Stable Isotopes in Biospheric-Atmospheric-Earth System Research SIBAE (closed)

Predicting impacts of global change on the Earth system requires detailed understanding of interactions between biota and biogeochemical processes in different environments and management regimes. Stable isotopes are a powerful tool for studying such interactions in natural and managed ecosystems, offering insights beyond classical methodologies.

COST Action ES0806 SIBAE

As integrative, coordinated European platform for the use of stable isotopes in biosphere-atmosphere-Earth system studies, COST Action ES0806 SIBAE aimed to:

1. synthesize existing isolated stable isotope experiments on carbon, nitrogen, oxygen and water cycles to identify innovative process- and system-oriented research areas;
2. assess current state-of-the-art models to improve process representation and to better link experimental and modelling communities;
3. benchmark and advance innovative cutting-edge technologies for stable isotope analysis to stimulate interdisciplinary research; and
4. train early-stage researchers from diverse disciplines.

Funding was provided by COST and ESF:

European Science Foundation
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cost
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Stable Isotopes in Biospheric-Atmospheric Exchange SIBAE

An ESF scientific programme (2002 to 2007)

The scientific focus of the ESF Programme SIBAE did lie in the following three themes, (1) Understanding stable isotopic signals of the terrestrial biosphere, (2) Partitioning net fluxes into their component fluxes and (3) Interpreting spatial and temporal variability of terrestrial and atmospheric isotopic signals. All activities within the ESF Programme SIBAE (i.e., exchange visits, workshops, short courses and conferences) were therefore linked to one or more of these themes and were addressed with great motivation and engagement. The enhancement and support of the new/young generation of European scientists in terms of stable isotope applications in biospheric-atmospheric exchange research was the main focus of the ESF Programme SIBAE as can be easily seen from our activities. Here, the most progress was urgently needed (stable isotopes are typically not taught in university curricula, so knowledge about isotopes and groups working with isotopes are still very limited), here the most prominent achievements could have been shown, particularly with the exchange visits and short courses. The new development of stable isotope laser spectroscopy, supported during a joint workshop, had grown into full-fledged conference series and attracted many young scientists.

News & Events

News

In 2002, the ESF programme SIBAE finished successfully in stimulating application of stable isotopes in biospheric-atmospheric CO_2 and H_2O exchange. The continued efforts to provide ample opportunities at national and international scales for research advancement, network development, cross-site training and joint workshops resulted in the new COST Action ES0806 SIBAE which started in May 2009 and ran until November 2013.

About us
Funding

About us

Scientific Background

Detailed information about element pools, associated element and trace gas fluxes, and about their controlling factors is needed to elucidate the role of the terrestrial biosphere in global biogeochemical cycling, particularly under the currently changing environmental conditions. Understanding ecosystem functioning is not only of primary interest for many researchers globally, but also for European societies to develop adequate strategies to comply with international treaties. Research on element cycling within or above terrestrial ecosystems can employ various means. In addition to classical methods and approaches, stable isotopes proved to be useful tools in terrestrial ecology and global change research, providing additional information that could not be obtained otherwise. Many different disciplines – some of them already using stable isotopes – are typically needed to understand the functioning of the black box "ecosystem", e.g., the biospheric-atmospheric exchange, the complex interactions with the environment or the impact of human use. However, often these disciplines do not interact or communicate well.

The ESF programme SIBAE aimed at integrating these very different
perspectives on stable isotopes in biospheric-atmospheric trace gas exchange research, particularly of CO_2 and H_2O. We strived to reach scientists from different disciplines working at different scales (local to global), using different methods (e.g. experimentalists or modellers) and investigating different organisms (e.g. microbes, plants or animals) or ecosystems (from tropical to boreal, grasslands to forests).

The following objectives were the unifying mechanisms within the ESF programme SIBAE:

- to provide a platform for European researchers of different disciplines for promoting and integrating stable isotopes to biospheric-atmospheric exchange research;
- to initiate new research activities using stable isotopes in the field of biospheric-atmospheric gas exchange in Europe, crossing discipline boundaries;
- to provide means, including exchange visits, conferences, workshops, summer schools, common databases and an interactive web page, for the development and promotion of common approaches for measurements of stable isotopes in gas exchange studies at different spatial and temporal scales and for ecosystem flux measurements;
- to provide opportunities for training young investigators in latest advances in experimental and modelling methodology of stable isotope fluxes in biospheric-atmospheric exchange projects; and
- to join with the Biospheric-Atmospheric Stable Isotope Network (BASIN) program in the US and form a global network for the exchange of experiences, methodology, and data.

The ESF programme SIBAE focussed around the following three themes:

1. Understanding stable isotopic signals of the terrestrial biosphere
2. Partitioning net fluxes into their component fluxes
3. Interpreting spatial and temporal variability of
terrestrial and atmospheric isotopic signals

TOP

About us
Funding

Funding

The ESF programme SIBAE aimed to bring together European researchers from different areas for promoting and initiating research activities applying stable isotope methods, crossing discipline boundaries. ESF scientific programmes are principally financed by the Foundation's Member Organisations on an *à la carte* basis. The ESF programme SIBAE was supported by:

Fonds zur Förderung der wissenschaftlichen Forschung, Austria; Österreichische Akademie der Wissenschaften, Austria; Fonds voor Wetenschappelijk Onderzoek - Vlaanderen, Belgium; Statens Naturvidenskabelige Forskningsråd, Denmark; Suomen Akatemia/Finlands Akademi, Finland; Max-Planck-Gesellschaft, Germany; Consiglio Nazionale delle Ricerche, Italy; Nederlandse Organisatie voor Wetenschappelijk Onderzoek, Netherlands; Gabinete de Relações Internacionais da Ciência e do Ensino Superior, Portugal; Vetenskapsrådet, Sweden; Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung/Fonds National Suisse de la Recherche Scientifique, Switzerland.

People
Steering Committee
ESF Liaison
Institutes, partners and related links

People

Achieving all the addressed objectives, the ESF programme SIBAE relied on the great enthusiasm and the engagement of the people involved; the members of the steering committee, the liaison people at the ESF, the participants of the SIBAE activities and the partners from related organisations and initiatives.

Participants of the SIBAE workshop on 'Disentangling abiotic and biotic effects on soil respiration' Innsbruck 12-13 March 2007

People
Steering Committee
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Institutes, partners and related links

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Institutes, partners and related links

Listed here are the home institutes of the steering committee members, partner institutions and links to organisations dealing with topics related to the focus of the ESF programme SIBAE.

Institutes

Swiss Federal Institute of Technology, Institute of Plant Sciences, Grassland Group
CNR, Institute of Agro-Environmental Biology and Forestry (IBAF)
Max-Planck-Institute for Biogeochemistry
Swedish University of Agricultural Sciences, Department of Forest Ecology
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Riso National Laboratory, Plant Research Department
University of Vienna, Institute of Ecology and Conservation Biology
Paul Scherrer Institute, Laboratory of Atmospheric Chemistry

Partners

Biogeosphere-Atmosphere Stable Isotope Network (BASIN)
Weizmann Institute of Science, Faculty of Chemistry
Laboratory of Forest Ecology, University of Tuscia, Viterbo

Related links

ISOGEOCHEM web page
Joint European Stable Isotope User-Group Meeting (JESIUM)
International Atomic Energy Agency (IAEA)
Global Network of Isotopes in Precipitation (GNIP)
Intergovernmental Panel on Climate Change (IPCC)
Volatile Organic Compounds in the Biosphere-Atmosphere System (VOCBAS)
CarboEurope-IP

Research

Terrestrial ecosystems play an important role in the global element cycles, e.g., the global carbon (C) budget. Anthropogenic C emissions are much larger than the observed increase of atmospheric CO_2 concentrations, suggesting considerable C uptake over land and in the oceans.

After accounting for a large oceanic sink, models predict a large C sink to be located in the terrestrial biosphere, particularly in the Northern Hemisphere. However, partitioning among different terrestrial C sinks, effects of land use, socio-economic impacts, and future changes in the global C budget are still under debate. Furthermore, European politicians are increasingly faced with the consequences of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), seeking ways to decrease C sources and increase C sinks, e.g. by C sequestration in the terrestrial biosphere.

Thus, ecosystem physiology, specifically the CO_2 exchange between terrestrial ecosystems and the atmosphere as well as the C sink strength of various ecosystem types, is of primary interest for global change research and European societies.

The analysis of stable C and oxygen (O) isotope ratios ($d^{13}C$ and $d^{18}O$) in plant and soil material as well as CO_2 has proven to be a useful tool to address global change research questions at various temporal and spatial scales. The use of ^{13}C analysis in atmospheric research provided a scientific breakthrough by allowing the partitioning of atmospheric CO_2 exchange between the ocean and the terrestrial biosphere. It is anticipated that the use of ^{18}O in CO_2 will bring the next breakthrough by allowing the partitioning of terrestrial CO_2 exchange between canopy and soil.

Understanding changes in the isotopic signatures of CO_2, but also of other trace gases such as methane, nitrous oxides, etc., requires detailed knowledge about the isotopic signatures of different compartments and fluxes in terrestrial ecosystems and the fractionation taking place during the biospheric exchange with the atmosphere as well. In this new research field on biospheric-atmospheric interactions, many scientific questions remain unresolved. Which biotic and abiotic processes control the isotopic signatures of terrestrial ecosystems and the biospheric-atmospheric trace gas exchange? Which environmental factors determine the temporal and spatial variability of stable isotopic signals in the terrestrial biosphere? How can stable isotopes help to separate flux components (e.g., assimilatory or respiratory) of net ecosystem fluxes measured with eddy covariance techniques? How can we scale up stable isotopic signatures from leaves and soils to the canopy, ecosystem and to regional and global scales? Can we use the currently available mechanistic understanding of physiological processes to simulate isotopic trace gas exchange in models? How can we link ecosystem scale measurements to atmospheric measurements of the convective boundary layer? These are some of the questions that were fundamental for the ESF programme SIBAE.

Understanding stable isotopic signals of the terrestrial biosphere

The terrestrial biosphere is made out of a complex network of organic and inorganic element pools with their associated element and trace gas fluxes. All those pools and fluxes provide an individual "fingerprint", i.e., stable isotopic signature, to learn more about their origins, transformations and interactions. For example, foliar stable carbon isotope ratios ($d^{13}C$) are influenced by the $d^{13}C$ of canopy CO_2 and by discrimination against ^{13}C (D_{leaf}) during photosynthesis. Discrimination against ^{13}C is strongest in C_3 plants, but also occurs in C_4 and CAM plants. Within each of these photosynthetic plant groups, there can be considerable variation in D_{leaf}. Any factor that affects stomatal resistance, such as light or vapour pressure deficit, will affect the isotopic discrimination during photosynthesis and thus the $d^{13}C$ of plant biomass, and later on, of litter input into the soil. Internal recycling of CO_2 from respiration inside the leaf and variations in the $d^{13}C$ values of canopy air CO_2 outside the leaf, are further factors affecting $d^{13}C_{leaf}$ values. In theory, it should be possible to use the ^{13}C signature of plant biomass to derive information about climatic conditions when these tissues were produced. However, despite all detailed process knowledge, the problem of scaling up single leaf measurements to obtain a canopy isotopic signal remains unsolved.

Set-up for measuring isotopic signatures of branch gas exchange

TOP

At the next organisational scale, the ecosystem, biospheric gas exchange with the atmosphere is also influenced by many factors, particularly by turbulence regime and ecosystem physiology. While the turbulence regime will influence the mixing of trace gases between the biosphere and the atmosphere, ecosystem physiology will affect the magnitude of the biospheric flux and – in case of CO_2 – its carbon and oxygen isotopic signatures ($d^{13}C$ and $d^{18}O$). Furthermore, strong feedback mechanisms exist such as the effect of high turbulence on ecosystem assimilation or low ecosystem gas exchange rates on the trace gas concentrations. In addition, ecosystem processes that alter the isotopic signature of ecosystem trace gas exchange typically carry isotopic signals that are integrated over different time spans, e.g., assimilation vs. decomposition. These examples clearly demonstrate both the potential of and the difficulties associated with stable isotopes. There are many research fields in which stable isotopes have already contributed significantly to progress made in recent years, but in many other fields, progress is hampered by a lack of understanding of the isotopic signal, especially at the ecosystem scale.

