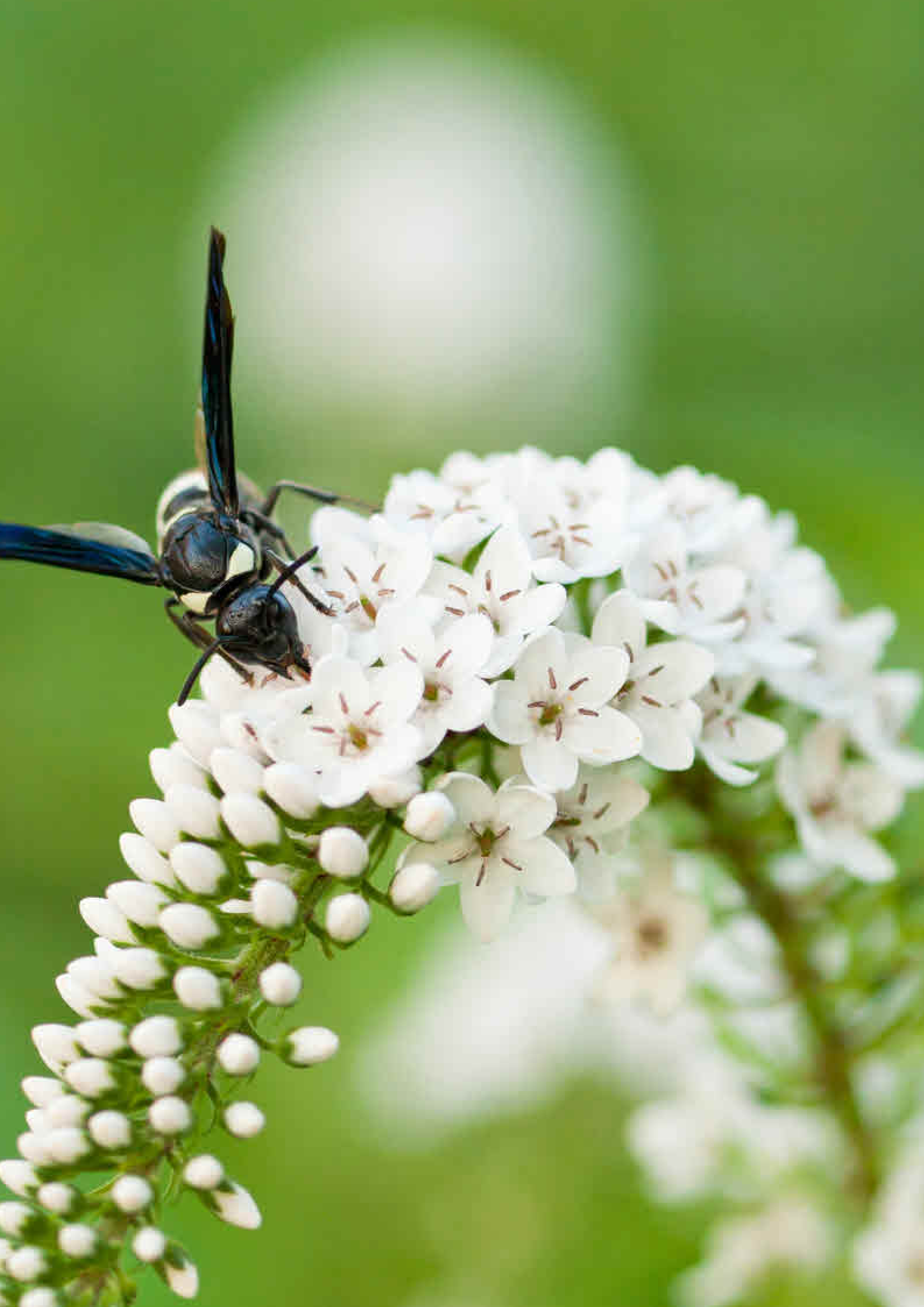


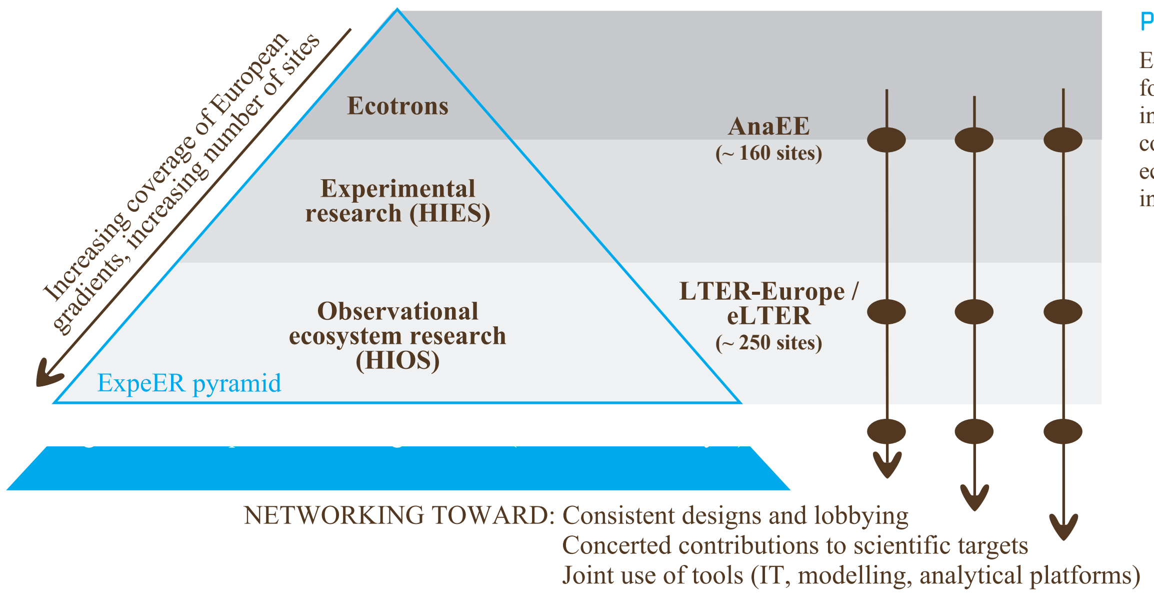
BEYOND ExpeER

There is a need for infrastructures covering observational and experimental ecosystem research. The non-invasive comparative approach consists in observations and monitoring of a large number of ecosystem types and sites in order to capture and analyse the diversity along gradients through statistical analysis and modelling, whereas the experimental approach deals with the manipulation of relevant forcing variables within a restricted number of ecosystem types and sites in order to analyse the cascade of responses at process level and their interactions for understanding modification of ecosystem structures and functions. The comparative approach provides contextual information over large geographical, anthropogenic and ecosystem gradients that allows the come to generalisation and extrapolation of results provided by experimental approach, and also a way for validation and calibration of models. The experimental approach allows the identification of causal relationships. It allows then the prediction of ecosystem development under different scenarios of environmental changes, and also the elaboration of relevant actions for mitigation or remediation.
ExpeER has catalyzed the development and formalization of both approaches at the European scale and contributed to integration efforts (Picture below). The coupling between the experimental and comparative approach was facilitated by the further development of commonly relevant standards and services in the field of standardization and harmonization of parameters and methods, information management, field methods and ecosystem modelling.

