European Cooperation in the field of Scientific and Technical Research - COST -

Secretariat

Brussels, 11 December 2008

COST 255/08

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES0806: Stable Isotopes in Biosphere-Atmosphere-Earth System Research (SIBAE)

Delegations will find attached the Memorandum of Understanding for COST Action ES0806 as approved by the COST Committee of Senior Officials (CSO) at its 172nd meeting on 24-25 November 2008.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action ES0806

STABLE ISOTOPES IN BIOSPHERE-ATMOSPHERE-EARTH SYSTEM RESEARCH (SIBAE)

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 270/07 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to use stable isotopes on carbon, nitrogen, oxygen and water cycles as a critical research tool in Biosphere-Atmosphere-Earth System research across scales and disciplines to: 1) synthesize isolated experiments in Europe 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; (4) create a training/teaching network across Europe.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 68 million in 2008 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

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. An integrative, coordinated European platform for the use of stable isotopes in biosphere-atmosphere-Earth system studies is urgently needed to coordinate such research. Reaching out from a small already established network of European scientists, this Action aims 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. This Action provides unique opportunities to integrate scientists across Europe, to promote stable isotope applications for new research issues, e.g., sustainability research, and to link to international activities, thus creating added-value for policy-making and European societies. It leads to more integrated coordinated environmental research and to promote Europe at the forefront of science in this field.

Keywords: global change research, process- and system-oriented biogeochemistry, experiments and models, advancing technologies, training in stable isotopes

B. BACKGROUND

B.1 General background

There is a long tradition of environmental research in Europe, particularly within the framework of Environmental and Global Change, which has been supported by several national and European programmes over the last decades. However, major questions remain unresolved, especially with regards to the impact of land-use and management changes, increasing nitrogen (N) deposition and atmospheric carbon dioxide (CO_2) concentrations, and of interannual variation of meteorological parameters on carbon (C) sequestration in terrestrial ecosystems. This has an important effect on the temporal and spatial trend of the atmospheric CO_2 concentration and, thus, on future climate change and on sustainable use of natural resources. Our ability to predict the response of carbon exchanges between the biosphere and the atmosphere in response to climate change, and to study the feedback between climate and ecosystem functions is, for instance, limited by a lack of mechanistic description of carbon allocation in the plant-soil system, and it is therefore not possible yet to accurately predict carbon residence time in each of the ecosystem compartments. In this context, the linkage of carbon and water cycles is essential, as terrestrial carbon assimilation is often limited by water availability, which will be of high importance for the future (e.g., plant productivity in agriculture) but might experience an increasing limitation with the continuous global warming. To address this linkage, stable isotopes (^{13}C and ^{18}O) represent a very powerful tool. Another issue of high importance is the fate of nitrogen deposited in natural and managed ecosystems and the resulting impact on ecosystem C and N cycling that could lead to a stimulation of C sequestration on one hand, but to enhanced nitrous oxide (N_2O) emissions on the other; such effects could potentially outweigh the benefits of increased C sequestration due to the large greenhouse potential of N_2O.

Therefore, there is increasing urgency to better understand, both at basic and applied research levels, the Earth-System response to global change. However, the research tools available to us to address this highly complex issue and to constrain predictive models are greatly limited. Although stable isotopes provide an indispensable and powerful research tool, they have not yet been well integrated into European Biosphere-Atmosphere-Earth System research across scales and disciplines.

This is the more surprising as stable isotopes have already yielded significant breakthroughs, such as partitioning of CO_2 (using ^{13}C) and of oxygen (O_2, using ^{18}O) exchange fluxes between the land and the ocean; providing the only direct means to partition CO_2 fluxes on land between photosynthesis and respiration (^{13}C and ^{18}O), and between soil evaporation and plant transpiration (^{2}H and ^{18}O); providing the only tracer to quantify local and regional scale recycling of water (e.g. ~50% recycling in the Amazon based on water vapor ^{18}O and ^{2}H); partitioning between autotrophic and heterotrophic respiration in soils (using ^{13}C); estimating the rate of global O_2 cycle (^{18}O and ^{17}O); identifying trophic levels in ecosystems (^{15}N); quantifying atmospheric N_2 input to ecosystems (^{15}N); allowing distinctions in paleoclimatic records between temperature and precipitation effects; and many more. In all of these cases, stable isotopes helped address key issues that limited advance in our understanding of Earth-system processes.

Although of great potential, stable isotopes have been under-utilized in the European Biosphere-atmosphere research, due to different reasons: the need for special equipment and training, distinct applications in different disciplines (e.g. atmospheric science, hydrology, soil science, plant physiology, etc.). But currently, new opportunities arise with rapid technological development in stable isotope applications: (1) The traditional magnetic-sector isotope ratio mass spectrometry (IRMS) has recently been complemented by high precision near infrared spectroscopy, providing a whole new temporal dimension to stable isotope measurements and the ability to measure isotopologues. (2) The greatly increased precision now achieved in IRMS permits the use of long-neglected minor isotopes, such as ^{17}O, and the identification of non-mass dependent isotope effects. (3) New techniques have become available to assess compound-specific and site-specific isotopic compositions in organic materials. These new advances virtually opened new frontiers in science in general and in stable isotope research in particular that are only slowly penetrating into the wider Earth-System research community.

In spite of previous successful initial steps, there is currently no continental-scale European system, mechanism or platform to harmonize, train and integrate local and thus fragmented efforts in stable isotope research.

This COST Action is specifically focused on addressing this shortcoming with a multi-disciplinary, integrated approach with scientists from a range of disciplines, addressing highly relevant topics such as the turnover of soil carbon, the effect of global change on greenhouse gas exchange between ecosystems and the atmosphere, and the role of biodiversity for ecosystem processes in a changing environment. Furthermore, the joint scientific effort in stable isotope research, enabled by this Action, will help to quantify the response functions of current proxies for climate reconstruction, to partition ecosystem trace gas fluxes into gross fluxes, to model soil biotic-abiotic interactions and C-N coupling at various spatial scales, to provide relevant information for a sustainable use of natural resources, and to facilitate new approaches and innovative technologies to answer these questions. Thus, this COST Action has the potential to greatly advance European research standing in the face of local, regional and global changes.