Research goals within theme 1 were

. to synthesise knowledge on isotopic patterns within Europe;

. to provide a framework for European researchers that will allow easy and fast information exchange;

. to help select the best methodology and its uniform application for determining the isotopic signature of trace gas fluxes as well as the isotopic signatures of important element pools;

. to develop scaling protocols from the leaf, canopy, region to the continent;

. to investigate underlying principles of isotopic patterns, particularly to test hypotheses on fractionation;

. to identify the sources of trace gas fluxes and the proportions of their component fluxes;

. to advance our understanding of processes determining
isotopic signals in soils and vegetation and their interactions with the atmosphere;

. to initiate further model development for predicting stable isotopic signals;

. to extend our database on isotopic signatures for
representative European ecosystems, particularly taking into account different land use management.

Research
Understanding iso signals
Partitioning net fluxes
Variability

Partitioning net fluxes into their component fluxes

At the ecosystem scale, several micrometeorological techniques offer the potential to measure net fluxes of water vapour, CO_2 and other trace gases between ecosystems and the atmosphere. In case of CO_2, however, two opposing fluxes contribute to this net flux: CO_2 uptake during photosynthesis and CO_2 release during respiration. For water vapour, leaf transpiration and soil evaporation are the major contributors to the combined net flux. Because environmental parameters differentially affect biological activities, deconvolution of the net flux into its component fluxes is critical to obtain insights into the processes underlying ecosystem responses to climate forcing. Observing a net annual increase in any net flux of an ecosystem in response to climate change, e.g., is not sufficient to determine whether this is due to a change in gross uptake or gross release of any particular trace gas species.

Girdled stem at the Flakaliden study site in Sweden helps to distinguish autotrophic from heterotrophic soil respiration.

Stable isotope compositions of different ecosystem components provide a powerful tool towards quantifying the contribution of these components to net ecosystem exchange. When this tool is used in conjunction with concentration or flux measurements, an even greater amount of information is derived. Deciphering the individual fluxes of an ecosystem using stable isotopes can be approximated by knowledge of the isotopic identity of the major ecosystem components or can be inferred by direct measurements that are currently being developed. These new measurements might include combining isotopic and flux measurements or completely new tools from other fields of research. However, to date, there are still many difficulties in precisely estimating those individual components. Further studies are needed that provide validations to earlier results and that advance our technology and theory.

Soil chamber to collect respired CO2.

Research goals within theme 2 were:

. to integrate stable isotope measurements to flux measurements;

. to compare and develop different experimental approaches for isotopic analyses of trace gas fluxes;

. to initiate joint studies that aim at partitioning fluxes into their component fluxes in relevant European terrestrial ecosystems;

. to stimulate new approaches for determining isotopic signatures of individual flux components;

. to improve our theoretical understanding and modelling of isotopes in biospheric-atmospheric exchange.

Activities
Exchange Visits
Workshops
Spring School
Conferences

Activities

Defined as main objectives of the ESF programme SIBAE were: the provision of a platform for European isotope research, the initiation of new research activities crossing discipline boundaries, to offer means for the exchange and the dissemination of knowledge (i.e. exchange visits, workshops, conferences, etc.), to provide training opportunities for young researchers, and finally to tighten the cooperation with researchers from the US sister programme BASIN (Biospheric-Atmospheric Stable Isotope Network).

Activities
Exchange Visits
Understanding iso signals
Partitioning fluxes
Variability
Workshops
Spring School
Conferences

Exchange Visits

Exchange visits within the ESF programme SIBAE provided a unique opportunity mainly to young researchers, to learn the latest advances in the field, make contacts and work on collaborative research, outside their home country, within the themes of the programme. These exchange visits further allowed the establishment of a network of stable isotope measurements in ecosystem gas exchange studies throughout Europe. Applications were granted based on the quality and the suitability of the submitted proposal to the programme as well as on past research performance and letters of recommendation. Within the ESF programme SIBAE 35 exchange visits were granted for up to six months.

Understanding stable isotopic signals of the terrestrial biosphere

Isotope signals in tree rings as a tool to monitor forest 'health'
Isotopic composition (13C, 18O) in Siberian tree-ring chronology
Factors influencing photosynthetic discrimination of 13C and its relationship with the composition of foliage respired 13CO2 in Mediterranean ecosystems
Fractionation processes of poikilohydric functional groups and their impact on ecosystem processes determined by d18O in organic matter, H2O and CO2
Effects of water and light on C and O isotopic signatures in grazed grasslands
Stable isotopes and vegetation water sourcing in semi-arid ecosystems
Stable isotopes applied to the study of water budget in Mediterranean oak-woodland ecosystems
The use of compound specific isotopic ratio to investigate the fate of C compound in the soil
The use of PLFA as biomakers to investigate the fate of C compound from decomposing litter to soil microbial community
Carbon isotope signatures of soluble sugars and starch
Why is fungal material heavier than its carbon source?
Sample analysis of enzymatic extraction of leaf carbohydrates and determination of their isotopic composition, field experiments, and planning of long-term collaboration

Partitioning net fluxes into their component fluxes

Transpiration mediated emissions of greenhouse gases from beech (*Fagus sylvatica L.) trees*
Towards a better understanding of the partitioning of CO2 sources and sinks in two Mediterranean oak-woodland ecosystems
Combining enrichment and natural abundance techniques to differentiate between soil sources of nitrous oxide
Oxygen isotopes in plant material as a tool to trace transpiration in biodiversity and ecosystem functioning studies
Testing methods of studying the isotope composition of soil respiratory components
Application of stable isotopes for separating autotrophic and heterotrophic components of grassland soil respiration

Interpreting spatial and temporal variability of terrestrial and atmospheric isotopic signals

Stable isotopes in tree rings as a powerful tool in environmental research
Diurnal variation in the carbon isotope composition of phloem sap in *Picea abies*
Drought in the Aegean assessed by stable isotopes in tree rings
To study the relationship between short-term C- and N-dynamics in a grazed pasture
Oxygen isotopic signature of CO2 from combustion processes - differentiation by diverse burning regimes
Oxygen isotopic signature of CO2 from combustion processes - enhanced analyses of fundamental driving parameters
Dendroecology study in FACE sites
Carbon sequestration, isotopic characterization and soil flux partition in different soils under the footprint of a coastal CO2-eddy-flux tower
Contribution of the most recalcitrant part of the soil organic matter to total soil respiration
Comparison of the diurnal and seasonal variations in pi/pa with carbon isotope discrimination of leaf and stem soluble sugars in a managed oak forest with differencing understory
Diurnal variation in the delta13C of soil respired CO2 on girdled and non-girdled plots of Scots Pine (*Pinus sylvestris*)
Climatic variations and N supply as determinants of d13C of foliage of *Pinus sylvestris* L.

Understanding stable isotopic signals of the terrestrial biosphere

Exchange visits performed within this theme:

Isotope signals in tree rings as a tool to monitor forest 'health'
Isotopic composition (13C, 18O) in Siberian tree-ring chronology
Factors influencing photosynthetic discrimination of 13C and its relationship with the composition of foliage respired 13CO2 in Mediterranean ecosystems
Fractionation processes of poikilohydric functional groups and their impact on ecosystem processes determined by d18O in organic matter, H2O and CO2
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Carbon isotope signatures of soluble sugars and starch
Why is fungal material heavier than its carbon source?
Sample analysis of enzymatic extraction of leaf carbohydrates and determination of their isotopic composition, field experiments, and planning of long-term collaboration

Isotope signals in tree rings as a tool to monitor forest 'health'

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Abstract

The large number of publications and the main political decisions reflect the strong interest in the implications of increased CO_2 in the context of global change, while the knowledge is still lacking to what degree the increase of nitrogen depositions affects the forest ecosystems.

The most abundant reactive N compounds in the atmosphere are represented by oxidized (NO_x) and reduced (NH_x) forms. NO_x comes principally from fossil fuel combustion in car engines (although there is a fall in the output of lead and other pollutants from cars, with introduction of lead-free petrol and catalytic converter since the eighties (Pearson *et al*, 2000), and since industrialisation (estimated to contribute up to 70% of total NO_x emissions). Agricultural activities are the main input for NH_x emissions (Bragazza *et al*., 2005).

On the one hand nitrogen depositions can act as fertilizer, by stimulating growth especially in temperate forest where nitrogen is a limiting factor. On the other hand chronic depositions could also have toxic effect on the global nitrogen cycle which may lead to soil acidification and an imbalance in nutrients with subsequent change in the structure of the plants. An increase in nitrogen availability for trees, in fact, can reduce the root/canopy ratio with implication for the stability of plants and the balance between water uptake and loss. Other effects can be the changes in composition of vegetation in a forest ecosystem (Kirchner *et al.*, 2005) and a reduction in biodiversity at the global scale (Phoenix *et al.*, 2006). Nitrogen isotopes measured in plant materials seem to be a very useful tool for detecting the incorporation of nitrogen from air pollution, in particular NO_2 coming from the motorway (Amman *et al.*, 1999, Siegwolf *et al*, 2001, Saurer *et al.*, 2004).

By combining carbon, oxygen and nitrogen stable isotopes it is possible to understand how such anthropogenic factor can affect tree physiology. $\delta^{15}N$ measured in needles and tree rings shows that there is a signal of N uptake by the stomatal pathway (Siegwolf *et al*., 2001) and this signal is still kept in tree rings, eventhough dampened in the latter. NO_x emissions from traffic seem to have a fertilizing effect on trees more exposed to pollution (Siegwolf *et al*., in prep).

The main goal of this research is to study the effect of nitrogen emissions coming from an oil refinery on trees more exposed to this source of pollution. Do trees show the same physiological response shown for emissions coming from the motorway?

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Wood-core drilling

TOP

Leaf material sample

Refinery

Isotopic composition (13C, 18O) in Siberian tree-ring chronology

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Abstract

The purpose of the SIBAE Exchange Visit was to reveal the response of larch trees on natural variations of temperature and moisture during two different phases of the past to develop a better understanding of environmental changes in north-eastern Yakutia based on tree ring and isotopic chronologies.

We related tree ring width (TRW), maximum density of tree-rings (MXD) and isotopic composition of $d^{13}C$, $d^{18}O$ of wood and cellulose from four larch trees (*Larix cajanderi* Mayr.) to climate parameters. The material was sampled in north-eastern Yakutia [70° N /148° E] for the recent (AD 1880-2004) and for the beginning of the Medieval period (AD 900-1000). The June, July and August air temperature were positively correlated with isotope data ($d^{13}C$, $d^{18}O$ of wood and cellulose) while July precipitation was negatively correlated, a parameter which can not be detected by dendrochronological analysis. The vapour pressure deficit (VPD) of July and August was significant correlated with $d^{13}C$ of wood and cellulose, but no correlation was found to $d^{18}O$ of wood. The temperature regime of the first ten days of July is significant for the $d^{13}C$ of wood as well as for cellulose as detected by analysis of the date of middle of pentad. A strong relationship between MXD and $d^{13}C$ of cellulose was found that could be explained by similar reaction of these parameters to climatic changes. Strong positive correlations between $d^{18}O$ of cellulose with Greenland ice-cores (GISP2) data were detected for the beginning of the Medieval period ($R=0.71$; $p<0.05$) while it was not observed in tree-ring width. The tree-ring width and isotope data sets ($d^{13}C$, $d^{18}O$) illustrated that the beginning of the Medieval AD 900-1000 and recent period AD 1880-2004 are characterized by similar climatic conditions.

945 years old Larix cajanderi Mayr. (Photo: M.M. Naurzbaeva)

Tree-ring sample preparation

Publications:

Sidorova O.V., R. T. W. Siegwolf, E. A Vaganov, M Saurer, M. M. Naurzbaev, (2006) Isotopic composition ($d^{13}C$, $d^{18}O$) in Siberian tree-ring chronology
Abstract:. Isotopes as traces of ecological change. SIBAE-BASIN Stable Isotope Meeting, March 13-15, Tomar, Portugal, p 51.

