HEALTH and WEALTH of the environment

Science Strategy 2002 - 2007

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Contents

The CEH Management Board wishes to thank all those who provided feedback on the early versions of this document; our stakeholders, CEH Advisory Committee, Programme Development Groups and CEH staff.

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Health and Wealth of the Environment

Health and Wealth of the Environment sets out a five-year science strategy for CEH based on the priorities of our investors and the key scientific challenges ahead. One of the greatest challenges is to balance the often conflicting demands of healthy and wealth-creating environments to achieve sustainability. CEH will direct its science to address the broad questions of 'Why is the natural environment as it is?' and 'What is it likely to be in the future?'

What is the Centre for Ecology and Hydrology?

The Centre for Ecology and Hydrology (CEH) is the foremost research centre for the sciences of ecology and hydrology in the United Kingdom, our parent organisation being the Natural Environment Research Council (NERC). We conduct independent research, funded partly by a central grant from Government, and partly by income from contracted work. Our main customers are government departments and agencies; we also work with the private sector and the European Union. Research projects are carried out within CEH, in collaboration with scientists in other NERC research centres, and in consortia with academics from universities and research institutes in the UK and across Europe. Our research and the application of our science is carried out at scales from local to world wide – Earth Systems Science.

The skill and expertise of our research staff is our greatest asset, and combines a spectrum of environmental disciplines into a very powerful 'engine' for providing knowledge about the environment. CEH undertakes wide ranging and integrated investigations, and can take advantage of major new opportunities for work in interdisciplinary areas of environmental science. We are particularly interested in the impacts of human activities on the natural environments. We aim to generate practicable solutions, so that the UK can maintain, enhance and benefit from a healthy environment.

Zdenek Tunka/Ardea London

Setting the agenda

In the next five years CEH will make a world-class contribution in ecology and hydrology through:

- **Strategic scientific research and intelligent data collection**
- **Synthesis of our science into an integrated framework to address pressing environmental problems**
- **Developing solutions for a sustainable future to meet national and international needs**

CEH has the capacity, unique in the UK, to conduct integrated and multi-disciplinary studies across terrestrial and freshwater ecosystems. Moving forward, CEH research and data collection will exploit this capacity to develop a greater understanding of the biophysical processes and man-biosphere interactions that govern and affect Earth's life support systems, contributing to NERC's strategy, *Science for a sustainable future*.

Through this understanding we will provide stakeholders with the knowledge base needed to develop, inform and guide policy, and fulfill the UK's commitments under international agreements such as the Kyoto Protocol, United Nations (UN) Convention on Biological Diversity, the European Union's (EU) Water Framework Directive, and the recommendations of the World Summit on Sustainable Development. Through dialogue with stakeholders we will ensure our outputs can contribute to decision-making on prediction, impacts, mitigation, audit and monitoring.

Defining the strategy

CEH will build on its understanding of the processes governing **Earth's life support systems** (water, biogeochemical cycles and biodiversity) and provide the scientific underpinning to tackle two key environmental issues:

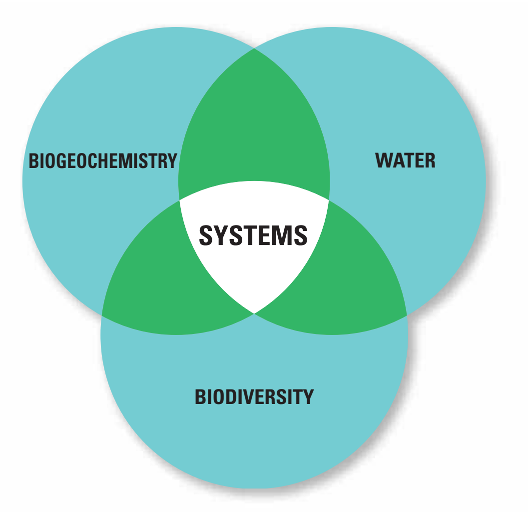
Global change – predicting and mitigating the impacts, including changes in climate and climate variability;

Sustainable economies – identifying and providing sustainable solutions to the challenges associated with energy, land and water use, and environmental hazards.