An integrative, coordinated research framework in the form of this Action is the appropriate tool to foster such an interdisciplinary approach by: (i) aggregating the ongoing fragmented research activities and results on C, N, O and water cycles in terrestrial ecosystems at the European level, which are still being carried out almost exclusively in thematically very narrow national or European projects, in integrated projects or project clusters; (ii) synthesizing and publishing the combined knowledge; (iii) identifying knowledge gaps and future research needs; and (iv) defining strategies for future research activities.

B.2 Current state of knowledge

Determining the spatial and temporal variability of stable isotopes of the most common elements in ecosystems (H, C, N, O) and the isotopic signatures of key ecosystem compounds, as well as applying stable isotopes in specific tracer studies have been demonstrated previously to belong to the most powerful tools in environmental studies, in particular for: i) understanding the influence and impact of various biotic and abiotic variables and driving forces on ecosystems; ii) quantifying matter fluxes within ecosystems, and between ecosystems and the atmosphere and hydrosphere; iii) partitioning these fluxes into their single components; and iv) up-scaling of ecosystem fluxes to regional and global scales.

A prominent example for the successful application of stable isotope research is the analysis of $^{13}C/^{12}C$ ratios of atmospheric CO_2 to differentiate between terrestrial and oceanic CO_2 uptake.

However, our lack of knowledge regarding post-photosynthetic fractionation occurring between carbon assimilation and respiration still limits our ability to predict isotopic signatures of evolved CO_2 from various ecosystems at a regional scale. Analysis of $^{18}O/^{16}O$ ratios in CO_2 has been used for partitioning the net ecosystem exchange of carbon dioxide into its component fluxes, i.e. assimilation and respiration. More recently, the $^{2}H/^{1}H$ and $^{18}O/^{16}O$ ratios of water vapor have been used for partitioning evapotranspiration into evaporation and transpiration. By following the fate of ^{13}C-labeled soil organic matter, different decomposition pathways and organisms can be identified. The tracing of carbon in the soil plant system has been done by pulse-labeling plants with $^{13}CO_2$. The potential importance for biogeochemical processes of carbon flux to the rhizosphere through roots and mycorrhiza is widely recognized but it is still poorly documented by in situ measurements.

Stable carbon and hydrogen isotopes record past ecophysiology in tree rings, sediments or leaf-wax lipids, but better knowledge of the numerous fractionation steps occurring between carbon assimilation and wood formation for instance will strengthen the reconstruction of past environmental conditions. Another example for successful application of stable isotope analyses is the ^{15}N isotope pool dilution technique for quantifying gross nitrogen mineralisation and gross nitrification. Thus, highly relevant information could be obtained and used for model validation/improvements not available before.

The implementation of stable isotope research is still restricted to a small number of research groups within the European Research Area (ERA), despite the great opportunities to provide additional information about processes beyond classical methodologies. In spite of substantial research activities in Europe on C, N and water cycles, also including stable isotope research, e.g. in the integrated projects (IP) CarboEurope IP, CarboOcean IP and NitroEurope IP, a comprehensive stable isotope ecosystem research approach, focusing not only on single elements (e.g. carbon) or compounds (e.g. CO_2), is still hampered by the isolation and fragmentation of single research fields. Some research groups might not even be aware about the potential benefits of applying stable isotope techniques to their particular research question, thus integrating research communities should be a next step.

This Action not only contributes to overcoming the isolation of research fields by building a common platform for ecosystem C, N, O and water (H_2O) cycle research, but it also promotes the application of stable isotope techniques in all research fields relevant to biosphere-atmosphere-Earth system interactions. This Action helps scientists to be at the forefront of comprehensive ecosystem research, not only in Europe but also in comparison with research activities beyond Europe, by bringing together researchers from different fields and subjects, and by advancing the latest stable isotope techniques in biosphere-atmosphere-Earth system research.

B.3 Reasons for the Action

This COST Action is motivated by the identification of several urgent needs in the Biosphere-atmosphere research community.

- During 2002 to 2007, an ESF program called Stable Isotopes in Biospheric-Atmospheric Exchange was successful in stimulating application of stable isotopes in biospheric-atmospheric CO_2 and H_2O exchange. The US sister-program Biosphere Atmosphere Stable Isotope Network (BASIN) to this ESF program was recently renewed in 2007 in the USA for another five years (i.e., 2007 to 2011), highlighting the international significance of this research area. While both programs were complementary in scope, providing ample opportunities at national and international scales for research advancement, network development, cross-site training and joint workshops), there was no continuation in any form of the European efforts.

- A questionnaire sent to participants of the previous ESF program revealed that it was considered as very good for filling the gap between isolated isotope research activities within Europe, in particular with respect to communication, networking and training. Thus, future activities addressing these three aspects were asked for, and a scheme like this COST Action is ideal to address these aspects. Such an integrated, coordinated platform does not only bring together isolated research groups within Europe, but also networks with the US program BASIN (see above) and other overseas partners, e.g., the Chinese Academy of Sciences, etc. on the one hand, and exposes the field of stable isotope applications to the Earth system science community.

- There is acute need for a scheme to harmonize, standardize and strengthen existing research activities in Europe by building a common platform for scientists working with stable isotopes to address urgent questions related to biosphere-atmosphere-Earth system CO2 and H2O exchange.

- There is on-going need for full greenhouse gas (H2O, CO2, CH4, N2O, O3) budgets that include identification of sources and sinks (natural and anthropogenic), but also for water quality assessments and development of adaptive management strategies for sustainable resource use of ecosystems under present and future environmental conditions, which is not only of significant scientific importance, but has also of high societal relevance. New technological advances in the field of stable isotope analyses can help addressing these issues, but their application is currently hampered by lack of experience and sometimes also by lack of confidence. This COST Action helps overcoming both drawbacks.