Sidorova O.V., E. A. Vaganov, R.T.W. Siegwolf, M. Saurer
Isotopic composition ($d^{13}C$, $d^{18}O$) of the medieval and recent wood in Siberian tree-rings,
J. Geoph. Res (in preparation).

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Factors influencing photosynthetic discrimination of 13C and its relationship with the compositions of foliage respired 13CO2 in Mediterranean ecosystems

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Abstract

The purpose of this exchange visit was to build on previous work investigating the $d^{13}C$ signatures of ecosystem components relevant for partitioning CO_2 sources and sinks in Mediterranean ecosystems. Previous work in two *Quercus* forests in Italy indicated a very large shift (of up to 9 ‰) in the $d^{13}C$ isotope composition of foliage respired CO_2 ($^{13}C_{Rf}$) over the diurnal period. This involved an enrichment throughout the photoperiod and subsequent depletion back to predawn values through the night. This indicated that foliage $^{13}C_{Rf}$ can be dynamic in time over time periods shorter than that often used in sampling for partitioning and determination of the ecosystem $d^{13}C$ respiratory signal. Analysis of the $d^{13}C$ of the main substrate pools (soluble sugars, starch and lipids) over the periods of investigation revealed no significant changes that could be reconciled with the observed enrichment in $^{13}C_{Rf}$. Another interesting feature of this study was the observation that the extent of the daytime enrichment (above predawn values) was highly correlated with the total C assimilated by the leaves to that point in time. This led to the hypothesis that a change in the carbon status of the leaves can influence the composition of the respired CO_2. This indicates that both the pool size and composition of the recently assimilated carbon are important determinants of the $^{13}C_{Rf}$.

However, estimates of the $d^{13}C$ composition of recent assimilate from gas exchange data during the photoperiod indicated that this is not a simple relationship. Furthermore, these measurements were made under quite severe drought conditions for these forests (the hot summer of 2003), hence the influence of drought (an important feature of Mediterranean ecosystems) on photosynthetic discrimination needs also to be considered as an important factor in attempts to elucidate the controls on the $d^{13}C$ composition of the various pools and fluxes of C within the canopy. Therefore this work was focussed on investigating and quantifying the influence of drought on discrimination through changes in mesophyll conductance ad photorespiration, and on the relationship between foliage respired $^{13}CO_2$ and the various carbon pools in the leaf (recently assimilated C, total soluble sugars, starch, lipids).

Leafs of Quercus suber

TOP

Publications:

G.J. Hymus, **K. Maseyk**, R. Valentini and D. Yakir (2005)
Large daily variation in ^{13}C-enrichment of leaf-respired CO_2 in two Quercus forest canopies
New Phytologist 167, 377-384

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Fractionation processes of poikilohydric functional groups and their impact on ecosystem processes determined by d18O in organic matter, H2O and CO2

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Host Institute: Faculdade de Ciências da Universidade de Lisboa, Departamento de Biologia Vegetal, Campo Grande, Edificio CS, 1749-016 Lisboa, PORTUGAL

Abstract

The project was focusing on open questions in basic research of poikilohydric physiology and their impact on ecosystem processes. It conducted experimental research to determine ecosystem components and tried to lay the foundations for ecosystem function of cryptogamic communities at low productive terrestrial ecosystems and as soil cover influencing the effective hydration rate.

The overall results of the exchange grant are:

(i) new standard protocols for "in tube" experiments could be developed to study $^{13}CO_2$ and $C^{18}O^{16}O$ during respiration and $H_2{}^{18}O$ during evaporation of cryptogams,

(ii) the influence of thallus resistance on the stable isotopes ^{13}C and ^{18}O was studied, and

(iii) a new methodology was developed for Keeling-plot-approaches at microhabitat-scale. The results contribute to the knowledge of fundamental principles of $d^{13}C$ and $d^{18}O$ discrimination in cryptogams and their role as above ground components in ecosystems.

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Effects of water and light on C and O isotopic signatures in grazed grasslands

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Host Institute: Eidgenössische Technische Hochschule, Institute of Plant Sciences, Universitätsstrasse 2, 8092 Zürich SWITZERLAND

Abstract

The isotopic signatures of C and O in grasslands can give insight on how species with different resource use strategies respond to land- use and climatic changes, share the niche space available in a community and result in feedbacks at ecosystem functioning level. During the exchange grant it was possible to analyze data from grazed grasslands experiments in NE Spain showing various effects of grazing on plant community water use efficiency. At the same time we designed new methodologies for assessing water source in herbaceous species (which resulted in a published paper; Barnard et al. 2006 in RCMS).
This pilot experiment was then complemented by an extense field work campaign in the Jena-experiment (http://www.the-jena-experiment.de) giving insight on different effects of facilitation and complementarity for water among grassland species.

Grazed grassland

Fieldwork

Publications:

Barnard, R. L., **de Bello, F**., Gilgen, A. K. and Buchmann, N. (2006)

The $d^{18}O$ of root crown water best reflects source water $d^{18}O$ in different types of herbaceous species.

Rapid Communications in Mass Spectrometry 20: 3799-3802

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Stable isotopes and vegetation water sourcing in semi-arid ecosystems

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Abstract

To determine the water source of two co-occurring shrubs, we collected soil and plant samples from an experimental site in semi-arid SE Spain, and analyzed them with respect to their isotope signature. In particular we characterized the water source of two co-occurring shrubs (*Pistacea lenticus*, lentisc; *Juniperus phoenicea* subsp. *turbinata*, juniper) that inhabit a coastal sandy dune ecosystem affected by a salty and shallow water table. Previous research had shown contrasting differences in xylem water potential, chlorophyll fluorescence and photosynthesis and transpiration rate between these two species, and here we hypothesized that these contrasting carbo-water relationships were due to differing access to soil moisture.

Our hypothesis could not be accepted since the isotopic signature of xylem water in both species was nearly equal. On the other hand, $d^{18}O$ of soil water at any depth differed significantly from those of xylem water. These results are in disagreement with previous knowledge on species rooting depth, water status and osmotic potentials, which underline extreme differences in physiological status between lentisc and juniper. This made us think that more complex hydrological dynamics in such sand dunes should have been taken into account. Currently, we are carrying out a more complex study that involves full soil profile samples, water table drills and a two-year-monitoring period.

Leaf material sampling

Soil trench digging

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Stable isotopes applied to the study of water budget in Mediterranean oak-woodland ecosystems

Cathy Béatrice Kurz Besson

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Abstract

A study was realised in summer 2003 to identify water depth uptake variability for 27 15-years old *Quercus suber* trees located in a Montado agroforestry system in southern Portugal under a Mediterranean mesothermic humid climate (N 38º31.664 / W 8º01.380). To define water sources during the drought period, 3 soil profiles were collected under 3 different vegetation types in late August, each at 0.1 m until 1 m depth. Samples of twigs, leaves, water from precipitation and the ground water table were collected in June and early September. Water was extracted from samples by cryodistillation and analysed by mass spectrometry (Paul Scherrer Institute, Switzerland) to determine the dD and $d^{18}O$ relative to VSMOV standard.

Evidence for hydraulic lift was substanciated by similar $d^{18}O$ values found in tree xylem sap, soil water and groundwater. Hydraulic lift was also supported by the daily variations observed in soil water potential at 0.4 m depth during the drought period. However, the soil isotopic dD signature was more negative than xylem water and groundwater which could be explained by a fractionation process of the hydraulically redistributed water leading to more depleted soil water under the trees. Hydraulically lifted water was estimated to account for 17 – 81% of the water used during the following day by tree transpiration at the peak of the drought season, i.e., 0.1 – 14 L $tree^{-1}$ day^{-1}. Significant relationships found between xylem sap isotopic composition and leaf water potential in early September emphasized the positive impact of the redistribution of groundwater in the rhizosphere on tree water status.

Mediterranean ecosystem with of Quercus trees

Publications:

C. Kurz-Besson et al. (2006)
Hydraulic lift in cork oak trees in a savannah-type Mediterranean ecosystem and its contribution to the local water balance
Plant and Soil 282, 361-378

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The use of Compound Specific isotopic Ratio to investigate the fate of C compound in the soil

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Abstract

The scientific purpose of the visit was to test the hypothesis that during microbial breakdown of litter a fraction of the C lost from the litter is not released as CO_2, but remains in the soil as microbial bio-product. This C is thus proportional to mass loss, but may vary in relation to litter quality and the dynamics of litter decomposition. With this objective, soil and litter samples derived from a previous lab-experiment performed at the Department of Environmental Science (Second University of Naples, Caserta, Italy) were brought to the Max Planck Institute for Biogeochemistry (Jena) for compound specific isotope analysis.

In particular, the lab experiment litter (3 g) from three different C3 species, generated under elevated atmospheric CO_2, [i.e. *Liquidambar styraciflua* ($d^{13}C$ = -43.0 ‰), *Cereis canadensis* ($d^{13}C$ = -43.7 ‰), Pinus taeda ($d^{13}C$ = -43.7 ‰)] were incubated in four replicates in jars (1000 ml) with 70 g of C4 soil ($d^{13}C$ = -17.7 ‰), and let decomposing for 8 months under controlled environmental conditions. The soil C content and its isotopic composition changed during the decomposition of litter because the soil was enriched in C derived from the litter.

Specific aims of the work performed during the visit were to:

1. determine differences in the quality (i.e. degradability) of the three litter used, before and after the lab-incubation;

2. identify the soil compounds where litter derived C is retained.

Lab facility, GCMS

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The use of PLFA as biomarkers to investigate the fate of C compound from decomposing litter to soil microbial community

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Abstract

The scientific purpose of the visit was to test the hypothesis that during microbial breakdown of leaf litter a fraction of the carbon (C) lost from the litter is not released as CO_2, but remains in the soil microbial biomass. In particular, we wanted to find out which groups of micro organisms retained the highest percentages of litter derived C after 1-year field decomposition experiment. With this objective, soil and litter samples derived from a previous field-experiment performed at the EUROFACE experimental site in Tuscania (Dipartimento di Scienze Forestali e Ambientali, Università della Tuscia, Viterbo, Italy) were brought to the School of Chemistry (University of Bristol, UK) for extraction of Phospholipids Fatty Acids (PLFAs), quantification and compound specific isotope analysis of extracted PLFAs. The reason why PLFAs can be used to identify groups of micro organisms acting the leaf litter decomposition process is based on the fact that some PLFAs (or groups of PLFAs) are produced by specific groups of micro organisms. Thus, it is sometimes possible to relate a specific PLFA (or a group of PLFAs) to the group of micro organisms that produced that (or those) PLFA(s). Together with the isotopic labelling, this provides a good method to trace the fate of C going from the decomposing leaf litter into the soil organic matter (SOM).

In details, the original leaf litter of *Populus nigra* (10 g at the begininning of the experiment), generated under ^{13}C-enriched atmospheric CO_2 ($d^{13}C \sim + 160$ ‰), were confined in collars (20 cm diameter) over the soil ($d^{13}C \sim - 25$ ‰) and let decomposing for 11 months under two different treatments: (1) atmospheric CO_2 concentration and (2) nitrogen (N) fertilization.

Soil C content and its isotopic composition changed during the decomposition of litter because of the enrichment in litter derived C and heterotrophic respiration of native SOM. Specific aims of the work performed during the visit at the School of Chemistry in Bristol were to identify the soil microbial PLFAs where litter derived C is mostly retained and to quantify the percentage of litter derived C in identified PLFAs. Furthermore, by comparing the amount and isotopic composition of PLFAs of soils from different treatments (CO_2 fumigation and N fertilization), the effect of the two treatments on the soil microbial community can be tested.