Regarding the follow-up of ExpeER and the pursuit of more permanent infrastructures for ecosystem research, substantial progress was made since 2010: The ESFRI preparatory project AnaEE (2013-2016) conceptualizes and implements the experimental approach (See annex A). LTER-Europe streamlines its network and tests cross-site analyses in the Horizon 2020 project "eLTER". An eLTER ESFRI proposal was submitted in March 2015 (see annex B).
Both AnaEE and eLTER are involved in the Horizon2020 environmental research infrastructures cluster project ENVRIplus, which will provide the major framework for developing the "ecosystem and biodiversity domain" in the European research infrastructures landscape. This will be done in close interaction with related infrastructures both in term of collocation of the research infrastructure components (sites, platforms) and in term of setting-up research programs across these infrastructures, providing a consistent infrastructure picture for stakeholders, both nationally and at the European scale.

Authors

Michael Mirtl
& Jacques Roy



Picture

ExpeER paves the way for the European integration of various complementary ecosystem science infrastructures.

AnaEE, ANALYSIS AND EXPERIMENTATION ON ECOSYSTEMS

A EUROPEAN DISTRIBUTED RESEARCH INFRASTRUCTURE (ESFRI PREPARATORY PHASE)

Authors

Jacques Roy, Abad Chabbi and the participants to the AnaEE workpackage "Vision".