- Particularly with opening of this platform to Eastern European countries, there is a need as well as a great chance to broaden the geographical, political and societal scope. Currently, no such formal network exists where information, techniques and standardized protocols could be exchanged, existing data sets synthesized and new research initiated.

- Furthermore, members of this Action will be in a much better position to identify research gaps, to disseminate new techniques and models, and to find partners to develop integrated, multi-disciplinary research consortia and attract additional funding. This will add further value to national and European science investments.

B.4 Complementarity with other research programmes

Stable isotope research is conducted in many national and European level funded projects (e.g., FP6 CarboEurope IP and NitroEurope IP), but no framework is currently available to coordinate these separated isotope-efforts, typically carried out as isolated satellite-projects within these larger FP6 projects. Thus, this COST Action creates such a platform and links activities among these different research fields, standardizes and improves methodologies used in stable isotope environmental research, and establishes contacts among this Action and other existing European projects and bi/trilateral networks.

As the COST Action has its foundation on a former ESF program, ideas and research needs identified there, were taken up partially by the new European Strategy Forum on Research Infrastructures (ESFRI) Integrated Carbon Observation System (ICOS) project or the FP7 project CarboExtreme. Contacts will be established with highly specialized, brand-new science efforts, such as the new ESF Program Molecular structures as drivers and tracers of terrestrial C fluxes (MOLTER) and the new COST Action ES0804 (on monitoring trace gas exchange). However, with its focus on stable isotope applications in C, N, O and water cycle research, this COST Action is unique in the scientific field of biosphere-atmosphere-Earth system studies in Europe. Thus, through close communication and collaborations among many of these actors, the intellectual benefit for science will increase, large overlap is avoided, but complementarity is achieved. Through this synergism, biospheric-atmospheric-Earth system science will get another great tool to address their critical science issues.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to use stable isotopes on C, N, O and water cycles as a critical research tool in Biosphere-Atmosphere-Earth System research across scales and disciplines to: 1) synthesize isolated experiments in Europe 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; (4) create a training/teaching network across Europe.

C.2 Secondary objectives

Secondary objectives of the COST Action are:

- To critically review and synthesize past and on-going field (and lab) studies to make use of this wealth of existing information available on stable isotope applications in biosphere-atmosphere-Earth system studies. Not only will this allow us to develop and prioritize new research programs/projects, but it will also provide a great learning and training portfolio for the next generation of researchers and neighbouring scientific communities;

- To develop stronger links between experimentalists and modellers across disciplines to improve process-based, mechanistic models of one of the most important but often neglected ecosystem component, i.e., the soil compartment; to screen existing state-of-the-art soil models to identify current constraints and next steps for improvement; to create a meta-database on stable isotope experiments available for model development and validation;

- To advance innovative novel technologies for stable isotope measurements in biosphere-atmosphere-Earth system studies such as compound-specific analyses or laser-spectroscopy; to stimulate development of new instruments in close collaboration with manufacturers; to develop protocols and standardization procedures for these new technologies to ensure comparability among instruments and applications, leading to increased scientific understanding of the Earth system;

- To train early-stage researchers in stable isotope applications, a topic generally ignored/neglected in European graduate and postgraduate education; to efficiently use existing experimental and analytical facilities for stable isotope teaching in Europe and to create a network of experts and expertise to facilitate the use of stable isotopes in future biosphere-atmosphere-Earth system studies.

All secondary objectives aim to increase knowledge and application of stable isotopes in process- and system-oriented interdisciplinary research, with benefits for a large range of potential end-users, from the original contributing research groups and neighboring scientific communities (e.g. in hydrology or atmospheric circulation) to more applied research communities addressing questions of sustainable resource use and adaptive management strategies (e.g., sustainable water or soil management) as well as small and medium enterprises developing new technologies and instruments.

C.3 How will the objectives be achieved?

This Action is based on a multidisciplinary approach and integrates scientists from geology, hydrology, soil science, microbial science, plant sciences, ecosystem sciences, biogeochemistry, ecosystem and global modelling. Networking and coordination of the research is carried out by a Management Committee (MC), including all national MC delegates. This ensures ample opportunities for expansion into the whole of Europe and representation of all different disciplines. In addition, early-stage researchers as well as female scientists are encouraged to take responsibility as national MC delegate/country representative as well as Working Group (WG) Coordinators. The MC and WGs meet regularly to decide on the direction of the COST Action and to assess its progress, also allowing fast response to emerging new science topics.

The integration and coordination of this COST Action is achieved using various mechanisms. Specialized workshops, conferences and training schools, along with expert questionnaires and publications in highly-ranked journals, are used to assess, synthesize and disseminate knowledge across disciplines and end-users. Targeted workshops but also exchange visits of scientists and position papers help to advance new technologies, to involve manufacturers as well as to make this information available to new research groups interested in the topics of the Working Groups. A dedicated webpage facilitates efficient information transfer within the COST Action and beyond as well as serves as a first contact point for the interested public.

Training on stable isotope applications in biosphere-atmosphere-Earth system studies takes place in training schools, workshops, and through exchange visits of early-stage scientists, supported by web-based materials. Products range from an open-access web-page with relevant resources (e.g., meta-database on targeted stable isotope field experiments, lab and field facilities, job offers, teaching materials, etc.) to synthesis papers, methodological documentations and improved soil models.