PopFACE experiment

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TOP

Carbon Isotope signatures of soluble sugars and starch

Yann Louis Baptiste Salmon

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Host Institute: University of Vienna, Faculty of Life Sciences, Department of Chemical Ecology and Ecosystem Research, Althanstrasse 14, 1090 Wien AUSTRIA

Abstract

Innovative enzymatic techniques (developed by Andreas Richter, Wolfgang Wanek and Collaborators; Wanek et al. 2001) allows to measure the ^{13}C signature of starch and the other one to measure the ^{13}C signature of soluble sugars. The interest in the study conducted during the exchange visit was to focus on the dynamics of ^{13}C from the assimilation of carbon to its respiration, under controlled and monitored conditions in phytotrons. The objective is to understand how biological and environmental conditions influence carbon circulation in the biosphere through ecosystem processes as well as spatial and temporal variability of isotopic signatures. This requires measurement of $\delta^{13}C$ not only in respired CO_2 and bulk organic matter, but also in starch and soluble sugars, because I expect to see the first signal of an isotopic response to environmental changes in assimilates from photosynthesis. Since it seems that respiration does not lead to an isotopic fractionation, any change of isotopic signature along the atmosphere – assimilate – organic matter – plant and soil respiration chain should start by changes in Δ.

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Why is fungal material heavier than its carbon source?

Björn Boström

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Sample analysis of enzymatic extraction of leaf carbohydrates and determination of their isotopic composition, field experiments, and planning of long-term collaboration

Graham Hymus

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Response of larch trees from North-Eastern Yakutia to climatic changes after major volcanic eruptions inferred by tree-ring and isotope (d13C, d18O) data

Olga Sidorova

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RUSSIA
Host Institute: Laboratory of Atmospheric Chemistry, Stable Isotopes and Ecosystem fluxes, Paul Scherrer Institut, 5232 Villingen PSI, SWITZERLAND

Abstract

We analyzed the reaction of larch trees (*Larix cajanderi* Mayr) growing in the North-Eastern Yakutia [70°N -148°E] to extreme global climatic changes after major volcanic eruptions in the special periods A.D. 516-560, 1242-1286, 1625-1675, 1790-1835 based on dendro-chronological and isotope ($d^{13}C$, $d^{18}O$) data.

With this study, a unique isotope data set of $d^{13}C$ and the $d^{18}O$ of wood and cellulose was obtained for the first time. Special attention was focused on the period AD 516-560, which had a great catastrophic effect for environment and civilization. For this period we analyzed four trees separately for $d^{13}C$, $d^{18}O$ of wood and cellulose. A strong relationship was obtained between four different trees for oxygen (stronger than for carbon), indicating a high common signal and according to a reliable composite site-curve from the average of the trees. We found a significant correlation between June-July air temperature reconstruction and $d^{13}C$ of cellulose, $d^{18}O$ of cellulose and wood, however no significant correlation with $d^{13}C$ of wood. These results indicate that not only ring-width, but also the isotope ratios are significantly affected by the volcanic eruptions. Preliminary results for the other periods mostly show a similar response.

In conclusion, the isotope values confirm the information fixed in tree-ring width and show a decrease of isotope values in the same time like tree-ring width after major volcanic eruptions that could be explained by an increase of relative humidity concurrently with a decrease in temperature, which lead to higher stomatal conductance and lower photosynthetic capacity due to reduction of solar radiation and temperature.

Elemental Analyser

Sample extraction

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Activities
Exchange Visits
Understanding iso signals
Partitioning fluxes
Transpired emissions
Source partitioning
C and N dynamics
N2O soil sources
Transpiration tracer
Soil respiration
Grassland soil
Variability
Workshops
Spring School
Conferences

Partitioning net fluxes into their component fluxes

Within this theme the following exchange visits were performed:

Transpiration mediated emissions of greenhouse gases from beech (*Fagus sylvatica L.) trees*
Towards a better understanding of the partitioning of CO2 sources and sinks in two Mediterranean oak-woodland ecosystems
Combining enrichment and natural abundance techniques to differentiate between soil sources of nitrous oxide
Oxygen isotopes in plant material as a tool to trace transpiration in biodiversity and ecosystem functioning studies
Testing methods of studying the isotope composition of soil respiratory components
Application of stable isotopes for separating autotrophic and heterotrophic components of grassland soil respiration

Transpiration mediated emissions of greenhouse gases from

Mari Katriina Pihlatie

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Abstract

Transpiration mediated nitrous oxide (N_2O) emissions from beech (*Fagus sylvatica* L.) trees were studied in laboratory and in field conditions. The aim of the work was to assess whether water soluble greenhouse gases (e.g. N_2O) can be transported from the root zone to the leaves and to the atmosphere via transpiration. Laboratory experiments were conducted with young beech seedlings, measurements in the field were conducted at the forest field station in Sorø. Results from laboratory experiments show clear increase in N_2O concentration during chamber enclosure. In the experiment N_2O was transported from the root compartment of a seedling to the leaves and thereafter into the atmosphere. Field measurements at the forest site did not show any increase in N_2O concentration inside the chamber. This was, however, not surprising since windy conditions made it difficult to keep the chamber air-tight during the measurement.

Publications:

M. Pihlatie, P. Ambus, J. Rinne, K. Pilegaard and T. Vesala (2005)
Plant-mediated nitrous oxide emissions from beech (*Fagus sylvatica*) leaves
New Phytologist 168, 93-98

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Towards a better understanding of the partitioning of CO2 sources and sinks in two Mediterranean oak-woodland ecosystems

Kadmiel Maseyk

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Host Institute: University of Tuscia, Department of Forest Sciences and Resources, Viterbo ITALY

Abstract

The focus of the study was on processes within the canopy, and in particular the relationship between the $d^{13}C$ of the assimilated carbon and the respired CO_2 in the forest canopies. The work was performed at the height of the summer time drought period, as this is a particularly important ecological facto within Mediterranean ecosystems. For example, due to drought imposed limitations of photosynthetic activity, carbon uptake at this time may not be much greater, or even less, than respiratory losses. This may necessitate the use of stored carbon substrates for respiration, such as starch from more favourable periods of activity, or even stores or turnover of lipids, in order to meet respiratory demands. In addition to the importance of drought in the Mediterranean and other parts of the world, understanding the strategies of ecosystems under drought stress are of much interest considering the potential increase in areas experiencing drier conditions under many climate change scenarios.

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To study the relationship between short-term C- and N-dynamics in a grazed pasture

Mette Sustmann Carter

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Abstract

The objective of the work conducted during the visit was to study the relationship between short-term carbon (C)- and nitrogen (N)-dynamics in a grazed pasture. More specifically, the objective was to investigate the connection between nitrous oxide (N_2O) production and carbon mineralization in urine spots.

The hypothesis is that part of the reason for the high N_2O emissions from urine spots is enhanced denitrification caused by ammonia-induced leaching of labile carbon compounds from the plants. Thus, the N_2O emission will be coupled to a decrease in the ^{13}C signal of the evolved CO_2. This link will be observed as a N_2O pulse conforming time wise to a temporal $^{13}CO_2$ depletion.

Other results will be interpreted as follows: If the $^{13}CO_2$ and N_2O pulse deviate in time it is concluded that plant C is mineralized, however not as a result of denitrification. If the $^{13}CO_2$ pulse appears immediately before the N_2O pulse it is likely that the decomposition of labile carbon lowers the oxygen level, which promotes denitrification.

Vegetation chambers

Sampling from enclosure inside

Publications:

M.S. Carter, K. Klumpp and X. LeRoux (2006)
Lack of increased availability of root-derived C may explain the low N_2O emission from low N-urine patches
Nutrient Cycling in Agroecosystems 75, 91-100

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Combining enrichment and natural abundance techniques to differentiate between soil sources of nitrous oxide

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Host Institute: Imperial College London, Wye Campus, Department of Agricultural Sciences Wye, Kent TN25 5AH UNITED KINGDOM

Abstract

We developed a ^{15}N, ^{18}O enrichment approach to differentiate between N_2O production from different soil processes such as nitrification, nitrifier denitrification and denitrification. Besides incubations with single- and double-^{15}N-labelled ammonium nitrate, a treatment with ^{18}O-labelled water (H_2O) was introduced, since ammonia oxidisers use O_2 from soil air for the oxidation of NH_3, but H_2O for the oxidation of the resulting hydroxylamine to NO_2^-. Thus, N_2O from nitrification should reflect the ^{18}O signature of soil O_2, while the O in N_2O from nitrifier denitrification can come either from soil O_2 or H_2O, depending on which O is split off in the reduction of NO_2^- to N_2O. It was assumed that a) no preferential removal of ^{18}O or ^{16}O takes place during nitrifier denitrification or nitrification-coupled denitrification and b) that no O-exchange between $H_2{}^{18}O$ and NO_3^- takes place. The assumptions were tested and accepted for the soil investigated. The new method was successfully checked against an inhibition method using low concentrations of acetylene and high concentrations of oxygen. Application of the new enrichment method indicated interesting shifts in N_2O-producing processes with changing WFPS and fertilizer type.

Publications:

N. Wrage, J.W. van Groeningen, O. Oenema and E.M. Baggs (2005)
A novel dual-isotope labelling method for distinguishing between soil sources of N2O
Rapid Communication in Mass Spectrometry 19, 3298-3306

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Oxygen isotopes in plant material as a tool to trace transpiration in biodiversity and ecosystem functioning studies

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Abstract

A major limitation in applying ecophysiological methods to large ecological experiments, e.g. addressing the effect of biodiversity on ecosystem functioning, is the big number of samples required. Consequently, integrative methods are needed that reduce the effort of sampling and data collection. In this respect, stable isotopes have been shown to be highly valuable tools that integrate over time and space and record information in plant tissue. The potential of $\delta^{18}O$ records in plant material to hold information on physiological processes such as water fluxes or photosynthetic performance is, however, just beginning to be explored. The main goal of the SIBAE funded exchange grant was therefore to advance the understanding of $\delta^{18}O$ signals in plant material so that oxygen isotopes in plant material can be used as an integrative tool for plant – water relations in ecosystem studies. To meet this main goal two specific objectives were addressed:

1) To develop a standard protocol that allows the rapid extraction of soluble carbohydrates (SCH) and cellulose form large numbers of plant samples for $\delta^{18}O$ analyses.

2) To separate environmental from physiological effects on the diurnal and seasonal variability of $\delta^{18}O$ in leaf water, soluble carbohydrates and cellulose of winter barley (*Hordeum sativum*).

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Testing methods of studying the isotopic composition of soil respiratory components

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Abstract

In the present study CO_2 flux and $d^{13}C$ of soil respiration were measured over the growing season (once per month from June to September 2003). The measurements were performed at two study sites in northern Sweden (at Flakaliden ca. 70 km to the north-west of the city of Umeå [63° 47′ N / 20° 17′ E] and at Storskogsberget ca. 30 km to the north-east of Umeå). The trees at both sites were girdled in June 2002. Comparison of the CO_2 flux rates of the girdled and non-girdled plots enabled us to estimate the contribution (and its seasonal variation) of autotrophic and heterotrophic respiration to total soil respiration. In addition d13C values of soil respiration gave some insight to changes in C sources used for metabolic soil processes.

Since we were not only interested in the fraction of autotrophic respiration to total soil respiration, but also in the spatial influence of the root sphere of individual trees, CO_2 respiration was measured along transects from girdled to control plots.

By the comparison of soil respiration of fertilised areas (both girdled and non-girdled plots) with control areas (girdled and non-girdled plots) the affection of nutrient supply on soil respiration could be detected at Flakaliden, a study site previously used for nutrient experiments.

An additional experiment was carried out to determine the relative contribution of autotrophic and heterotrophic respiration to total soil respiration by the supply of a labelled carbon substrate originating from a C4 plant to the soil.

Soil respiration chamber

Girdled plot at Flakaliden study site

top

Publications:

S.G. Göttlicher, **K. Steinmann**, N.R. Betson and P. Högberg (2006)
The dependence of soil microbial activity on recent photosynthate from trees
Research Article, Plant and Soil 287, 85 – 94

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Application of stable isotopes for separating autotrophic and heterotrophic components of grassland soil respiration

Michael Schmitt / Nadine Pfahringer

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Activities
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Understanding iso signals
Partitioning fluxes
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Phloem sap
Aegean droughts
Burning regimes
Combustion parameters
FACE study
C sequestration
Recalcitrant soil
Variations pi/pa
Girdling study
Foliage 13C
Workshops
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Interpreting spatial and temporal variability of terrestrial and atmospheric isotopic signals

Exchange visits performed under the topic of this theme:

Stable isotopes in tree rings as a powerful tool in environmental research
Diurnal variation in the carbon isotope composition of phloem sap in *Picea abies*
Drought in the Aegean assessed by stable isotopes in tree rings
To study the relationship between short-term C- and N-dynamics in a grazed pasture
Oxygen isotopic signature of CO2 from combustion processes - differentiation by diverse burning regimes
Oxygen isotopic signature of CO2 from combustion processes - enhanced analyses of fundamental driving parameters
Dendroecology study in FACE sites
Carbon sequestration, isotopic characterization and soil flux partition in different soils under the footprint of a coastal CO2-eddy-flux tower
Contribution of the most recalcitrant part of the soil organic matter to total soil respiration
Comparison of the diurnal and seasonal variations in pi/pa with carbon isotope discrimination of leaf and stem soluble sugars in a managed oak forest with differencing understory
Diurnal variation in the delta13C of soil respired CO2 on girdled and non-girdled plots of Scots Pine (*Pinus sylvestris*)
Climatic variations and N supply as determinants of d13C of foliage of *Pinus sylvestris* L.