We will achieve this understanding through fundamental and applied research characterized by:

- Long term, large scale survey and 'intelligent monitoring' (to detect and quantify the occurrence and rate of environmental change, provide a measure of environmental health and quantify the impact of environmental policies and success of mitigating measures);
- Observation and experimentation (to provide new insights into the causes of, and the mechanisms by which ecological and hydrological systems change), including coordination of major field experiments and replicated ecosystem manipulation;
- Modelling and prediction (synthesis of data and process understanding to predict the nature and effects of likely future change).

The unique capability of CEH to undertake co-ordinated large area, long term and multi-disciplinary research will enable us to apply a systems approach to ecological and hydrological processes, integrating specialist and generalist expertise. Such an approach will allow CEH to build knowledge at the interfaces of Earth's life support systems. We will enhance this capability by developing further our strong collaborations with academic, governmental and industrial partners.

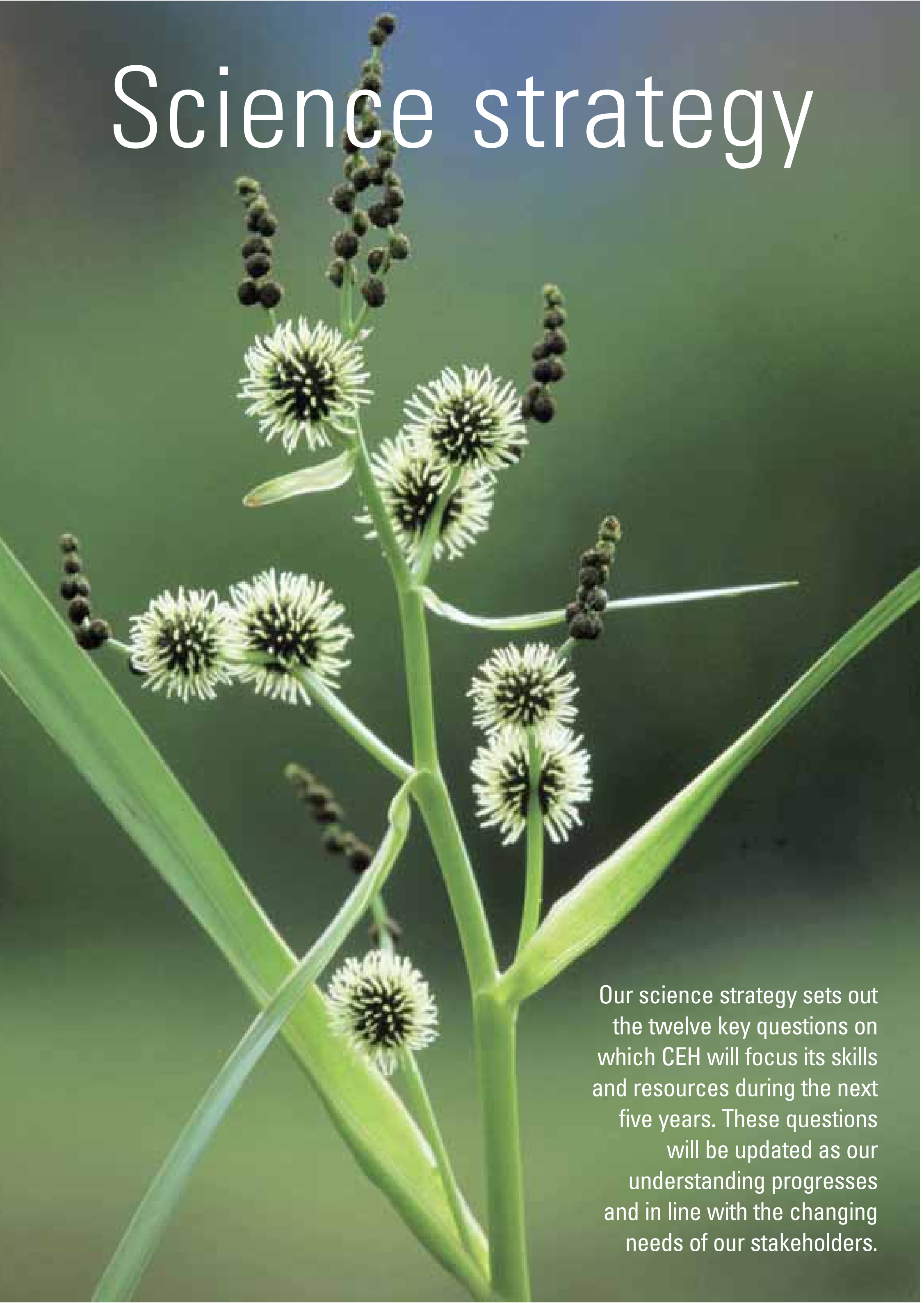


CEH will build knowledge in its core disciplines and at the interfaces (green segments) within Earth's life support systems.