C.4 Benefits of the Action

This COST Action offers a unique opportunity to build on and strongly expand an already existing small network of mainly Central European scientists. It provides a discussion, coordination, dissemination, integration and sounding board for European and overseas researchers at different stages of their careers. It also involves different disciplines for development, training and promotion of harmonized, innovative approaches for stable isotope applications in experiments and models within and beyond the Action. This strongly facilitates and accelerates the progress and success of the COST Action, since open discussions on new and the most effective experimental and modelling set-ups are anticipated, identifying gaps of knowledge and on better scientific grounds, strengthening future transnational cooperations in Europe and beyond and facilitating the acquisition of additional research funding. Currently, no such formal network exists where information, techniques, standardized protocols could be exchanged. Members of the Action will be in a much better position to identify research gaps, apply stable isotopes in fields where such analyses were formerly absent, find partners to develop integrated, multi-disciplinary research consortia globally, to use existing experimental and analytical facilities more efficiently and attract additional funding. This will add further value to national science investments.

Demonstration of chances and risks, challenges and benefits of using shared databases, but also of improved, more reliable process models and innovative techniques for stable isotope measurements such as compound-specific analyses or laser-spectroscopy, not only leads to increased scientific discussion but ultimately also to the selection and deployment of best practice instruments and routines. The Action thus leads not only to a faster, deeper and more embracing mechanistic understanding of processes and their controls in the Earth system but also to a faster promotion and prove-of-concept of innovative technology led by European scientists.

Information otherwise hidden in research consortia or not accessible on personal computers is made openly available by provision and advertisement of several meta-databases on stable isotope experiments, training facilities, technologies etc. on an interactive webpage. This will further stimulate the discussion and application of stable isotopes in research disciplines within biosphere-atmosphere-Earth system science. Other outputs such as harmonized protocols or high impact publications on original research as well as reviews will have a strong impact on global change research as well as terrestrial C, N, O and water modelling to understand future climate-land interactions. Based on the improved understanding of the biosphere-atmosphere-Earth system, it will be easier to develop adaptive management strategies for sustainable resource use. This is supported by fast, efficient and effective exchange of ideas, data and models as well as various synthesis efforts across all WGs.

This COST Action strongly improves networking of particularly early-stage, but also senior researchers who will motivate early-stage researchers to stay in science, pursue scientific careers (for academia or business later on) and act as multipliers to transfer scientific understanding into many areas of European societies as well as to decision- and policy-makers.

C.5 Target groups/end users

This COST Action provides relevant information for a large range of potential end-users, from the original contributing research groups and neighboring scientific communities (e.g. in hydrology or atmospheric circulation) to more applied research communities addressing questions of sustainable resource use and adaptive management strategies (e.g., sustainable water or soil management) as well as small and medium enterprises developing new technologies and instruments (e.g., mass spectrometer, Nuclear Magnetic Resonance (NMR) and laser-based systems).

Furthermore, the better understanding of the biosphere-atmosphere-Earth system helps decision-makers at various levels (European, national, regional, local) as well as policy-makers to shape the European and global perspectives on current and future global challenges to allow the refinement of global environmental policies and international institutions based on sound science.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The main objective of this Action is to coordinate and integrate the diverse and isolated stable isotope activities in biosphere-atmosphere-Earth system research (including atmospheric chemistry, hydrology, soil sciences and plant ecophysiology) in Europe to provide a scientific impact that is greater than that of its individual components. The COST Action reviews and synthesizes existing data, stimulates and initiates new joint research activities, and creates standardized methods and protocols for stable isotope measurements. The COST Action brings together scientists from multidisciplinary backgrounds and various scientific communities to work jointly towards these goals and to train the next generation of scientists. A primary list of communities to connect includes CarboEurope IP, NitroEurope IP, FLUXNET, ICOS, Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS), and the Moisture Isotopes in Biosphere and Atmosphere (MIBA) network of the International Atomic Energy Agency (IAEA). The network created by this Action is open to other communities and makes products and outcomes of the COST Action available for a wider use by other researchers, environmental organizations, policy and public. Funding through a COST Action provides a unique opportunity to create such a transnational European platform. No other funding instruments exist at national and European level to support the activities specified below. To achieve this main objective, the following four secondary objectives are addressed:

1. Review and synthesis of existing isolated experiments using stable isotope analyses as quantitative tools to understand, trace and partition C, N, O and water cycles within the biosphere-atmosphere-Earth system and to identify innovative process- and system-oriented research areas.

Specific research questions asked include:

- What are the time-lags between environmental controls and changes in isotopic signatures in various compartments of an ecosystem? How to monitor these changes with high time-resolution? What additional fractionation steps do occur during metabolic and transport processes?

- How can C, N, O and water fluxes of complex ecosystems be partitioned?

- How do effects of global change phenomena (e.g. land use, invasion, climate change) on biodiversity affect C, N, O and water fluxes?

- How do extreme events (drought, flooding, and heat) influence C, N, O and water fluxes at different scales and for different species or functional groups?

- How does phenology affect C and N allocation patterns for different plant species and in different biomes (alpine versus temperate grasslands, annual versus perennial crops, evergreen versus deciduous trees), and how are these processes affected by global change?

- How suitable are tree rings and geological proxies for climate reconstruction and as recorders of the hydrological and nutritional state of ecosystems, e.g. δD in leaf-wax lipids and δ15N in tree rings?

2. Assessment of current state-of-the-art models to improve process representation, particularly of the soil component, based on stable isotope studies and to better link experimental and modelling communities.

Specific research questions asked include:

- What are the dominant controls of soil C and N turnover? How do quality and quantity of soil C and N input affect stabilization and destabilization of soil organic matter and microbial decomposition?

- At what timescales do plant-microbe interactions need to be considered for different soil processes? What are the importance and the seasonality of carbon flow to the rhizosphere through roots and through mycorrhiza for both carbon and nutrient budgets of soils?

- How should soil organic matter quality be defined? How can this be translated into models?

- How is the response of ecosystems and its components to extreme events, such as drought, correctly modelled?

- What level of plant or microbial diversity is needed in biogeochemical soil modules, and how does coupling of plant and microbial diversity influence ecosystem processes?

- What processes underlie potential isotopic fractionation in the plant-soil-atmosphere system and how could they be represented in models?

3. Harmonizing and benchmarking the development of innovative cutting-edge technologies for stable isotope analyses.

Specific research questions asked include:

- Which new laser-based technology provides the most reliable results at which level of integration and under which conditions?