Picture

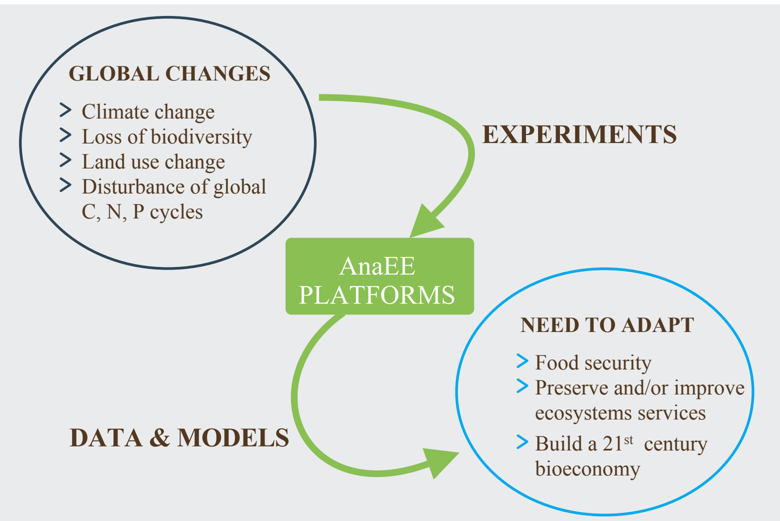
Scheme of AnaEE context and approach.

The vision

AnaEE will be a research infrastructure for experimental manipulation of managed and unmanaged terrestrial and aquatic ecosystems. It will strongly support scientists in their analysis, assessment and forecasting of the impact of climate and other global changes on the services that ecosystems provide to society. AnaEE will support European scientists and policymakers to develop solutions to the challenges of food security and environmental sustainability, with the aim of stimulating the growth of a bio-economy. AnaEE will accomplish this mission by building permanent and substantial links among researchers, science managers, policy makers, public and private sector innovators, and citizens.

The context

The sustainability of agricultural, forested, freshwater and other managed and natural ecosystems is critical for the future of mankind. However, the services provided by these ecosystems are under threat due to climate change, loss of biodiversity, land use changes and disturbance of biogeochemical cycles. In order to meet the challenges of preserving or improving ecosystems services, securing food supply and building a 21st century bio-economy, we need to understand and forecast how ecosystems will respond to current and future changes including new management approaches and potential environmental tipping points. Without sufficient understanding of the sensitive interdependencies between ecosystems and the environment, Europe will be unable to assess the impacts, control the risks, or potentially utilize the benefits of anticipated large changes in ecosystems structure and function. Key benefits will include greenhouse gas mitigation and climate adaptation.



The approach

At the core of AnaEE's approach are the distributed experimental facilities needed to expose ecosystems to future conditions to quantify the role of each of the drivers of change and to identify their interactions. To produce results that will inform predictive models and deliver realistic simulations, AnaEE research has to be process-oriented and will address how major biogeochemical cycles, biodiversity and the relationship between biodiversity and ecosystem functions will change under the various experimental treatments. These platforms, nationally owned, are spread in Europe across various climates and ecosystem types. The *raison d'être* of AnaEE however is to provide added value to stakeholders using these platforms through services best developed and delivered jointly at a supra-national level. These services will be delivered by 3 Centres coordinated by a Central Hub.

The national platforms components

> Experimental *in situ* platforms: These will comprise the predominant land use types of agriculture, forestry and nature, and the interfaces between managed and unmanaged as well as terrestrial and continental aquatic ecosystems transecting Europe's climatic zones.

> Experimental *ex situ* platforms (such as Ecotrons and mesocosms): they will complement *in natura* platforms by enabling higher level of environmental control and process measurement on ecosystems.

> Analytical platforms: will offer advanced biological, physical and chemical analyses for a deeper insight into processesdeeper insight into processes;

> Modelling factories and platforms: the first ones offer the tools to develop, combine and use models. The second ones give access to a variety of models to analyse and synthesise the data from experimental platforms and to make predictions at a range of spatial and temporal scales.

1

AnaEE Supra-National Facilities

They will develop the visibility and optimum international use of the national platforms, improving their technological and experimental capacities and providing services to the platforms owners, the scientists using the platforms, and the stakeholders including industry, policy makers, and education practitioners. The activities of the Hub and Centres will involve both scientists from the national platforms and AnaEE appointed officers.