Stable isotopes in tree rings as a powerful tool in environmental research

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Abstract

The aim of the project is twofold: 1) to understand whether $d^{13}C$ and $d^{18}O$ recorded in tree rings can be used to reconstruct climatic information at a site with temperate weather conditions or how much they are influenced differently in the different species due to genetic variations by seasonal timings or climate variability and 2) to investigate the relationship between the isotopic signals presented in bulk tissue, starch in leaves and latewood observed in the different species and related to environmental factors. These studies are carried out using carbon and oxygen ratio ($d^{13}C$; $d^{18}O$) of cellulose in the last 37 annual tree rings of three common tree species: Fagus sylvatica, Quercus robur and Pinus sylvestris and in the same time data include $d^{13}C$ and $d^{18}O$ analyses of leaf water and leaf matter (cellulose and starch) in order to provide a more complete picture of the fractions occurring between tree crown and stem, and to model these changes mechanistically.

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Diurnal variation in the carbon isotope composition of phloem sap in Picea abies

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Abstract

During my visit I tested and adapted a method for the isolation of sugars from phloem sap samples for stable carbon isotope analysis.

The phloem sap exudation technique was first described by King and Zeevaart (1974). The protocol involves exudation of phloem sap into an EDTA solution. EDTA as a chelating agent prevents callus formation induced by Ca^{2+}. As the ratio of EDTA to phloem sap sugar in the exudation solution is high mere calculation of the contribution of carbon isotope composition of EDTA to the carbon isotope composition of the total sample (i.e. EDTA + phloem exudate) is not reliable. We compared two different protocols for ion-exchange chromatography to remove EDTA and other ionic substances.

The adapted method was used for the determination of the $\delta^{13}C$ value of phloem sap samples taken during a field study in a boreal forest. In this study soil respired CO_2 from girdled and non-girdled plots was sampled over a 48 h period with sampling intervals of 4 h in a *Picea abies* forest. Additionally, phloem sap samples were taken in the non-girdled plots.

We found no correlations between the $\delta^{13}C$ of phloem sap and meteorological parameters. However, the $\delta^{13}C$ of the phloem sap was significantly correlated with the corresponding $\delta^{13}C$ of soil-respired CO_2 measured at the same time Thus it seems that the carbon isotope composition of phloem sap sugars could be used as a proxy for the carbon isotope composition of carbohydrates that are shuttled down to the roots and feed autotrophic respiration. The data obtained during my visit at the Department of Chemical Physiology of Plants has been published in Tree Physiology 27, 749-756.

Girdled stem (Pinus sylvatica)

King RW, Zeevaart JAD (1974) Enhancement of phloem exudation from cut petioles by chelating agents.
Plant Physiology 53:96-103.

Publications:

N.R. Betson, **S.G. Göttlicher**, M. Hall, G. Wallin, A. Richter and P. Högberg (2007)
No diurnal variation in rate or carbon isotope composition of soil respiration in a boreal forest
Tree Physiology 27, 749 – 756

S.G. Göttlicher, K. Steinmann, N.R. Betson and P. Högberg (2006)
The dependence of soil microbial activity on recent photosynthate from trees
Research Article, Plant and Soil 287, 85 – 94

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Drought in the Aegean assessed by stable isotopes in tree rings

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Abstract

The use of stable isotopes will allow the investigation of the development of drought trends in the Eastern Mediterranean as experienced by long-living organisms, aiming to offer a test of IPCC scenarios and, thus, assist model verification. Including the $d^{18}O$ from tree rings we can study how trees in the Mediterranean adapt to severe decreasing trends of annual precipitation. Our purpose has been to determine if there is a change, in tree water uptake zones during drought conditions, and to identify temporal shifts in periods of rainfall that are particularly important for annual tree growth.
The goal of this visit therefore was to shed light on the climatic development during the last century in the eastern Mediterranean and on how trees of this region have coped with these conditions.

The ^{13}C signals of three "drier habitat" old aged trees present a declining trend. These signals are derived from selected pointer years of both high and low growth rates during the last 80 years. The declining trend of the Δ signals suggests that plant ^{13}C discrimination decreased during the last decades. For the same period both tree growth (irrespective of age trend) and annual precipitation data for the island of Samos present a declining trend. The highest values in Δ signals appear at the first decades of the 20^{th} century during the years 1920 (Δ = 18,47) and 1927 (Δ = 18,22), while the lowest values appear during the last decades at the years 1990 ($\Delta^{13}C$ = 16,67) and 1983 ($\Delta^{13}C$ = 16,75) and match with periods of low precipitation.

From the "wetter" habitats, where we analysed middle-aged trees for the last two decades of the 20^{th} century, we obtained results from one tree. The Δ signals for ^{13}C from this tree, that cover both years of high and low growth rate for the period of the last 55 years, shows a declining trend as well. The highest values in the Δ signals appear in the middle of the 20^{th} century during the years 1949 (Δ = 24,48) and 1946 (Δ = 24,35), while the lowest values appear during the last decades in the years 2000 (Δ = 15,40) and 1997 (Δ = 15,53). These years also coincide with the two years of the lowest annual precipitation ever recorded for the island of Samos, which was 409 mm of rainfall in 1997 and only 353 mm in the year 2000 (Samos mean annual precipitation for the period 1931-1940, 1947 – 2000 is 806 mm).

Therefore signals from pointer years of low growth rate of *Pinus halepensis* are a good indicator for the frequency and intensity of drought during the last century, using chronologies of trees of different age classes, growing on both, ridges and depressions.

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Oxygen Isotopic Signature of CO2 from Combustion Processes – Differentiation by diverse Burning Regimes

Marcus Schumacher

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Abstract

Aim of the project was the qualification of the oxygen isotope ratio in combustion derived CO_2. Until now a general $d^{18}O$ value of -17‰ (VPDB-CO_2) for combustion CO_2 is assumed [Ciais et al. 1997], deduced from the complete consumption of all available atmospheric oxygen. Hypothesis of the project was that fractionation might happen, because of diffusive processes during the combustion processes and because of diverse burning conditions, resulting in different $d^{18}O$ values.

By laboratory experiments it could be shown that the oxygen isotopic signature ($d^{18}O$) of combustion derived CO_2 varies with different material, oxygen availability and combustion conditions by several promille. To identify the drivers and to quantify their potential contributions the primarily defined investigation strategy had to be enhanced. In order to show the impact of these variabilites a wide range of materials and subsamples (like needles, wood, bark) were measured from a number of sites along west-east and north-south transects through Europe. Depending on the oxygen availability the $d^{18}O$ in the derived CO_2 from natural gas combustion differed about 3 ‰. The difference in $d^{18}O$ from the combustion of coal and wood was in the order of about 5 ‰.

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Fire Life Cycle

Oxygen Isotopic Signature of CO2 from Combustion Processes – Enhancend Analyses of fundamental Driving Parameters

Marcus Schumacher

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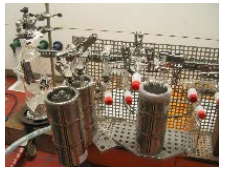
Fuel material samples



Combustion and extraction system

Wild fire

Abstract

Consumption of fossil fuels, biomass fuels and emissions from wild fires contribute directly to the global carbon cycle. For the comprehension of the full cycle precise information about all involved processes are necessary which are however not yet achieved. To reach this goal suitable tracers are still asked for the qualification and the quantification of the diverse sources and to enhance the knowledge that forms the basis for further modelling efforts. Stable isotopes might be probate tools to add useful information.

From laboratory studies performed with optimal oxygen availability variability in the isotopic signature ($d^{18}O$) of combustion derived CO_2 in the order of about 25 ‰ became obvious. Complex interactions and reaction couplings of the key parameters

chemical composition and structure of the material and of the combustion temperature and its timing could be identified as drivers regulating via the burning reaction the specific isotopic signatures. A clear differentiation of about 7 ‰ was also found in car exhausts which were sampled directly under ambient atmospheric conditions.

Publications:

M. Schumacher, R.E.M. Neubert, H.G. Jansen, H. Geilmann, W.A. Brand, R.A. Werner, H.A.J. Meijer
Oxygen Isotopic Signature of CO_2 from Combustion Processes

In preparation

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Dendroecology study in FACE sites

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Abstract

Tree rings are good proxies for reconstruction of the past climate and environmental changes. Stable isotope analysis in tree rings are a useful tool for studying various aspects of tree physiology and metabolism: in several studies $d^{18}O$ and $d^{13}C$, are used to interpret tree responses in terms of photosynthetic capacity or stomatal conductance (Farquhar et al. 1994; Yakir & Israeli 1995; Scheidegger et al. 2000) and to evaluate the effect of elevated CO_2 on trees (e.g. Cooper & Norby, 1994; Pataki et al. 2003).

In this project, we propose with a unique effort involving most of the forest FACE sites in Europe and USA, to investigate the effects of CO_2 enrichment on tree rings and plant physiology. PopFACE in Tuscania (Italy); Oak Ridge in Tennessee and Duke FACE in Orange County in North Carolina are experimental sites where trees are exposed to elevated (more or less 200 ppm over ambient level) and ambient CO_2 concentrations as control. A part of the PopFACE site is a plantation where Populus tree species were planted at the beginning of the fumigation, in 1999; in the other 2 sites the trees are older (the Oak Ridge site plantation was established in 1988 while the CO_2 treatment started in 1998; the Duke forest stand was planted in 1983 and the fumigation started in 1996).

Wood core drilling

Publications:

Dendroecology Study in FACE Systems (in preparation)

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Carbon sequestration, isotopic characterization and soil flux partition in different soils under the footprint of a coastal CO2-eddy-flux tower

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Abstract

The intention of the study was to examine the carbon dynamics in three different ecosystems (agricultural, marsh grassland and sandy islands) positioned under the footprint of the eddy-flux tower of Lutjewad. Therefore it should be determined: (i) soil carbon content, (ii) the age of the soil organic carbon and (iii) its recycle time. With these information and the basic characterization of the soils the contribution of these ecosystems to the atmospheric CO_2 content should be calculated. Furthermore new information to the question of the carbon budget in coastal seas area should be delivered to help interpreting the eddy-flux measurements at the Lutjewad tower.

During the study soil profiles from all the sites were analyzed for basic characterization (pH, bulk density and texture). Total budget of soil organic C and N was estimated. Samples of bulk soil were prepared and are on the way to be measured for their radiocarbon content.

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Contribution of the most recalcitrant part of the soil organic matter to total soil respiration

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Abstract

Topic of the project was to assess the contribution of the recalcitrant part of soil organic matter (SOM) to total soil respiration with respect to different land use histories. Therefore we considered a chronosequence, covered by a marsh grassland and by two agricultural fields. The marsh grassland represents the original soil of the area, while the two agricultural fields were recovered from the sea in the 1929 and 1802, respectively. All sites are located in the surrounding of the Eddy flux tower in Lutjewad (Groningen).

Samples of the bulk density were taken in each horizon; oven dried, weighted, sieved at 2 mm and analysed for their basic characteristics (pH, texture, carbon and nitrogen). For the analysis of the ^{14}C concentration, by using proportional gas counter technique, the samples from the first two horizons of the three sites had additionally underwent a chemical fractionation according to Rovira and Ramòn Vallejo (2002).