- How is quality and comparability of newly developed cutting-edge methodologies being assured?

- Which new instruments would be needed to improve our understanding of the biosphere-atmosphere-Earth system?

- What are the research areas where the new technical advancements open the door to ask new scientific questions?

4. Training and capacity building in stable isotope applications across Europe through training schools, workshops and Short-Term Scientific Missions (STSMs)

Specific questions asked include:

- How should early-stage scientists best be trained and motivated to create a long-lasting and effective network of stable isotope research in Europe?

- How can scientists from various scientific backgrounds be best brought together and learn from each other?

- How can lab technicians best be included in such training efforts for early-stage scientists?

- How can potential end-users, such as policy- and decision-makers, best be reached to transfer knowledge on the Earth system?

D.2 Scientific work plan – methods and means

The COST Action is structured in four Working Groups (WGs) in order to create a well-organized workflow with a clear and transparent distribution of responsibilities and tasks among the scientists involved in the COST Action. The organizational and scientific work plan allows - if appropriate - the addition of new activities during the initial implementation of the Action. Major deliverables (e.g., meta-databases, guidelines, recommendations, protocols, publications) and means (e.g., workshops, conferences, STSMs, training schools) will be achieved and carried out within one WG or (most often) jointly across WGs or even across all WGs (particularly the training aspect). The work plan of the four Working Groups is as follows:

WG1. Review and synthesis of existing isolated experiments using stable isotope analyses as quantitative tools to understand, trace and partition C, N, O and water cycles within the biosphere-atmosphere-Earth system and to identify innovative process- and system-oriented research areas.

This WG1 will

- Review and synthesize existing field and lab experiments as well as observational studies using stable isotope analyses on C, N, O and water cycles within the biosphere-atmosphere-Earth system,

- Identify knowledge gaps and initiate and potentially prioritize innovative process- and system-oriented research areas,

- Develop, evaluate and recommend protocols and standardization for stable isotope applications in future field studies,

- Present the outcome of this WG in high impact journals as well as at workshops/conferences of the COST Action and beyond,

- Develop and apply mechanisms to include neighbouring disciplines, such as hydrology, atmospheric circulation, etc.

Deliverables:

- Meta-database presenting an overview of existing (ongoing and finished) stable isotope experiments in Europe and providing access to the data to modellers, related research communities and other end users;

- Review publications on the current state-of-the-art of stable isotope applications in studies of C, N, O and water cycles within the biosphere-atmosphere-Earth system;

- Guidelines and recommendations for future research experiments.

Means:

- Questionnaire to scientists active in stable isotope research in Europe in order to inventory ongoing and finished stable isotope experiments;

- One expert workshop to analyze questionnaire, review activities and develop guidelines;

- One multi-disciplinary conference integrating over WG1 to 4, possible jointly with scientists from the US sister-program BASIN.

WG2. Assessment of current state-of-the-art models to improve process representation, particularly of the soil component, based on stable isotope studies and to better link experimental and modelling communities.

This WG2 will

- Assess existing state-of-the-art soil models and identify current constraints to represent plant-soil interactions;

- Identify and prioritize the next steps for soil model improvement, including neighbouring disciplines of hydrology, soil microbiology, plant physiology, etc.;

- Evaluate the suitability for model improvements of experimental data from stable isotope studies in the field and in the lab as well as observational studies, communicate requirements and recommend innovative stable isotope labelling experiments (e.g., large-scale pulse labelling under field conditions, deployment of high-time resolution analyses);

- Improve state-of-the-art soil models by incorporating new insights from stable isotope studies, and calibrate them against other soil modules;

- Present the outcome of this WG in high impact journals, at workshops/conferences of the COST Action and beyond.

Deliverables:

- Review publication of current state-of-the-art soil models and critical assessment of their performance,

- Defined framework for a new generation of process-based soil models,

- Recommendations for new experiments critical to advance the capabilities of soil models to simulate appropriately soil processes in Earth system models.

Means:

- One multi-disciplinary workshop for model intercomparison and development of criteria for the assessment of model performance,

- One multi-disciplinary workshop bringing together experimentalists and modellers (WGs 1 and 2) in order to design new experiments necessary to fill gaps identified by modelling exercises and to integrate new findings into process-based models.

WG3. Harmonizing and benchmarking the development of innovative cutting-edge technologies for stable isotope analyses.

This WG3 will

- Bring together research groups working on innovative technologies for stable isotope measurements such as triple isotopes as in oxygen, double labelling, compound-specific and laser-spectroscopy analyses, quantitative NMR across national boundaries,

- Harmonize calibration and measurement procedures for these new technologies to ensure comparability among instruments and applications,

- Define best practice calibration routines, organize cross-laboratory comparisons and present the outcome of this WG in high impact journals as well as at workshops/conferences of the COST Action and beyond,

- Identify potential sources for uncertainty in these measurements,

- Identify technological requirements and stimulate development of new cutting-edge technologies in collaboration with manufactures, start-ups etc.

Deliverables:

- Guidelines for best practice calibration routines and data quality assurance,

- Meta-database of existing facilities/experiments making this information available for the modelling community.

Means:

- Cross-laboratory comparisons of instrument performance and of standard material,

- Expert workshops on instrument development, calibration and application, possibly jointly with instrument manufacturers and members of WG1.

WG4. Training and capacity building in stable isotope applications across Europe.

This WG4 will

- Establish a web-based information centre as a dedicated website for dissemination of information,

- Create a network of experts and expertise to facilitate the use of stable isotopes in biosphere-atmosphere-Earth system studies,

- Create a database of existing experimental, analytical and training facilities for stable isotopes as well as isotope-related job offers in Europe,

- Make teaching materials on stable isotopes in environmental sciences available to members of the COST Action and beyond, including materials for the general public,

- Train early-stage researchers in stable isotope applications through training schools, workshops or science camps on selected topics across WG 1 to 3,

- Develop suggestions on how to train technical staff on scientific approaches and requirements in biosphere-atmosphere-Earth system studies.