The coordinating Central Hub with the AnaEE Director will have five main activities: (1) conduct the implementation of AnaEE and its continuous strategic development, (2) conduct AnaEE communication and in particular organising and running the general AnaEE portal, (3) promote quality management, (4) administer the infrastructure.

The Technology Centre will be responsible for (1) setting up Technology Specialists Groups to implement the harmonisation and training on instruments and procedures, (2) organising technology foresight workshops to determine directions for innovative instruments, (3) developing innovative technologies in partnership with private industry, (4) training platforms staff on Technology development, Quality, Industry and Innovation procedures and (5) feeding the AnaEE portal for technology related aspects and coordinating an open technical forum.

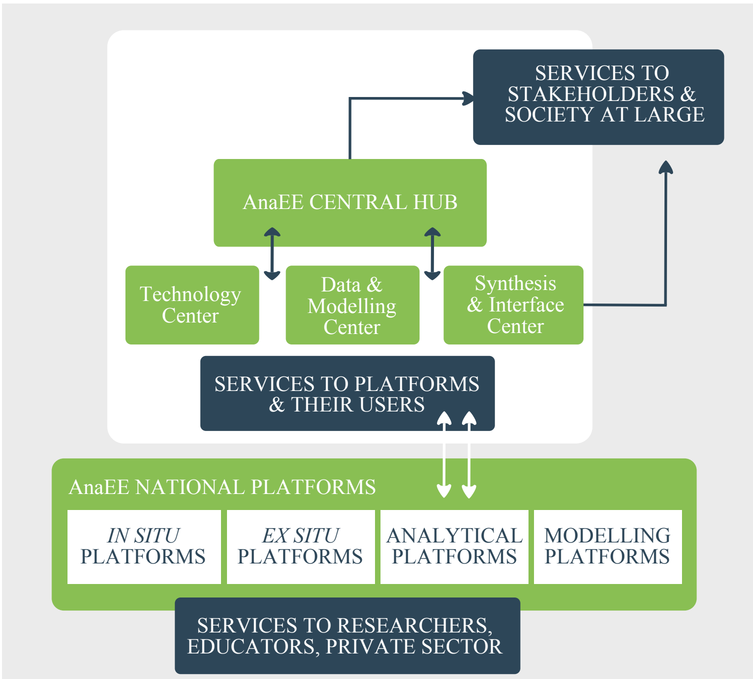
The Data & Modelling Centre will be responsible for (1) harmonizing the national platforms metadata, data and quality check procedures, (2) giving greater visibility and access to AnaEE platforms' data, (3) providing access to a range of ecosystem models, (4) offering tools (model factories) to develop, improve, inter-compare models, (5) facilitating the use of models by non-model developers, (6) feeding the Data & Modelling section of the AnaEE portal (available data sets, models, modelling factories, training…)

The Interface and Synthesis Centre will develop activities upstream and downstream of the experimental activities in the national platforms: (1) scientific and societal prospective to anticipate future ecosystem research areas, (2) project building capacity to gather the best researchers on these research areas, (3) thematic syntheses of ecosystem research, (4) developing summary information products, (5) analysing societal consequences of science results and providing recommendations.

Pictures

1 The four types of AnaEE platforms: *In situ* (1) and *ex situ* (2) experimental ones, analytical (3) and modelling (4) ones.

2 AnaEE overall structure.



2

LTER iN EUROPE INTEGRATED EUROPEAN LONG-TERM ECOSYSTEM, CRITICAL ZONE AND SOCIO-ECOLOGICAL SYSTEM RESEARCH

Author
Michael Mirtl

Mission and role

Ecosystem and biodiversity research are challenged to disentangle processes and their drivers in order to understand the planet or "earth system" in search of answers to the great challenges for humanity like climate change, loss of biodiversity, eutrophication and pollution. Key questions for managing and sustaining ecosystem services in the face of continuing global change are:

> How are ecosystems/biodiversity changing or adapting to global-change stresses?

> What are determinants of ecosystem resilience?

> What are threshold interactions resulting in system shifts?

> How can we respond locally, nationally and at international levels to support systems that are more resilient to global change effects?

LTER represents one of the few research networks worldwide whose infrastructure organization has been considering the long-term character of most processes at multiple scales: 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.