The sample preparation requires also a combustion phase in which the CO_2 evolved from the soil sample is isolated, purified and collected. Subsequently the CO_2 is stored for one month to let the Radon decay, before the measurement of the ^{14}C concentration can be performed. Measured ^{14}C concentrations of the recalcitrant fraction from the first two horizons will be used to determine the relative turnover time at the three sites. These results will be subsequently entered into the simple model proposed by Harrison et al. (2000), combined with the data of total soil CO_2 flux measured at the Lutjewad Eddy tower to get an estimate of the contribution of the recalcitrant SOM fraction.

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Agricultural field (meliorated 1802)

Agricultural field (meliorated 1928)

Comparison of the diurnal and seasonal variations in pi/pa with carbon isotope discrimination of leaf and stem soluble sugars in a managed oak forest with differencing understory

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Diurnal variation in the delta13C of soil respired CO2 on girdled and non-girdled plots of Scots Pine (Pinus sylvestris)

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Publications:

N.R. Betson, S.G. Göttlicher, M. Hall, G. Wallin, A. Richter and P. Högberg (2007)
No diurnal variation in rate or carbon isotope composition of soil respiration in a boreal forest
Tree Physiology 27, 749 – 756

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Climatic variations and N supply as determinants of delta13C of foliage of Pinus sylvestris L.

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Workshops

· ***Stable Isotopes in Soil Science, Plant Ecology and Biosphere-Atmosphere Exchange***

Umeå, Sweden, 15-24 September 2003

Since the first European short course on the use of stable isotopes in ecology, in Evora, Portugal, which was a success and had many applicants, we decided that such courses should be arranged regularly. The Umeå course was organized jointly by SIBAE and The Research School in Soil Science at SLU. More than 50 students from throughout Europe applied, out of which 37 were admitted. Lecturers were SIBAE SC members as well as other internationally recognized researchers. The course received a very favourable final evaluation by the students.

· ***Stable isotopic signals of the terrestrial biosphere: linking ecosystem C fluxes to isotopic signals of plant components***

Orvieto, Italy, 18-21 November 2003

The objective of the workshop was to review the state-of-the-art in the field of stable isotopes across a range of topics from leaf to ecosystems scale. The topics were the isotopic signals in plant and ecosystem components and compound specifics, and respiratory sources and ecosystem discrimination. The workshop provided the opportunity for open discussion on methodologies and their current constraints, and new opportunities and approaches on the horizon. New joint studies concerning oxygen isotopes in the hydrological cycle in terrestrial ecosystems were discussed, coordinated among SIBAE and BASIN scientists, contributing to the global network being set up by IAEA-Vienna (MIBA).

· ***Stable isotope ratio infrared spectroscopy (SIRIS)***

Vienna, Austria, 6-8 September 2004

The first international workshop on "Stable Isotope Ratio measurements by means of Infrared Spectrometry" (SIRIS 2004) was attended by a total of 45 scientists (of whom 32 speakers) in the fields of laser spectroscopy, laser development, and stable isotope ratio measurements. The interaction between optical isotope ratio instrumentation developers and the (potential) end users was deemed highly timely and very useful by all. The workshop has already led to a number of joint research projects/proposals and collaborations as well as a COST Action proposal.

· ***Oxygen isotopes as a tracer linking global O_2, CO_2, and H_2O cycles***

Joint BASIN-SIBAE workshop in Marshall, USA, 19-22 October 2004

Current understanding of mechanisms for oxygen isotope fractionation and their application in global biogeochemical cycles was summarized. Gaps of knowledge as well as critical uncertainties were identified that must be addressed before using oxygen isotope tracers as a tool in understanding biological functioning at ecosystem, regional, and global scales. Topics included oxygen isotopes of water from the leaf to the globe, oxygen isotopes of atmospheric CO_2, and isotopic composition of atmospheric O_2.

· ***Analysis of Carbon Isotope Composition of Soluble Carbohydrates and Starch***

Jena, Germany, 2-4 November 2004

A prerequisite for partitioning of net fluxes into their component fluxes is the precise knowledge of the isotopic signatures of the substrates of plant respiration. The workshop therefore aimed at evaluating existing methods for the determination of the carbon isotope composition of starch from plant tissues. The comparisons elucidated that the various methods yield significantly different $d^{13}C$ values, indicating the urgent need for refining existing methods or develop new ones. A network of researchers across Europe was established to further approach the identified problems.

· ***Stable Isotopes in Dendroclimatology – Current Status and Future Prospects***

Potsdam, Germany, 11-16 February 2007

The workshop primarily assed the potential of isotope dendroclimatology for climate reconstruction, including also the possibility of incorporating other tree ring proxies such as density or tissue increment. Questions were addressed with respect to the identification of necessary future developments to advance the interpretation of isotope proxies, to pave the way for novel ideas and to denote fields in which projects should be promoted or encouraged.

· ***Disentangling abiotic and biotic effects on soil respiration***

Innsbruck, Austria, 12-13 March 2007

Aim of the workshop was the exploration of possibilities to improve our understanding of processes determining soil CO_2 efflux. In a first section the state of the art was elaborated by short overview presentations and a poster session, forming the basis of grouped discussion forums dedicated to the identification of major research questions which need to be addressed in the future. During the third part of the workshop hypotheses and experimental approaches to the conclusions of the forums were discussed and finally the possibilities of a joint integrated study was considered.

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Innsbruck workshop

'Disentangling abiotic and biotic effects on soil respiration'

Programme (pdf, 52kb)

Markus Reichstein: Linking soil process models and experiments for improved understanding of soil organic matter dynamics (pdf, 800kb)
Nina Buchmann: Components of soil respiration and their response to environmental drivers (pdf, 1200kb)
Ivan Janssens: Should ecosystem manipulation experiments address temperature acclimation? (pdf, 14kb)
Jorge Curiel Yuste, Dennis Baldocchi, JW Tang and L Xu : How switches and lags in biophysical regulators affect spatial-temporal variation of soil respiration (pdf, 2600kb)
Alf Ekblad, Daniel Comstedt and Björn Boström: Linking canopy photosynthesis and soil respiration using stable isotopes (pdf, 940kb)
Phil Ineson, Andreas Heinemeyer, Iain Hartley and Jens Subke: Forest ectomycorrhizal contributions to soil CO2 efflux (pdf, 2900kb)
Sébastien Fontaine: The priming effect and its implication for soil modelling (pdf, 120kb)
Karolien Denef: Soil organic matter quality: implications for microbial functioning and carbon turnover (pdf, 138kb)
Andreas Richter: Does environmental change affect soil respiration through activity shifts in microbial communities?
Richard Bardgett: Trophic interactions and their role for soil C fluxes (pdf, 7700kb)
Rolf Siegwolf: Variation in soil d13C: a seasonal or temperature driven change? (pdf, 900kb)
Daniel Epron: Can we use 13C for separating autotrophic versus heterotrophic respiration? (pdf, 1000kb)
Jaleh Gashghaie: Carbon isotope fractionation during root respiration (pdf, 400kb)
Bernard Longdoz: Isotopic fractionation during CO2 diffusion in soil (pdf, 310kb)
Dan Yakir: Can we use O2 and 18O-O2 in soils to distinguish biotic/abiotic effects? (pdf, 72kb)
Yakov Kuzyakov: Potentials and limitations of mesocosm experiments for evaluation of abiotic and biotic effects on soil respiration (pdf, 1100kb)
Peter Högberg: A larger scale forest 13C-labelling experiment. Design and preliminary results

Report (pdf, 50kb)

ESF programme „Stable Isotopes in Biospheric-Atmospheric Exchange (SIBAE)“

Workshop on ‘Disentangling abiotic and biotic effects on soil respiration’

Innsbruck, 12th - 13th March 2007

Abstract

The workshop aims to gather a group of scientists encompassing a variety of perspectives on processes determining soil CO_2 efflux in different types of ecosystems in order to explore novel approaches for disentangling abiotic and biotic effects on soil respiration and incorporating this process understanding into a formalized model.

Summary of background and aims

Soil respiration constitutes the second largest flux of carbon between terrestrial ecosystems and the atmosphere. Due to this substantial contribution of soils to the global carbon cycle it is essential to improve our estimates of current and future soil CO_2 efflux. Unfortunately, current models of soil respiration are mostly based on simplistic assumptions that largely ignore biotic influences on soil CO_2 efflux. Such biotic factors include seasonal shifts of fine root mass and microbial populations and their respective activities, as well as priming effects on SOM decomposition by inputs of labile organic carbon as related to photosynthesis and fresh litter. Due to confounded effects of co-varying environmental drivers and biotic processes, monitored diurnal and seasonal changes of soil respiration in the field are of limited value for developing and testing more process-based models. For this purpose it would be useful to design experiments manipulating single drivers of soil respiration in undisturbed soil while tracing the various soil carbon sources using stable isotopes. The proposed workshop aims to explore possibilities of improving our understanding of processes determining soil CO_2 efflux that may emerge by 1) carrying out controlled mesocosm and ecosystem manipulation experiments, 2) incorporating the findings in a process-based model of soil C cycling and CO2 efflux and 3) testing and validating the model for a range of different ecosystems.

Meeting Programme

12th March 2007

9:00 – 9:30 Welcome and Introduction of workshop aims and participants

9:30 – 10:30 **State of the art and identification of major issues** (1)

Markus Reichstein: Linking soil process models and experiments for improved understanding of soil organic matter dynamics

Nina Buchmann: Components of soil respiration and their response to environmental drivers

Ivan Janssens: Should ecosystem manipulation experiments address temperature acclimation?

Jorge Curiel Yuste, Dennis Baldocchi, JW Tang and L Xu : How switches and lags in biophysical regulators affect spatial-temporal variation of soil respiration

Alf Ekblad, Daniel Comstedt and Björn Boström: Linking canopy photosynthesis and soil respiration using stable isotopes

Phil Ineson, Andreas Heinemeyer, Iain Hartley and Jens Subke: Forest ectomycorrhizal contributions to soil CO_2 efflux

10:30 – 11:00 Coffee break

11:00 – 12:30 **State of the art and identification of major issues** (2)

Sébastien Fontaine: The priming effect and its implication for soil modelling

Karolien Denef: Soil organic matter quality: implications for microbial functioning and carbon turnover

Andreas Richter: Does environmental change affect soil respiration through activity shifts in microbial communities?

Richard Bardgett: Trophic interactions and their role for soil C fluxes

Rolf Siegwolf: Variation in soil $d^{13}C$: a seasonal or temperature driven change?

Daniel Epron: Can we use ^{13}C for separating autotrophic versus heterotrophic respiration?

Jaleh Gashghaie: Carbon isotope fractionation during root respiration

Bernard Longdoz: Isotopic fractionation during CO_2 diffusion in soil

Dan Yakir: Can we use O_2 and ^{18}O-O_2 in soils to distinguish biotic/abiotic effects?

12:30 – 14:00 Lunch break

14:00 – 18:00 **Identification of major issues** (3)

Yakov Kuzyakov: Potentials and limitations of mesocosm experiments for evaluation of abiotic and biotic effects on soil respiration

Discussion on identification of major issues (three working groups)

16:00 – 16:30 Coffee break

17:30 – 18:00 Reports by working groups, plenary discussion

18:30 Dinner

20:00 – 21:00 Poster session

13th March 2007

8:30 – 12:30 **Experimental approaches (1)**

Peter Högberg: A larger scale forest ^{13}C-labelling experiment. Design and preliminary results.

Discussion on approaches for addressing major issues (three working groups)

10:30 – 11:00 Coffee break

11:00 – 12:30 Reports by working groups, plenary discussion

12:30 – 14:00 Lunch break

14:00 – 15:45 **Experimental approaches (2)** Reports by working groups, plenary discussion

General discussion (a.o. on possibilities of realizing a joint study) and conclusion

15:45 – 16:15 Coffee

Posters

Baptist Florence, C. Flahaut and Ph. Choler : The interplay of temperature and organic matter quality on the alpine soil respiration along a snow cover gradient

Brüggemann Nicolas and D. Steigner: Diurnal courses of concentration, $\delta^{13}C$ and $\delta^{18}O$ of CO_2 from the soil and above the canopy of maize growing on a former C_3-plant dominated field

Grünzweig José M., E. Rotenberg, K. Maseyk and D. Yakir: Climate and canopy controls over soil CO_2 efflux in a semi-arid pine forest

Karhu Kristiina and J. Liski: Temperature sensitivity of the decomposition of different SOM-fractions assessed by using carbon isotopes.