Building collaborative partnerships

CEH will build long lasting strategic partnerships with a wide range of organizations, in order to develop interdisciplinary UK and international research teams in areas where CEH does not have the full range of expertise. The issue of sustainability is one that cannot be fully tackled without social sciences, economics and other disciplines such as agriculture. CEH will use a range of options to build strong partnerships with other research groups to deliver holistic solutions. Mechanisms for achieving this will include:

- Developing strategic agreements with government departments, agencies and other stakeholders, e.g. by building on the Environmental Research Funders Forum (ERFF);
- Hosting and participating in international science initiatives;
- Participating in NERC, Research Councils UK and other national programmes e.g. the Lowland Catchment Research (LOCAR) and Quantifying the Earth System (QUEST) programmes;
- Participating in national collaborative research initiatives such as the Tyndall Centre, Joint Centre for Hydro-Meteorological Research (JCHMR) and Climate and Land-Surface Systems Interaction Centre (CLASSIC);
- Leading or participating in research projects with university partners e.g. NERC, other Research Councils, EU Framework 6 programme (EU FP6);
- Co-supervision of students with university partners;
- Sabbatical and temporary secondment opportunities within CEH, and between CEH and partner organisations;
- Active participation in international collaborations such as EurAqua (Network of European Freshwater Research Organisations) and PEER (Partnership for European Environmental Research);
- Extending existing research networks with institutions in developing countries.



Science strategy

Our science strategy sets out the twelve key questions on which CEH will focus its skills and resources during the next five years. These questions will be updated as our understanding progresses and in line with the changing needs of our stakeholders.

Mark Hamblin/Oxford Scientific Films

Earth's life support systems

Biodiversity provides the gene pool and character variability that enable species, populations and ecosystems to thrive and adapt to environmental change. From this premise arise two fundamental questions, the first of which is:

1 What rôle does biodiversity play in ecosystem function and ecosystem services?

At most trophic levels, the functional role of biodiversity is a 'black box.' Using new '-omic' techniques (genomics, proteomics and metabolomics) and bioinformatics, together with stable isotope labelling (combined with established ecological methods and novel approaches to modelling) we can now understand how biodiversity at the genomic level influences population ecology.

Indeed, the next five years will see unprecedented insights into the links between biodiversity and ecosystem function. The challenge for CEH is to integrate its unique range of ecological and taxonomic expertise (from micro-organisms to higher plants and animals) so that we ask not only how different trophic levels influence ecosystem function but also seek general rules across trophic levels. Such an holistic approach will enable us to determine the relationship between food web structure, impacts of keystone species, community structure and ecosystem resilience, and identify multi-species indicators of ecosystem health.

A further step is to understand the contribution of biodiversity to ecological services, such as carbon sequestration, water/air and soil quality, maintenance/ conservation of habitat quality, and the interaction between biodiversity and hydrology. Tackling these big questions will require the formation of multi-disciplinary teams both from within CEH and with academic, governmental and industrial partners.

The second fundamental and closely linked question for CEH is:

2 How can we quantify and mitigate environmental threats to biodiversity?

Potential threats to biodiversity in Europe arise from global climate change, land use change, water management, loss and fragmentation of habitats, introductions of non-native species and genetically modified (GM) crops, industrial activity, pollution and many other factors.

To understand how these factors affect biodiversity CEH will use observation and experiments, including our long-term datasets and recent investments in bioinformatics and GRID (distributed computing) technologies. Results will be integrated into predictive models and validated using long-term, wide-scale monitoring and survey data such as those of the National Biodiversity Network, Countryside Surveys, National River Flow Archive and Environmental Change Network (ECN).