The sites of LTER are designed to cover major European environmental zones and ecosystem types to support "exemplary ecosystem research", exploring mechanisms and structures specific for each zone and ecosystem type.

LTER provides the missing link between large scale environmental monitoring and experimental approaches in the environmental research infrastructures landscape. In addition to natural scientific research in about 250 benchmark ecosystems, LTER includes focal regions for socio-ecological research on human-environment interactions and sustainable use of environmental resources. At all these facilities, LTER research investigates how ecosystem structures and functions are affected by multiple drivers (such as pollution or changes in climate and land use), thereby contributing to the pool of knowledge society urgently needs for identifying proper adaptation and mitigation options.

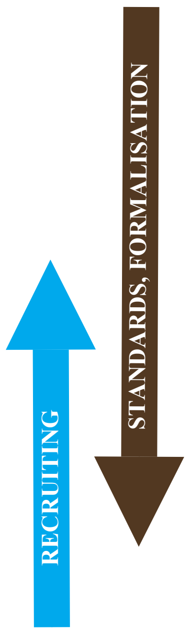
Foundation and process

The foundation of LTER in Europe consists of 25 formal national LTER networks, comprising about 400 LTER Sites (65% terrestrial, 26% aquatic and 9% transitional waters) and 35 LTSER Platforms (case study areas for socio-ecological research on human-environment interactions). About 250 Sites are Regular or Master Sites investigating ecosystems as a whole, amended by 150 less intensive Satellite Sites. This network of networks (LTER-Europe) represents Europe´s contribution to the global LTER network, ILTER. The stable network of institutions, which have been operating LTER sites over decades and the site based long-term

eLTER ESFRI initiative
- 11 initiating countries
- formalizing a core site network
- close interaction with related partner infrastructures

eLTER Horizon2020 project
- 21 LTER countries,
- 28 partner institutions
- 162 data providing sites
- 2015-2019

LTER Europe network
- European contribution to the global LTER network
- 25 countries
- 400 LTER Sites
- 35 Socio-ecological Research Platforms (LTSER)



research teams holding the in-depth system knowledge necessary to efficiently design further research on open questions of highest interest belong to the core assets of LTER.

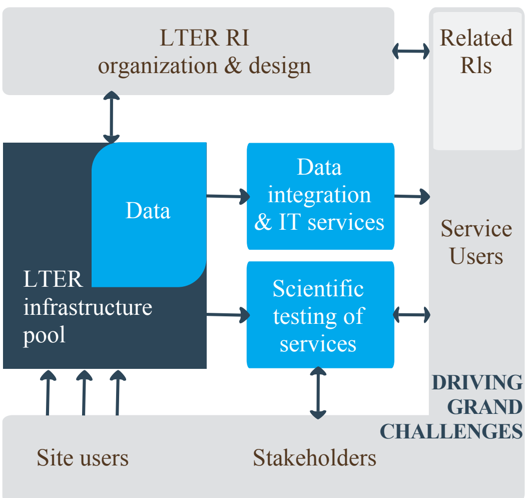
Major projects such as "eLTER H2020" and the eLTER ESFRI initiative capitalize on LTER-Europe. Site infrastructure and country involvements are recruited (bottom up) and - reversely - standards and generic services developed and distributed (top down).

eLTER H2020 flagship project

The overall strategy of eLTER H2020 is to develop research infrastructure services, standards and interactions alongside scientific use cases: eLTER H2020 organizes concerted data delivery of 162 selected LTER sites and offers Transnational Access to 18 top ecosystem research sites across Europe. Four exemplary scientific analyses are carried out with increasing complexity to assess data quality and services:

- comparison of temperature trend data with modelling results;
- coupled impacts of eutrophication and climate on biogeochemical cycles;
- biodiversity trends caused by climate change;
- role of green-blue infrastructures for ecosystem services.

IT architecture and service development are driven by practical requirements of data providing teams (eLTER Service Suite and Data Nodes) and the use cases. eLTER H2020 will detail the design of a future integrated eLTER ESFRI infrastructure well embedded in national, European and global RI landscapes.



eLTER ESFRI initiative: towards a multiple purpose & use research infrastructure

LTER sites have a long-term experience in securing basic infrastructure (power supply, towers, data transmission) and operation (baseline ecosystem monitoring of standard parameters, maintenance, data nodes), and adopting to the needs of various user communities (flexible site designs).