Misson Laurent, S. Rambal, R. Joffre and J. Ourcival: Ecosystem functions at different spatial- and temporal-scales

Ngao Jerome, M. Rubino, A. Castrillo, R. Wehr, L. Gianfrani and M.F. Cotrufo: Isotopic Discrimination During Leaf Litter Decomposition

Pumpanen Jukka, J.Heinonsalo, T.Rasilo and H. Ilvesniemi: Carbon budget of Scots pine and Silver Birch seedlings determined with CO_2 exchange measurements and ^{14}C pulse labeling under controlled laboratory conditions

Rubatscher Dagmar, K. Wohlmuth, H. Insam and M. Bahn: Is litter decomposition affected by plant and microbial functional diversity and land use?

Schmitt Michael, N. Pfahringer, R. Siegwolf and M. Bahn: Differential effects of fresh organic carbon supply on microbial versus root respiration in clipped and shaded grassland

Subke Jens-Arne and P. Ineson: A mesocosm approach to investigate soil C priming

Unger Stephan, J. Santos-Pereira, C. Máguas and C. Werner: Dynamics of $\delta^{13}CR$ and $\delta^{13}CSoil$ in a Mediterranean type ecosystem following rain pulse events after drought.

Wingate Lisa, U. Seibt, K. Maseyk, P. Almeida, D. Yakir, J.S. Pereira and M. Mencuccini: Oxygen stable isotope signals of net soil CO_2 efflux record changes in soil evaporation and indicate the presence of carbonic anhydrase in Mediterranean soils.

Yevdokimov Ilya and M. Bahn: Partitioning of root and microbial respiration in Alpine grassland

This workshop is financially supported by the European Science Foundation Programme ‘Stable Isotopes in Biospheric-Atmospheric Exchange’,
is carried out in collaboration with the European Science Foundation Programme ‘The Role of Soils in the Terrestrial Carbon Balance’
and is hosted by the Research Focus ‘Ecology of the Alpine Region’ of the University of Innsbruck.

Workshop Participants

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ESF programme „Stable Isotopes in Biospheric-Atmospheric Exchange (SIBAE)“

Workshop on ‘Disentangling abiotic and biotic effects on soil respiration’

Innsbruck, 12th - 13th March 2007

REPORT (compiled by M. Bahn)

1) Summary (up to 1 page)

The workshop ‘Disentangling abiotic and biotic effects on soil respiration’ aimed to explore possibilities of improving our understanding of processes determining soil CO_2 efflux.

In a first section the state of the art was elaborated in short overview presentations and a poster session that 1) addressed the importance of developing approaches to understanding components of soil CO_2 efflux and their abiotic and biotic controls (including the supply of fresh photosynthates, acclimation, trophic interactions, microbial community structure, the quality and accessibility of soil organic matter, as well as the soil carbonate system), 2) reviewed the potentials and limitations of applying stable isotopes (especially ^{13}C) for tracing fluxes and separating flux components, and 3) gave examples of ongoing research on the topic, comprising various scales from mesocosm to ecosystem.

The second part of the workshop was dedicated to an identification of major research questions that need to be addressed in the future. From discussions in three working groups it became apparent that these questions are best placed in the context of global change. The following issues emerged:

- Partitioning (substrate availability, allocation, link to N cycle, soil and vegetation type, phenology) as affected by changing environmental conditions
- Turnover of soil C: effects of quality/quantity of soil C input (litter, exudates, DOC, DIC) on decomposition and mechanisms of stabilization and destabilization (aggregates, priming) including aspects of soil type, vegetation type, and the N cycle
- Effects of different proportions of functional groups (e.g. fungi/bacteria, soil fauna) on SOM pools and fluxes
- Modelling: Generic soil model with improved interface between ecophysiology (C allocation) and soil modules; representation of vertical heterogeneity, biotic interactions including abiotic controls, and physico-chemical stabilization

During the third part of the workshop hypotheses and experimental approaches to the above topics were discussed. There was a common agreement that 1) mesocosm and field experiments should be combined, and should be closely linked to process modelling, 2) ecosystem experiments should make use of existing gradients in climate, vegetation and soil type, 3) isotopic tracing (^{13}C, ^{14}C) will be useful for improving our understanding of links between components, and 4) the quality and quantity of soil organic matter pools need to be defined and assessed more consistently with respect to stabilization and destabilization mechanisms and their link to microbial community structure. In a final session possibilities of realizing a joint integrated study were discussed. A future meeting next autumn will be dedicated to developing a proposal for a European project, as based on the outcome of this workshop.

2) Description of the scientific content of and discussion at the event (up to 4 pages) and 3) Assessment of the results and impact of the event on the future direction of the field (up to 2 pages)

State of the art

In a lecture and a poster session the state of the art of various perspectives on soil carbon fluxes was summarized, and examples of ongoing research on the topic were given, including a number of mesocosm and ecosystem studies. In recent years some advances have been made concerning our understanding of components of soil CO_2 efflux and their abiotic and biotic controls. This includes 1) the role of fresh organic carbon (as derived from photosynthesis or litter) for soil organic matter decomposition (priming effect) and mycorrhizal respiration, 2) the potential role of acclimation of autotrophic and heterotrophic respiration as resulting from a range of temperature-related effects on demand and supply rates, 3) the role of trophic interactions as determinants of litter quality, soil carbon turnover and its interaction with the nutrient cycle, 4) the importance of the microbial community structure and its link to the quality and accessibility of soil organic matter, 5) the potential importance of the soil carbonate system for soil CO_2 efflux. All these issues still remain major challenges. Future research needs to be based on concise and agreed definitions of the components and an improved integration of models and experiments at various scales. Such an integration will be better achieved by modelling the measurable and by designing experiments that provide multiple constraints on models and can be compared and linked at the same level of integration. Stable isotopes have been shown to be useful tools for tracing fluxes and separating flux components, yet the interpretation of results is often limited and complicated by the fact that little is known about the post-photosynthetic fractionation of $d^{13}C$ and about the metabolic origin of root and microbial respired CO_2 and the isotopic discrimination during diffusion.

Identification of major research questions

The second part of the workshop was dedicated to an identification of major research questions that need to be addressed in the future. From discussions in three working groups it became apparent that these questions are best placed in the context of global change. The following issues emerged:

- Partitioning (substrate availability, allocation, link to N cycle, soil and vegetation type, phenology) as affected by changing environmental conditions
- Turnover of soil C: effects of quality/quantity of soil C input (litter, exudates, DOC, DIC) on decomposition and mechanisms of stabilization and destabilization (aggregates, priming) including aspects of soil type, vegetation type, and the N cycle
- Effects of different proportions of functional groups (e.g. fungi/bacteria, soil fauna) on SOM pools and fluxes
- Modelling: Generic soil model with improved interface between ecophysiology (C allocation) and soil modules; representation of vertical heterogeneity, biotic interactions including abiotic controls, and physico-chemical stabilization.

In addition the following methodological questions were identified:

- Which soil physical factors (moisture, temperature, soil type) affect CO_2 fluxes and isotope fractionation?
- Can we identify biologically meaningful SOM pools?

Hypotheses and experimental approaches

During the third part of the workshop hypotheses and experimental approaches to the above topics were discussed in smaller working groups. The major outcome of these discussions, and on implications for a cross-cutting topic linking experiments and process models is summarized in the following four reports.

Report of the working group on 'Carbon Partitioning'
(compiled by N. Buchmann)

Objective: To understand carbon partitioning (substrate availability for heterotrophs, plant allocation belowground, phenology, link to N cycle, vegetation and soil types, …) and its response to environmental change

The group discussed some basic aspects first:

- What research approaches are more appropriate to tackle this objective: mesocosms (under controlled or ambient conditions), field studies or both? The unanimous opinion was: we need both approaches, nested, dependent on the research question we are interested in.
- The process of partitioning needs research at different temporal time scales, from hourly to decadal.
- Approach: use isotope tracer (^{13}C label, ^{14}C bomb carbon) to follow the C signal through the whole continuum from atmosphere to plant to roots to mycorrhiza to SOM.
- Short-term labeling could be done as pulse-chase experiment (above or below-ground label, dependent on vegetation height), continuous label, stepwise label (i.e., step-increase, longer label than pulse chase), transplants, space for time experiments.
- Long-term labeling: FACE, C3-C4 vegetation shift, labeled litter, bomb carbon, management/fertilization manipulation sites.
- Environmental change factors: There are plenty of relevant factors, but temperature and precipitation (average, sum, variability, extremes) as well as N (less so CO_2 or O_3) were of most interest to most of us.

- It was agreed on that several methods should be used (if appropriate) to define the upper and lower boundaries of our estimates.
- Since the set-up, the necessary infrastructure and previous knowledge is decisive for the success of the study, we suggested to make use of existing facilities, e.g. flux tower sites, FACE sites, manipulation sites, etc. (e.g., flux sites throughout Europe, drought sites in France, etc.).

The group then set out to design a generic, preferentially cheap pulse-chase experimental design that could easily be replicated and make more complicated if necessary/possible:

- Rather carry out experiment at many different sites than at only a very small number. Potential sites are in France (beech in Nancy, oak in Orsay and Puechabon, pine in Bordeaux), Switzerland (mixed deciduous forest, grasslands), UK (oak, pine), Germany (young beech, spruce/Höglwald), Portugal (oak in Mitra), Austria (grasslands), Sweden (mainly pine), Israel (pine), Finland (pine), others?
- Labeling at different times during the year, at phenological interesting times (thus info on phenology is critical)
- Labeling of forests and grasslands (nobody was interested in arable crops), much knowledge about pools, fluxes, phenology, soils needed. Electricity is crucial.
- Label with ^{13}C, short vegetation with chamber, large vegetation either only partially (difficult) or only soil (roots have PEPcarboxylase, mycorrhiza have pyridine-carboxylase, and take up CO_2 as well)
- ^{13}C in CO_2 measurements: preferentially with TDL/QCL connected to chambers (needs careful intercalibration among instruments, crosscalibration with IRMS, similar/identical chamber design across sites); flasks/exetainer collection and IRMS measurements possible but very time consuming and labor intensive
- Separation of soil respiration into components using mesh bags with different mesh sizes (not usable for pulse chase, but for fluxes only); for pulse chase: excised roots approach
- soil: soil physical properties need to be known as well as $d^{13}C$ of bulk soil, soil fractions, microbes (using fumigation, PLFA, maybe SIP-DNA)
- plant ecophys needs to be known (Amax, gs, NPP, etc.) at leaf and canopy level
- ^{13}C in carbohydrates (i.e., sugars, starch) in foliage, phloem, roots. IRMS periphery in Garmisch, Jena, Vienna, Paris, Ghent, maybe in Montpellier
- link to N cycle; either with N cycle measurements (NH4 and NO3 conc, Nmin, Nmic, N status of foliage) or using ^{15}N labeled litter to investigate long-term relationships to C stabilization
- In general: need to link up with other breakout groups, e.g. on soil C turnover and soil fauna.

<u>Report of the working group on 'Turnover of soil C'</u>
(compiled by K. Denef)

Objective: To understand the turnover of soil C, in particular effects of quality/quantity of soil C input (litter, exudates, DOC, DIC) on decomposition and mechanisms of (de)stabilization (aggregates, priming) including aspects of soil type, vegetation type, N-cycle

Hypothesis 1: *A change in quantity and quality of carbon inputs (e.g. litter, exudates) will affect the decomposability of existing SOM pools*

Methodology:

1. *Challenges:*

- Defining C input 'quality'
    - Conventional indices: C/N, lignin/N,…
    - Alternatives (potential biological meaning)?

i. Respiratory quotient ($CO_{2,\ produced}/O_{2,\ consumed}$)
ii. ^{13}C (from labeled substrate) incorporation into microbial PLFAs

- What do we mean with 'existing SOM pools'
  - Development of a (simplified?) fractionation scheme to isolate meaningful SOM pools with specific stability/recalcitrance (providing indication of the mechanisms of stabilization)
    i. Physical fractions (aggregate-occluded vs. free POM; light vs. heavy POM fractions)
    ii. Microbial pools (microbial biomass, microbial residues)
    iii. DOC/DIC pools
- How to follow SOM pool dynamics ((de)stabilization): Dual-tracer incubations (possible?):
  i. ^{13}C-labeled substrate addition: to follow the incorporation into and transfer between SOM fractions of new substrate-C
  ii. ^{14}C measurements to follow dynamics of older C
  iii. Microbial communities involved (e.g. fungi vs. bacteria?)