Through understanding impacts on biodiversity, CEH will identify where biodiversity is most at risk, what measures of mitigation, restoration or conservation can be taken, and the likely course and state of recovery. CEH will provide ecological, biological and molecular tools to predict and/or measure impacts and to audit the success of mitigating and remedial actions.

A key policy driver for our work will be the targets set by the UK Biodiversity Action Plan, the EU Habitats Directive and the Water Framework Directive. CEH plans to extend its current international lead in generating the knowledge that will enable these policies to be implemented.

Earth's life support systems

Water is essential to Earth's life support systems. Understanding the processes governing water quantity and quality at all scales is critical to maintaining healthy freshwaters and adequate water supplies, reducing risks of flooding, and providing and supporting sustainable sources of energy.

CEH will address water-related issues through research that capitalises on CEH's large-scale and long-term data recording, maintenance and analysis of extensive databases. These include the National River Flow Archive, Acid Waters Monitoring Network, the Plynlimon experimental catchment long-term record, long-term lakes and river databases, ECN, links to Environment Agency databases, and data from NERC Thematic Programmes.

During the next 5 years, CEH will focus on two high level questions that reflect major scientific challenges and the needs of government bodies and industry, the first of which is:

3 How do processes on land and in the air affect the transfer and quality of freshwater?

CEH is a major national and international player researching the role of water in the Earth system. We also provide advice to government departments, environmental agencies and conservation bodies on water management issues raised by the numerous national and European directives that have a strong focus on water quality and quantity.

CEH will integrate areas of science ranging from soils and land use, through hydrology, hydrochemistry, sediment and pathogen transfer, to the ecological response of freshwater plant and animal communities to changes in their environment. CEH is in a unique position to work at many different scales and to link these scales using models. We will work across CEH and with appropriate partners.

A key policy driver is the new EU Water Framework Directive, requiring a shift in management of water quality and quantity issues towards ecological targets. This demands procedures for classifying surface waters according to their ecological status and identifying indicators sufficiently sensitive to detect ecological disturbance, taking account of their physical and chemical contexts. It will require an understanding of a) ecological community response to hydrological, morphological, chemical and physico-chemical perturbations and b) the impacts of ecological systems (such as wetlands) on hydrology and water quality, in order to deliver new cost effective solutions to assess the ecological status of surface waters. CEH is ideally placed with its multi-disciplinary hydrology and river ecology groups to develop models and systems for the UK and European regulatory authorities, making best use of leading techniques which have been jointly developed with several government agencies such as the River Invertebrate Prediction and Classification Scheme (RIVPACS), physical habitat modelling, River Habitat Survey and the Lakes Prioritisation Scheme.

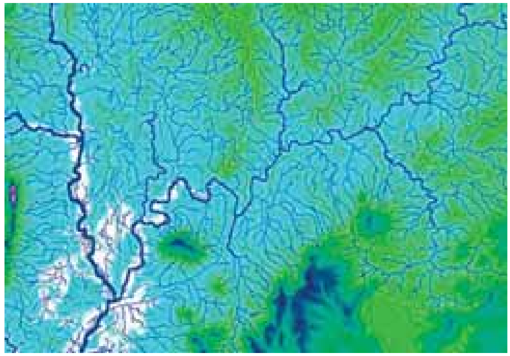
Important issues include the impacts of demographic redistribution, urbanisation and climate variability on water quality and water resources. CEH expertise in lake and river catchment science, integrated with microbial ecology and statistical risk to human health, will provide innovative catchment scale approaches to chemical and microbial contamination of freshwaters. Incorporating a probability component within catchment water quality models will aim to link the behaviour and fate of chemical pollutants to an assessment of ecotoxicological exposure risk.

Knowledge generated in tackling the first issue will be used to address the second key question, namely:

4 How can we integrate this knowledge to support the sustainable management of catchments and their water resources?

CEH will examine the hydrochemical and hydrobiological functioning of UK upland hard-rock and lowland permeable catchments and wetlands, assessing the impacts on the ecology of lakes and rivers of changes in population pressures, land-use, climate and flow regimes. An important focus will be to understand the dynamics and controls on the distribution of water resources in time and space, and their impacts on ecological communities in rivers, lakes and wetlands. From these studies new process-based hydro-biogeochemical models will be developed for examining catchment management scenarios and developing management solutions for European catchments under different pressures.