Deliverables:

- Website including databases from WG1 to WG3, teaching materials, and links to research groups active in Europe,

- Network of students and early-stage scientists from across Europe trained in the application of stable isotopes in biosphere-atmosphere-Earth system research,

- Recommendations for improved lab expertise by expert training for lab technicians.

Means:

- Two training schools (across WG themes) to train early-stage scientists (train the student),

- Inclusion of a small number of lab technicians in the training schools for early-stage scientists (train the tech),

- Short-Term Scientific Missions (STSMs across WGs) for early-stage scientists (but also senior scientists) to stimulate scientific exchange across Europe.

Briefly, during the four years of the COST Action, the following organizational and scientific milestones are anticipated across the Action. The responsible groups are given in parentheses:

Year 1

- 1st Annual MC and WG meeting: MC and WGs set up; working plan agreed across all WGs; Core Group for STSMs applications set up (MC),

- Interactive website established and email listserver running (MC),

- Annual progress report to MC submitted (all WGs),

- Questionnaire on ongoing and finished stable isotope experiments sent to scientists (WG1),

- Current state-of-the-art (soil) models reviewed and selected for intercomparison; framework for new generation models defined (WG2),

- Meta-database of existing facilities/experiments available (WG3),

- STSMs announced, applicants evaluated and selected (WG4),

- First teaching materials on website; recommendations for expert training for lab technicians available (WG4),

- First training school for year 2 announced; participants evaluated and selected (WG4).

Year 2

- 2nd MC and WG meeting: progress of the four WGs coordinated and monitored (MC),

- Website maintained, results disseminated beyond COST Action (MC),

- Annual progress report to MC submitted (all WGs),

- Expert workshop to analyze questionnaire, review activities and develop guidelines realized (WG1),

- Multi-disciplinary workshop for model intercomparison / improvement realized (WG2),

- Expert workshop on instrumentation (possibly jointly with instrument manufacturers) realized (WG3),

- STSMs announced, applicants evaluated and selected (WG4),

- First training school realized (WG4).

Year 3

- 3rd MC and WG meeting: progress of the four WGs coordinated and monitored (MC),

- Website maintained, results disseminated beyond COST Action (MC),

- Annual progress report to MC submitted (all WGs),

- Meta-database on existing (ongoing and finished) experiments available; publications available (WG1),

- Multi-disciplinary workshop with experimentalists and modellers (WGs 1 and 2),

- Review publication on model intercomparison available (WG2),

- Cross-laboratory comparisons of instrument performance and standard material realized (WG3),

- STSMs announced, applicants evaluated and selected (WG4),

- Extensive teaching materials on website; recommendations for expert training for lab technicians improved (WG4),

- Second training school for yr 4 announced; participants evaluated and selected (WG4),

- Final conference for yr 4 announced, speakers selected (WG4).

Year 4

- 4th MC and WG meeting: progress of the four WGs coordinated and monitored (MC),

- Website maintained, results disseminated beyond COST Action (MC),

- Annual progress report to MC submitted (all WGs),

- Access to experimental data via website; publications available (WG1),

- Conceptual publication with recommendations for new experiments available (WG2),

- Publications on guidelines for best practice available (WG3),

- STSMs announced, applicants evaluated and selected (WG4),

- Second training school realized (WG4),

- Final conference realized (WG4),

- Final synthesis and integration of outcomes of all WGs available (MC).

E. ORGANISATION

E.1 Coordination and organisation

The COST Action will run for four years and has a rather flat organizational structure, in full accordance with COST guidelines:

- The Action is coordinated by a Management Committee (MC), including all national delegates/country representatives, and if appropriate the Chairs of the four Working Groups (WGs). The MC meets once a year, preferentially at one of the COST Action meetings. Minutes of these meetings are distributed to all Action members via email. The MC supervises the overall progress of the work, coordinates WG activities, synthesizes results and ensures dissemination of the results to the wider scientific audience, to potential end-users as well as to society.

- At the first meeting of the MC, the four WGs are formally established and interim Coordinators determined. These interim Coordinators will collect commitments from all Action participants. Based on these commitments, the four WGs will be formed based on scientific expertise and interest in a specific topic. Each of the four WGs is responsible for the implementation and coordination of its respective WG (e.g., milestones such as publications, recommendations, protocols, guidelines) as well as for the integration of this knowledge into the entire Action (e.g., milestones such as workshops, conferences, STSMs).

WGs hold dedicated meetings (at least once a year; individually and jointly), workshops or training schools to facilitate information/data acquisition, training and transfer across WGs. These meetings are openly announced so interested scientists can participate. If appropriate, external experts are invited. Each WG selects a WG Coordinator as well as a Vice-Coordinator who reports to the MC to ensure integration at all levels. Leadership from early-stage scientists is strongly encouraged and supported. Also appropriate gender balance is sought within all WGs; responsibilities should be distributed across all participating countries.

- The COST instrument of Short-Term Scientific Missions (STSMs) is available for participants, especially for early-stage scientists, to maximize the overall benefit of the COST Action. However, also senior scientists are allowed to apply. STSMs are used to initiate contact, to attend courses/schools, to take part in workshops, etc. Calls for STSMs are issued and applications for the STSMs are evaluated and decided upon by a small Core Group, consisting of representatives of all four WGs, led by WG4.

- Based on the work plan, WG4 coordinates the activities associated with offering training schools for graduate/postgraduate students and for lab technicians. This latter group has so far been typically ignored/neglected for participation in such schools. So WG4 develops schemes to successfully approach and includes these users as well.

Action details as well as information of all activities (e.g., research announcements, meetings, call for short-term exchange visits, training schools, etc.) but also products of the Action are made freely available on the web to ensure open, fast and transparent communication flow. A password-secured web section is created for the MC members and the WGs to facilitate sharing of documents, archiving info, etc. An email listserver helps to spread the information efficiently to all interested.