The LTER conceptual pillars (long-term, in-situ, process orientation, systems approach, wide scale) are shared a range of user communities of the LTER infrastructure pool such as Critical Zone research, Macrosystems Ecology and Human-Environment Systems research.

The common overarching hypotheses result in similar infrastructure requi-rements and suggest the joint use of sites instead of building multifold separate infrastructures. Scientific users can focus on different system components and therefore use different subsets of the basic LTER infrastructure (installations). Moreover, projects or even specialized research infrastructures can cost efficiently integrate more specific installations (*e.g.* Expansion of the ICOS ecosystem component, small scale experimentation by AnaEE) and thereby contribute to unique knowledge and data hot spots.

The eLTER ESFRI initiative will...

- Prioritize requirements for ecosystem, critical zone and socio-ecological research infrastructure development derived from grand challenges and stakeholder needs.
- Develop network level services alongside the major research themes proposed for interoperability improvement of environmental RIs: Climate change, loss of biodiversity, eutrophication and pollutants.
- Secure the LTER Infrastructure´s coverage across European socio-economic, geopolitical and environmental gradients by guiding national LTER infrastructures networks in gap-filling site selections.
- Concretize the role of the LTER Infrastructure in the environmental RI landscape and operationalize the division of tasks with related European and global infrastructures.