By advancing integrated water resource management and providing solutions, CEH will meet the needs of national and international water industry, policy makers and environmental protection agencies. The flow requirements for sustainable ecological communities in rivers will be derived to help UK regulatory authorities assess the sustainability of water resource schemes, in support of the development of Catchment Abstraction Management Plans in England and Wales and their equivalent in Scotland. CEH will develop next-generation methods for the management of high river flows used in engineering practices (e.g. Flood Estimation Handbook and Catchment Flood Management Plans).



Dynamic models which integrate both surface and groundwater systems are essential for the sustainable management of catchments. Key challenges are to improve the understanding of the interaction between the surface, soil and groundwater environments and the physical, chemical and biological processes of the valley floor. The LOCAR thematic programme will enable CEH to advance its research partnerships with the British Geological Survey (BGS) and UK Universities and this will underpin applied research which addresses regulatory objectives.

Earth's life support systems


John Mason/Ardea London

Biogeochemical cycles define the turnover of essential elements such as carbon and nitrogen. They are of increasing interest to Governments taking a long-term view of climate and other global environmental change. We will work within programmes defined by the International Geosphere-Biosphere Project (IGBP), the EU and national consortia, exploiting E-science initiatives and our recent investments in computing capacity and GRID linkages to enable wider on-line collaboration, and open up new approaches (e.g. multiple simulations).

Carbon is a key driver of global warming and therefore is of major importance to sustainable development. A critical question driving CEH's science strategy derives from the fact that the terrestrial biosphere has a limited capacity to sequester carbon. We will ask:

5 What determines the limit of carbon sequestration and how can that limit be extended?

CEH is a major international player in research on the carbon cycle and is the primary advisor to the Department for Environment Food and Rural Affairs (DEFRA) on the UK terrestrial carbon budget and on issues raised by the Kyoto Protocol. We will work collaboratively with partners (including the NERC Centre for Terrestrial Carbon Dynamics) to understand the land-atmosphere carbon balance and predict how it may change in the future - will the land surface continue to be a sink for carbon dioxide, or will it become a source and under which scenarios?

To tackle this high level question, we need to know how factors such as carbon dioxide fertilisation, nitrogen enrichment, land use change, climate change, and natural disturbances (e.g. forest fires), contribute to the carbon balance between the atmosphere and the land surface. We also need to know how the land-surface sources of methane (including hydrates) are affected by global change (including global warming, changes in water balance, land-use change and sulphate deposition), and the contribution of methane, carbon monoxide and volatile organic compounds (VOCs) to carbon accounting.

A policy concern is the quantification of national carbon sinks and sources in the Kyoto Protocol and whether full carbon accounting is needed. We will examine the potential for deliberate land-use change to increase carbon sequestration, balancing any benefits against undesirable consequences.

Nitrogen has become a pollutant in the atmosphere, on land and in freshwaters. Anthropogenic release of reactive nitrogen into the atmosphere at an unprecedented rate is largely responsible. CEH has a critical mass of expertise concerning the fluxes, fate and effects of pollutant nitrogen in terrestrial and freshwater ecosystems. Using our expertise in running national deposition monitoring programmes and exposure facilities, we will address the key issue: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6 What are the consequences of nitrogen enrichment and how can adverse effects be mitigated?

Working with universities, government departments, European and other international partners, we will investigate perturbation of the nitrogen cycle by human activity, land use change and climate change, and its effects on atmospheric deposition, accumulation, gaseous losses and losses to freshwater. We will examine the trade-offs of mitigation options and help to develop integrated policies on nitrogen management.

Approaches will include long term field experimentation focussed on the impacts of nitrogen on ecosystem structure and function, on key resources such as soils, water and genetic diversity and on the interaction of nitrogen with carbon and other nutrient cycles. Detailed process studies will enable the development of process based models which link soil, vegetation and water components.