E.2 Working Groups

In order to achieve the above mentioned objectives, the Action is structured along four Working Groups (see section D):

- WG1: Review and synthesis of existing field experiments using stable isotope analyses as quantitative tools to understand, trace and partition C, N, O and water cycles within the biosphere-atmosphere-Earth system and to identify innovative process- and system-oriented research areas,

- WG2. Assessment of current state-of-the-art soil models to improve soil process representation based on stable isotope studies and to closer link experimental and modelling communities,

- WG3. Harmonizing and benchmarking the development of innovative cutting-edge technologies for stable isotope analyses,

- WG4: Training and capacity building in stable isotope applications across Europe.

The WGs are the core of the COST Action and are responsible for their respective outputs. After their establishment during the first MC meeting, they will need some time to find appropriate participants among the Action participating countries and to elect the WG Coordinator and Vice-Coordinator. Once this is accomplished, the WGs refine their program, organize and carry out their activities according to the Work Plan and report annually to the MC. This will allow feedback (monitoring as well as evaluation) of the WG goals by the MC in due time. Through the close collaboration with other European projects/programs, but also the US sister-program BASIN, outside feedback will also be available to the MC.

E.3 Liaison and interaction with other research programmes

As mentioned in B4, no coordination platform for stable isotope research exists in Europe. This COST Action aims to create such as platform and links its WGs to currently existing as well as emerging projects and programs in the future. Among those, existing projects (e.g., FLUXNET, iLEAPS, CarboEurope IP, NitroEurope IP, MIBA), infrastructure initiatives (such as ICOS) or new COST Actions (e.g., ES0804 on monitoring trace gas exchange) are clear partners for WG1, WG2 and WG3. In addition, the new ESF Programme MOLTER will be approached to coordinate efforts with WG1 and WG 2 to use the synergy developed. Both efforts are facilitated by the fact that this COST Action shares some key partners with these projects.

This COST Action is also closely linked to a comparable sister-program in the USA (BASIN). Such a link has already a very successful tradition: several workshops and two large international conferences were organized by BASIN and a former ESF program, providing great networking and research opportunities. This link is kept and further developed by all four WGs.

Also future projects/programs will be contacted by the MC or WG Chairs. Invitations to dedicated WG workshops or overarching efforts such as training schools are foreseen. With the focus on stable isotope applications in C, N, O and water cycle research, both in experimental and modelling studies, this COST Action has many links and partners across Europe, being at the core of efforts trying to understand the biological processes that govern the C, N, O and water dynamics in the biosphere-atmosphere-Earth system.

Taken altogether, close interactions with major international projects and relevant international players in stable isotope applications are supported or developed by the MC and WG members of this Action, increasing its impact and its benefits beyond the participating countries. This COST Action supports efforts to make European research and researchers known across the borders, spread information on European facilities, expertise and excellence, maybe even have an impact on (young) European researchers currently abroad to interact with scientists and establish new roots in Europe.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

Already from the very start of this COST Action, female participation has been comparably high. As of today, five out of 17 potential country representatives are female. Thus, this COST Action includes already many role models and aims to attract young female scientists into responsible positions within this Action. Since many activities are centered on workshops, reviews and synthesis, the chances to involve female scientists are high.

However, the same applies to the inclusion of early-stage researchers. Also in this respect, this COST Action can already report first success since four out of 17 potential country representatives are early-stage researchers. It is anticipated that also a high proportion of the WG Coordinators are recruited from early-stage scientists.

WG4 on training and capacity building is particularly set up to encourage participation of Ph.D. students and early-stage scientists, thus persons in the most decisive stage in scientific careers when science is losing young and female researchers across Europe. Also here, role models can help to inform and show solutions (beyond science).

Organizers of activities will be requested to involve both genders as well as early-stage scientists, and to ensure a fair selection process e.g. during the screening and decision process for STSMs or for lecturers at the training schools. All statistics will be made available to ensure transparency on these issues. Thus, this COST Action is well prepared to take up the responsibility to ensure gender balance throughout all its activities.

F. TIMETABLE

The COST Action will run for four years.

Phase 1 (yr 1): Launch of COST Action, implementation of working plan:

- Set-up of MC and WGs during 1st MC meeting; decision on interim WG Coordinators,

- MC: Supervision of progress and coordination of the four WGs; agreement on responsibilities and details of deliverables; establishment of interactive website and email list server; promotion of the Action,

- WGs: Collection of commitments from Action participants; selection of WG Coordinators; implementation of working plan of all WGs; dedicated meetings/workshops (see section D2); annual progress report to MC,

- Set-up of a Core Group for STSMs applications: announcement of STSMs, evaluation and selection,

- Announcement of first training school for yr 2 by WG 4; evaluation and selection.

Phase 2 (yrs 2 and 3): Realization of working plan, assessment, evaluation (for details see section D):

- 2nd and 3rd MC and WG meetings,

- MC: Coordination and monitoring of progress of the four WGs; dissemination of results to wider scientific audience, to potential end-users as well as to society; maintenance of website,

- WGs: Dedicated meeting/workshops (see section D2); annual progress reports to MC,

- Core Group for STSMs applications: announcement of STSMs, evaluation and selection,

- Realization of first training school in yr 2 by WG 4; Announcement of second training school for yr 4 by WG 4; evaluation and selection,

- Announcement of final conference for yr 4, selection of invited speakers.

Phase 3 (yr 4): Integration, synthesis, final products (for details see section D):

- 4th MC and WG meetings,

- MC: Coordination and monitoring of progress of the four WGs; final synthesis and integration of outcomes of the four WGs in collaboration with the WG Coordinators; dissemination of results to wider scientific audience, to potential end-users as well as to society; maintenance of website,

- WGs: Dedicated meeting/workshops (see section D2); final progress report to MC,

- Core Group for STSMs applications: announcement of STSMs, evaluation and selection,

- Realization of second training school by WG 4,

- Realization of final conference.