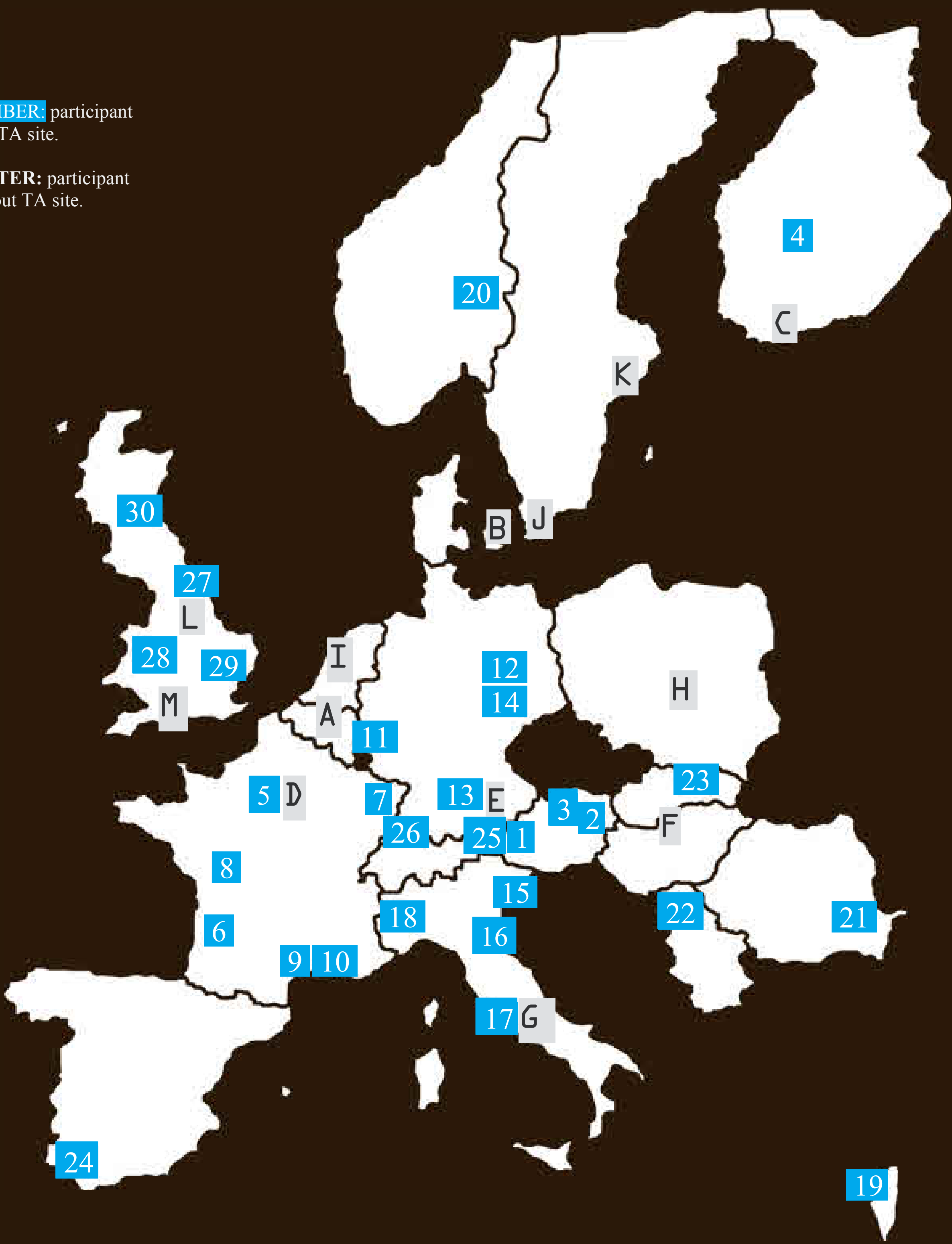
ExpeER PARTICIPANTS

ExpeER COMPRISES 35 RESEARCH INSTITUTES AND UNIVERSITIES FROM 19 COUNTRIES ACROSS EUROPE.

Map

NUMBER: participant with TA site.

LETTER: participant without TA site.



More information on www.expeeronline.eu

AUSTRIA
1. Achenkirch (HIES), Federal Research and Training Centre for Forests, Natural Hazards and Landscape.
2. Klausenleopoldsdorf (HIES), Federal Research and Training Centre for Forests, Natural Hazards and Landscape.
3. Zöbelboden (HIOS), Environment Agency Austria.

BELGIUM
A. University of Antwerp.

DENMARK
B. Technical University of Denmark.

FINLAND
C. Finnish Environment Institute.
4. Hyytiälä (HIOS), University of Helsinki.

FRANCE
5. Grignon (Analytical Platform), National Center for Scientific Research.
6. Pierroton (HIES - HIOS), National Institute for Agricultural Research.
7. Hesse (HIES), National Institute for Agricultural Research.
D. INRA Transfert.
8. Lusignan (HIES), National Institute for Agricultural Research.
9. Montpellier Ecotron, National Center for Scientific Research.
10. Puechabon (HIES - HIOS), National Center for Scientific Research.

GERMANY
11. Eifel (HIES - HIOS), Jülich Research Center.
12. Harz/Central German Lowland (HIES - HIOS), Helmholtz centre for environmental research.
13. Höglwald Forest (HIES), Karlsruhe Institute of Technology.
14. Jena (HIES), Friedrich Schiller University.
E. Technical University of Munich.

HUNGARY
F. Institute of Ecology and Botany.

ITALY
15. Beano (HIES), University of Udine.
16. Bologna (Analytical Platform), National Research Council.
17. Roma-Lecceto (HIOS), National Research Council.
18. Tetto Frati (HIES), University of Turin.
G. Tolfa-Allumiere, National Research Council.

ISRAEL
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20. Apelsvoll (HIES), Norwegian Institute for Agricultural and Environmental Research.

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H. European Regional Center for Ecohydrology.

ROMANIA
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THE NETHERLANDS
I. University of Amsterdam.

SERBIA
22. Fruška gora (HIOS), University of Novi Sad.

SLOVAKIA
23. Tatra Windstorm (HIOS), State Forests of Tanap.

SPAIN
24. Doñana (HIOS), Agencia Estatal Censejo Superior de Investigaciones Cientificas.

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J. Lund University.
K. Royal Institute of Technology.

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25. Seehornwald (HIOS), Swiss Federal Institute for Forest, Snow and Landscape Research.
26. Therwil (HIES), Research Institute of Organic Agriculture and Federal Department of Economic Affairs.

UNITED KINGDOM
27. Moor House (HIOS), Natural Environment Research Council.
28. Plynlimon (HIOS), Natural Environment Research Council.
29. Rothamsted (HIES - HIOS), Rothamsted Research.
L. University of Leeds.
M. University of Southampton.
30. Whim (HIES), Natural Environment Research Council.

Note

HIES: Highly Instrumented Experimental Site.

HIOS: Highly Instrumented Obsevational Site.

ExpeER (Experimentation in Ecosytem Research) brings together existing highly instrumented European infrastructures in the field of ecosystem research to improve their research capacity and to encourage their wider use, in particular through transnational access to various types of facilities.

Experimentation in Ecosystem Research

For more information: www.expeeronline.eu

ExpeER
Ecosystem Research

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