Where appropriate, CEH will build knowledge on other biogeochemical issues, particularly those involving the release or production of potentially hazardous chemicals such as heavy metals, organic compounds, radionuclides, phosphorus and ozone. Our overarching goal will be a better understanding of the drivers of changes in these cycles, their impacts and mitigating measures (see also Hazard mitigation). An important related issue (particularly for human health and climate change) is identifying the sources, properties and fate of particles in the air.

Models which couple the carbon, nutrient and water cycles within soil-vegetation systems, form a key component of global biogeochemical models. CEH has a large resource of such terrestrial models. CEH will work with the wider community of Earth system modellers to address the key question:

7 What is the tolerance of the Earth system to future human perturbation?

Many of the answers lie in a better understanding of past biogeochemical events. We need to know how the Earth's atmosphere gained its present composition and how this composition has been regulated within certain limits through biological feedbacks. CEH will place a high priority on understanding key interactions and feedbacks between biogeochemical and water cycles and climate, and identifying the important processes for the future.

CEH will also address the long-term response of biogeochemical cycles to human activities (beyond the century timescale), and biogeochemical fluxes from land to ocean and transformations in the estuarine and coastal zones. An underlying challenge is to reduce the uncertainty in predictions of present and future changes in biogeochemical cycles, which will be tackled by identifying the key process uncertainties and developing and applying novel predictive tools. The key question above is also closely related to the climate change issues developed on the next page.

Climate change

Predictions of the magnitude and speed of climate change suggest that there will be major impacts in the UK and globally, both directly and in response to knock-on effects. Apart from the many scientific challenges, there are policy drivers and international obligations (e.g. UN Framework Convention on Climate Change - UNFCCC) to which the UK must respond. Working with partners, CEH will focus on the question:

8 How can we reduce uncertainty in our predictions of climate change and its effects?

Global Climate Models based upon sound physical knowledge are the best tools to predict climate change. CEH has a major rôle in helping to reduce uncertainty within climate models by contributing to environmental issues related to its science base.

Improvements in global climate models (at the Hadley Centre and elsewhere) will be made by improving and validating the land components, focussing on hydrological representations, coupling the water, carbon and nitrogen cycles. Crucial challenges are: getting a true representation of the interactions between the land surface and climate at regional scales; predicting the interactions between climate change and vegetation distribution and ecosystem properties and how these may feedback to amplify or dampen future climate change; and understanding how changes to freshwater input to oceans can drive climate change. These are huge challenges and will involve continued participation in international land surface experiments, fundamental research on land-atmosphere interactions and ecosystems and full use of CEH's expertise and international datasets as well as progressive model development.

Allied with this, CEH will contribute to the coupling of land surface models with Earth Observation (EO) data. The key issues are the identification of global 'hot spots' where the land surface feedback affects climate, generation of long-term calibrated and tested EO data products, the development of accurate models of radiation interaction at the land surface, and the exploitation of these models to relate EO to land surface processes. CEH will continue to participate in data quality programmes for a range of European Space Agency (ESA) and the USA's National Aeronautics and Space Administration (NASA) instruments, underpinned by ground-based instrument development and deployment.

The CEH programme on greenhouse gases encompasses work on the carbon and nitrogen cycles (described above under Biogeochemical cycles). Recent investment in flux measuring equipment will enable new advances to be made on spatial and temporal variation in nitrous oxide and methane net emissions, as affected by climate and land management, as well as better quantification of land use and forestry impacts on carbon dioxide and total radiative forcing budgets.

As climate prediction is refined, CEH will contribute to an increasingly meaningful and urgent question, namely:

9 How can the potential impacts of climate change be accurately predicted and what adaptation strategies need to be developed?

Climate change impacts on vegetation and water resources at a global scale will be an integral part of CEH's core programme on the carbon cycle and land-atmosphere interactions.

Climate change is a major consideration in conservation and land use policies being formulated by government, Environment Agency/ Scottish Environment Protection Agency and the conservation agencies. CEH will develop further strength in modelling climate impacts upon species, communities and functional groups using both mechanistic and non-mechanistic correlative models. Such modelling activity is driven and checked against the uniquely detailed, rigorously sampled and long-term datasets held within CEH. These datasets cover biota ranging from plankton to terrestrial invertebrates and a range of biotopes including the vulnerable coastal zone.