2. Experimental approach

- Dual-tracer incubations (see above) and new fractionation scheme: measuring changes in SOM pools over time, as well as incorporation/loss of tracers into or from different SOM pools (physical fractions, microbial pools, DOC, DIC) over time; measurements of tracers in the SOM pools and in respired CO_2.
- Parameters to manipulate:
  i. 'quantity' of carbon input → possible manipulations by e.g. changing amount of litter or exudate substitute inputs; plant productivity; LAI (by clipping)
  ii. 'quality' of carbon input → different litter quality inputs (in terms of definitions described above)

Hypothesis 2: *Climate change will affect different SOM pools (as well as their conversion rates) not equally*

Methodology:

- Field experiments:
  i. Use of existing climate gradients (e.g. sites across Europe)
  ii. Transplanting different soil types (e.g. each soil type used across the climate gradient)
- Mesocosm experiments: to manipulate climate while keeping all other factors (soil, vegetation, moisture,…) the same.
- Dual-tracer incubations (see above) and new fractionation scheme: measuring changes in SOM pools (physical fractions, microbial pools, DOC, DIC) over time (e.g. soils from sites with past C3-C4 conversion for young (e.g. < 10 yr) vs. older (e.g. > 10 yr) SOM pools; ^{14}C for much older SOM pools (> 50 yr).

One extra idea we briefly discussed was to work with very old soils (paleosols) (→ presence of very old SOM-C) and to investigate how the C pool (old) in these soils can be altered

(manipulations) to better understand this fractions stability (mechanisms) and how to isolate/extract this fraction… (but we didn't have time to discuss this further).

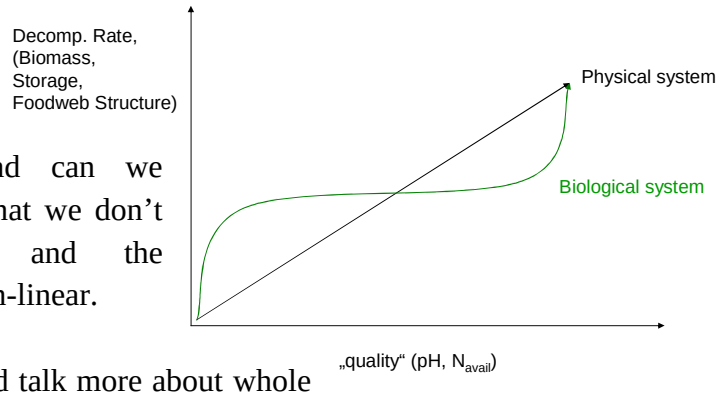
Report of the working group on 'Functional Groups'

(compiled by W. Kutsch)

Presumptions

There were some basic discussions in the beginning of the WG:

(1) Is it important to define the impact of the biological system in soils in terms of homeostasis (see: Lovelock's Gaia Hypothesis) and can we quantify this? Problems might be that we don't have any physical baseline and the physical processes also might be non-linear.



(2) Another premise was, that we should talk more about whole 'soil food webs' and less about 'functional groups'.

(3) Another basic idea was to define 'carbon availability'. This can not be done by chemical analysis alone, because easily decomposable compounds may be locked in aggregates and, therefore, unavailable. The role of soil biota in making soil organic matter available or unavailable has to be unravelled.

(4) It has be considered that the stoichiometry has an important influence on decomposition, priming and the fate of carbon that is entering the soil.

Key questions

There are basically two general types of soil food webs: bacteria dominated and fungi dominated FW and we defined two key questions for an experiment:

(a) What drives shifts between these FW? (pH, resource quality, vegetation type…)
(b) How does a shift between food webs influence carbon turnover, or better: the fate of carbon entering the soil.

Methodology:

(1) Constructing or destructing food webs
(2) Changing carbon and nutrient availability (Gradient A)
(3) Comparing different ecosystems (vegetation types) (Gradient B)

(4) 1-3 Combined with pulse labelling

The final suggestion was to make manipulation experiments (Gradient A) in different ecosystems (climate, vegetation, Gradient B).

Report on cross-cutting topic: Linking experiments and process models
(compiled by M. Reichstein)

The link between experiments, observational studies and process modelling was identified as a crucial cross-cutting issue during the workshop. A close link between modeling and experimental work strongly helps

- the design of experiments,
- with the interpretation of results from observational studies and experiments, and
- to evaluate the significance of experimental findings at higher levels of integration, e.g. ecosystem. region, earth system (up-scaling).

Presentations and discussions during the workshop revealed that current soil models underrepresent the role of soil biological-physicochemical interactions and of vertical transport and differentiation for biogeochemical processes, especially in the context of coupled climate-carbon cycle simulations like for the IPCC assessments. In particular, models of soil organic matter dynamics are largely based on passively decomposing pools, while the role of micro-biota with different strategies as well as meso- and macro-fauna is neglected, leading to a possible classification as "dead-soil paradigm models".

First examples of possible alternative model formulations have been presented and discussed. It is obvious that for example the 'priming effect' can be modeled once microbial populations are explicitly modeled. Also, the exact presentation of soil heterogeneity and soil physical processes (e.g. heat conduction, water distribution), has been identified as important issue, particularly when field experiments are conducted, where possible confounding factors (e.g. lag effects introduced by lagged heat penetration into the soil, as opposed to direct coupling to photosynthate transport) maybe corrected for by high-precision modeling.

There is a clear tradeoff between model complexity (and 'realism') and ability to parameterize the model from observations. However, once one is confident with the model structure, Bayesian multiple-constraint inverse modeling techniques can strongly facilitate the identification of model parameters of apparently overparameterized models. A discussion workshop on model-data integration techniques and model aided experimental design is planned for end of summer 2007 at MPI Jena.

Final discussion

The final discussion focused on the coupling of different soil carbon pools (including DIC) and microbial activity, and the necessity to improve the links between models and experiments. The workshop participants expressed their interest to work towards a joint project, possibly funded by the EU and complemented by smaller national projects. It is planned to meet again for one or two days in autumn in order to elaborate a project proposal. Such a meeting could either be hosted by the final conference of a possibly extended ESF programme 'The Role of Soils in the Terrestrial Carbon Balance' or be linked to the 5th Annual CarboEurope-IP Meeting in October.

Activities
Exchange Visits
Workshops
Spring School
Conferences

Spring School

Stable Isotopes in Ecology
Vienna, Austria, 2-13 April 2007

Stable isotopes of carbon, nitrogen, oxygen and hydrogen are built into organic substances by different physical and biological processes. These processes leave distinct isotopic fingerprints in organic matter, organisms, biosphere and atmosphere, that integrate in time and space. Therefore, stable isotope techniques are increasingly used in ecology, biogeochemistry and environmental sciences.
This course addressed graduate students and postdoctoral researchers that want to get a thorough introduction into the application of stable isotopes in ecology. The course focused on the use of stable isotopes of C, N, and O at the natural abundance level and as tracers.
It was based on lectures and discussions with internationally leading experts, on extensive seminars and practical experiments, which provided hands-on laboratory experience including the use of three continuous-flow isotope ratio mass spectrometers (Finigan Delta Plus and Advantage) equipped with GC, HPLC, pre-con, gas bench, and elemental analyzer front ends.

Activities
Exchange Visits
Workshops
Spring School
Conferences

Conferences

Joint SIBAE-BASIN conference in Interlaken, Switzerland, 1-4 April 2004

'Partitioning Fluxes between Biosphere and Atmosphere across Spatial Scales'

With a pre-meeting on "Technical aspects of mass spectrometry and atmospheric sampling", held 31 March 2004

Conference: Numerous ecosystem components contribute to the isotopic signal of biosphere-atmosphere exchange, thus increasing the uncertainties in attempting to partition the fluxes between major flux components. The purpose of this conference was to provide a forum to provoke discussions on open issues. It became very clear that our studies now have reached a temporal and spatial resolution, where the identification of isotopic signals of single metabolic intermediates and other storage pools is the next step. Prominent attention was given to regional and global isotopic disequilibria, illustrating the need for future integrated mass balance experiments under the coordination of SIBAE and BASIN.

Premeeting: A one-day methods premeeting on standards, calibrations and high precision measurements for stable isotopes was met by great interest of 61 participants from 21 countries. Great emphasis was given to methodological topics of atmospheric trace gas sampling, storage and analysis, prerequisites for scientific comparisons and good data acquisition. The need for cross-referencing and laboratory intercomparisons were discussed, and Prof. Diane Pataki distributed air and water samples for this purpose.

Joint SIBAE-BASIN conference in Tomar, Portugal, 13-15 March 2006

'Isotopes as Tracers of Ecological Change'

The 20th century has experienced environmental changes that appear to be unprecedented in their rate and magnitude during Earth's history. By the isotope composition of diverse materials including animal and plant tissues, soil organic matter, carbonates and the atmosphere proportions of these changes have 'recorded'. These data reveal that long-term monitoring of isotopes can provide indicators which may also be used to predict future environmental transformations. The meeting highlighted examples of where and how isotopic records from a wide range of research disciplines, from the fields of ecology, atmospheric science, anthropology, geochemistry and physiology, are reflecting changes in processes that can be seen in ecological times at different spatial scales.

The contributions of the conference were published in a book: Dawson T, Siegwolf R. 2007. Isotopes as Tracers of Ecological Change. Academic Press. Pp 350

Publications

Publications

· **Publication list from SIBAE activities**

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Water sources and water-use efficiency in Mediterranean coastal vegetation
Plant Biology 6: 350-357

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Rapid Communications in Mass Spectrometry 19: 1401 doi:10.1002/rcm.1911

S. Cerasoli, A. Scartazza, **E. Brugnoli**, M.M. Chaves, **J.S. Pereira** (2004)
Effects of partial defoliation on carbon and nitrogen partitioning and photosynthetic carbon uptake by two-year-old cork oak (*Quercus suber*) saplings
Tree Physiology 24: 83-90

J. Curiel Yuste, B. Konôpka, **I.A. Janssens**, K. Coenen, C. W. Xiao, Ceulemans R. (2005)
Contrasting net primary productivity and carbon distribution between neighboring stands of *Quercus robur* and *Pinus sylvestris*.
Tree Physiology, 25: 701-712

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Oecologia doi:10.1007/s00442-005-0078-4

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Tree Physiology 25: 1399-1408

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Pan-European $d^{13}C$ values of air and organic matter from forest ecosystems
Global Change Biology 11: 1065-1093, doi:10.1111/j.1365-2486.2005.00971.x

J.O. Kaplan, I.C. Prentice, **N. Buchmann** (2002)
The stable carbon isotope composition of the terrestrial biospheres. Modeling at scales from the leaf to the globe
Global Biogeochemical Cycles 16: 1060 doi:10.1029/2001GB001403

A. Knohl, **N. Buchmann** (2005)
Partitioning of net CO_2 flux of a deciduous forest into respiration and assimilation using stable carbon isotopes
Global Biogeochemical Cycles 19: GB4008, doi:10.1029/2004GB002301

A. Knohl, R.A. Werner, W.A. Brand, **N. Buchmann** (2005)
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Oecologia 142: 70-82, doi:10.1007/s00442-004-1702-4

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Comparison of fine root dynamics in Scots pine and Pedunculate oak in sandy soil
Plant and Soil 276: 33-45, doi:10.1007/s11104-004-2976-3

L.E. Nave and C.M. Gough (2006)
Quantifying ecological change using stable isotopes: digging deep into past to predict the future

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· **SIBAE Brochure**

Stable Isotopes in Biospheric-Atmospheric Exchange (SIBAE)
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