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Israel (IL), Italy (IT), The Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), and United Kingdom (UK). On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 68 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

This estimate is based on funds for personnel, infrastructure and third-party research for 17 countries.

H. DISSEMINATION PLAN

H.1 Who?

The main target audiences for the dissemination of the results of the Action are:

- Basic as well as applied research communities across Europe involved in the study of interactions between biota and biogeochemical processes in natural and managed ecosystems, as well as scientists studying biosphere-atmosphere-Earth system exchange of greenhouse gases. This includes observationalists, experimentalists and modellers working for universities and research centres, for operational centres and government agencies involved in understanding the biological processes that govern the flow of C, N, O and water of terrestrial ecosystems and/or in forecasting biosphere-atmosphere-Earth exchange of C, N, O and water. Disciplines addressed are global change science, Earth sciences, hydrology, biology, microbiology, functional ecology, ecophysiology, dendrochronology, terrestrial greenhouse gas emissions, etc.

- Post-graduate and graduate students conducting a M.Sc. or Ph.D. on issues such as land-atmosphere interactions, plant-soil interactions, soil C modelling, and ecosystem C, N and water cycling, have the opportunity to attend targeted training schools or exchange visits to obtain first-hand and first-class information as well as hands-on introduction into the applications of stable isotopes in biospheric-atmospheric CO2, N, O and water exchange.Based on wide-spread experiences, this audience is reached best and most effectively through such means and helps to shape a new generation of young scientist across Europe.

- Manufacturers developing e.g. new spectroscopic instruments for field measurement of isotopes and trace gases. Without the close connection among physicists, environmental scientists, and small and medium enterprises, the advancement of technology and its application in fast-moving research fields is almost impossible. Thus, lively communications as well as close collaborations are foreseen with WGs 3 and 4.

- Policy-makers (at various levels: European, national, regional, local) are one important target audience for this COST Action. Policy fields addressed by this COST Action are mitigation of greenhouse gas emissions (understanding the source and sink strength of European ecosystems), environmental assessment and management for sustainable resource use, improving current predictions of future terrestrial greenhouse gas emissions and hence better constrain current General Circulation Models.

- The general public, including school students and teachers interested in environmental issues, is also targeted by the Action through communication of important outcomes in a generally understandable way (with links to EU projects like CarboSchools+).

H.2 What?

The dissemination strategy includes nine major components:

1. Expert and multi-community workshops.

2. Review and synthesis papers as well as position papers using existing experimental data on stable isotopes. This furthermore provides an overview of the available datasets, their quality and leads to the extension of the overall efforts in stable isotope applications.

3. Guidelines, best-practice-protocols as well as recommendations on harmonized and standardized methods for measuring and processing stable isotopes.

4. Final conference inviting scientists from other European and global research networks linked to this Action (e.g. CarboEurope IP, NitroEurope IP, ICOS, MOLTER, MIBA, etc.), and in particular involving our sister-program in the US (Biosphere-Atmosphere Stable Isotope Network (BASIN) Research Coordination Network, coordinated by Prof. Todd Dawson, UC Berkeley), research groups specialized on isotopic labelling and/or research groups interested on applying innovative isotopic technologies.

5. Two training schools for students, early-stage scientists and technicians.

6. Short-Term Scientific Missions (STSMs), i.e., exchange visits for students and early-stage scientists to learn new techniques, transfer and build capacities in stable isotope applications in various research fields within the biosphere-atmosphere-Earth system studies.

7. Information provided through a dedicated open website (web-based information centre; see section D2) and flyers, through articles as well as by using existing list servers from various communities (e.g. FLUXNET, CarboEurope IP, NitroEurope IP, etc.).

8. Articles in daily/regional newspapers, interviews in local radios of policy-relevant issues originating from this COST Action.

9. Dedicated talks to teachers at various levels of education.

H.3 How?

- The workshops are organized within or across WGs and address expert and/or multi-community audiences. The way workshops are organized strongly depends on the respective aim and topics but can include invited key-note speakers, field comparisons, modelling sessions, bringing together experimentalists and modellers, etc. However, ample discussion times and strong involvement of early-stage scientists will be mandatory and will thus help to coordinate science fulfilling the deliverables mentioned in section D and produce the outputs wanted (e.g., synthesis, reviews, harmonized protocols, etc.).

- Review papers in highly-ranked international journals are coordinated within or across the WGs, depending on their goals. Smaller meetings might need to be held for these efforts. An additional goal of these synthesis papers, based on the analysis of current state-of-the-art methodologies, data sets, models, etc., is also to provide a baseline upon which standardized methodologies, improved experimental applications and modelling representations, are evaluated, improved or rejected.

- The final conference takes place towards the end of the Action, and will reach out beyond the COST Action. During the conference, the results achieved during the Action will be presented and critically assessed and evaluated. In addition, the end users of the various products will be invited to provide feedback on their needs and requirements for an optimal application of the datasets.

- Training schools are openly announced and organized to introduce young scientists to the challenges involved in applications of stable isotopes in biosphere-atmosphere-Earth system studies. A smaller Core Group will screen through the application and select the participants.

- Short-Term Scientific Missions (STSMs) are offered to qualified students or early-stage scientists upon application and screening by a smaller Core Group.

- The open website facilitates communication within the COST Action but also serves as the link to the general scientific community. It will be maintained on a regular basis and serves as a web-based information centre, including outputs from the Action itself, but also presents information on the various topics addressed in the Action. All WG Coordinators are responsible for maintenance concerning their WG. All activities will be announced through this web page, but also through a list server and the use of other email lists.

- Media coverage (newspapers, radio, press releases, PR offices of participating institutions, etc.) will allow spread of relevant topics to narrowly targeted audiences, e.g., general public, decision-makers, policy-makers.

- Dedicated talks to students, teachers, but also policy-makers will be offered in cases where contacts are already established (e.g., Israel, France, Germany) or specifically asked for.