Advances by CEH will occur as ecological modelling enters a second phase, allowing understanding of mechanisms driving and constraining the distribution and abundance of terrestrial and freshwater species and communities, and also their responses to changes in climate, weather events and atmospheric composition. CEH's strengths in this broad field are its abilities to work from the laboratory to the field scale and to examine whole ecosystems using multiple open-top chambers, lake instrumentation, solardomes and large field-exposure facilities.

Experimental observations and findings will be used to improve and parameterise CEH process-based ecosystem models, some of which have been custom-built to assess effects of climate change. Special attention will be given to quantifying uncertainty, coupling nutrient cycles, incorporating species development and life cycle processes, linking to socio-economic drivers, and assessing the opportunities for, and effects of adaptation. CEH will do this through the development of improved methods for detecting and forecasting long-term change in combination with the establishment of dynamic data-links with other observation networks in the UK (eg biodiversity, phenology, marine) and the rest of Europe.

Sustainable economies

Much of CEH's science strategy concerns the health of the environment. CEH will also contribute directly to wealth creation (particularly through technology transfer) but its main focus will be on sustainability – providing solutions when the demands for both a healthy and a wealthy environment conflict. CEH will take an holistic approach, working with socio-economists and technologists to derive optimal solutions.

Energy requirements must be met increasingly from renewable sources. Policy drivers include the Renewables Obligation, Green Fuels Challenge and Kyoto Protocol. CEH will help address the key environmental question of:

> **10** Where are renewable energy schemes best located for maximum output with minimum adverse impact?

CEH will provide scientific guidance for the optimum deployment of schemes to generate bioenergy, hydropower, and wind power, taking account of ongoing work funded by Government, industry and the EU, and existing research centres (eg the Tyndall Centre of which CEH is a part). Solutions will be based on identifying: (i) how much energy can be generated and how much is truly renewable – the net, non-fossil energy yield, and (ii) the biophysical and socio-economic constraints and how they can be minimized.

Biofuels include biomass energy from dedicated crops and agricultural and forestry residues, landfill gas and energy from waste. Energy crops will need to be grown over significant areas to make an appreciable contribution to UK energy supplies, eg 500,000 hectares would be needed to provide between one quarter and one third of the Government's target of 10% renewable energy generation by 2010.

Major questions concern the net renewable energy yield of biofuels (requiring complete fuel-chain analysis) and their impacts on water resources (important for biomass yield), hydrological extremes, air-soil and water quality, net radiative-forcing (taking into account all greenhouse gases), landscape, wildlife, local transport, noise and other nuisance. Similar research will be required for energy schemes based on the use of residues and waste.

Hydropower potential needs to be quantified with greater certainty in order to encourage investment, both in the UK and overseas.

CEH will improve assessment of available energy resources for both run of river and high head storage schemes by predicting the dynamics and statistics of hydrological regimes at locations without recorded river flow data. CEH's success in integrating hydrological models to the design of hydropower schemes will be advanced to include economic analysis of power output including the seasonal and annual variability and uncertainty of power predictions.

Allied to this will be the assessment of impacts on ecosystems of changes in river flows due to hydropower production. CEH is developing empirical and bioenergetic models for predicting the impact of reduced river flows on freshwater ecosystems. CEH will extend and apply this generic modelling capability to locations downstream of high head storage reservoirs and river diversions.

The sustainability of the **Nuclear fuel** cycle is crucially dependent on effective management of future, current and historic nuclear waste. With the Oslo and Paris Commission (OSPAR) agreement effectively excluding burial at sea, disposal of nuclear waste on land appears to be one of the few available options. Continued exploitation of nuclear power relies upon confidence in the environmental assessment models which are underpinned by sound science.

As a world-leader in terrestrial and aquatic radioecology, CEH can make a major contribution to environmental and human risk assessment of potential disposal options by using our knowledge of radionuclide transport and uptake processes to correctly parameterise and constrain radionuclide dispersion. A focus will be the development of a mechanistic understanding of the processes controlling the transfer of little-studied waste repository radionuclides within the environment and its incorporation into transfer models to support impact and risk assessment.

Jean-Francois Mutzig/Still Pictures

Sustainable economies

Land use is among the most pervasive and influential drivers of environmental change. The complexity in land use issues is exacerbated by changes in social and economic demands and by national (e.g. Food and Farming), European (e.g. Common Agricultural Policy [CAP] reform) and global (e.g. Millennium Development Goal) policy responses to these changes, primarily aimed at achieving sustainable growth. National and European governments have as a priority the need for scientifically-based policies to deal with competing demands for land resources. At an international level the emphasis will be on poverty reduction via improved use of natural resources.

In continuing to respond to both the scientific and policy issues concerning land use, the challenge for CEH is to build stronger integration of expertise across the organisation and with partners (for example through our membership of the Lancaster Environment Centre and the Landscape Europe network of research centres), particularly at the overlaps within Earth's life support systems (see figure on p.4) and those due to other influences (i.e. social and economic issues). The key question for CEH is:

11 How can we best identify and monitor land use changes and predict their ecological and hydrological impacts?

In addressing this complex question, CEH will contribute to the search for sustainable solutions to land use conflicts. CEH will develop a better understanding of the environmental costs, benefits and risks associated with major socio-economic drivers of change (e.g. CAP reform) or land management practices (e.g. GM crops). We will determine how science can best underpin the development and maintenance of multifunctional landscapes that deliver social, cultural, economic and environmental benefits.

Assessing environmental health in changing environments will require analytically tractable indicators applicable to ecosystems, landscapes, catchments and regions, and taking into account such diverse issues as biodiversity, carbon flux, diffuse pollution, 'broad and shallow' agri-environment schemes, economic potential, and the cultural and historic value of landscapes. These indicators need to be developed in the light of new EO technologies, validated using experimental and modeling studies, and must be consistent with emerging international standards. Thus, CEH will engage in the scientific underpinning of an indicator of countryside quality for DEFRA and the emerging European capacity for Global Monitoring for Environment and Security (GMES) by developing concepts for integrating ground and EO data.

We will develop our programme of monitoring land use change and environmental health by addressing these indicators within existing long-term programmes, notably Countryside Survey and the Environmental Change Network, and through building partnerships with other key players with complementary expertise (e.g. National Resources Institute, Institute of Arable Crops Research, Macaulay Research Institute, Institute of Grasslands and Environmental Research) or geographic scope (i.e. through Landscape Europe). This work will provide improved auditing of environmental quality and detection of early warning signals of long-term environmental change and will contribute to the Millennium Ecosystem Assessment.

CEH will develop its capacity to provide forecasts and scenarios of land use change in collaboration with other centres, and will focus on the environmental impacts of such change. The modelling underpinning these forecasts will apply to different processes and spatial and temporal levels. For example, at the site level, CEH will seek solutions to the damaging pressures (physical, biological or chemical) of land use change on the functional capacity of soils by applying its theoretical and practical understanding of the role of soil organisms in nutrient cycling and chemical breakdown. Through the FIRST Faraday network (Faraday Partnership for Innovative Remediation Science & Technology) and close partnerships with public and private sector bodies, CEH will exploit a multi-systems approach to identify new ways of evaluating the need for remedial action and methods for monitoring its success. At the landscape level, impacts of land use management and change on biodiversity will be modelled, drawing upon the databases of Countryside Survey and the Farm Scale Evaluations of GM crops. At the catchment level, we will address interactions among coupled terrestrial and freshwater ecosystems. At the European level, we will develop our work for the European Environment Agency on assessing threats to biodiversity. Such models and forecasts can be evaluated, at least in part, using CEH's extensive environmental databases.

Photofusion Picture Library/Alamy

To support decision-making by problem holders and policy makers, we will develop and use tools such as scenario visualization and virtual environments. These collaborations will identify areas where conflicts over natural resources occur between stakeholders and help resolve such conflicts by addressing the balance between multiple outcomes of land and water use, using economic evaluation of environmental goods and services where appropriate. Throughout the world poor people are especially dependent on water and other environmental goods and services for their survival and CEH science will make an important contribution to this area worldwide.

Sustainable economies

Hazard mitigation is a major societal need because many natural processes and all human activities have attendant hazards and benefits. Successful mitigation cannot be achieved without hazard characterisation and risk appraisal. CEH has national and international capabilities in all three of these areas that can deal with both acute and chronic environmental stressors. By building on our expertise in four key areas - monitoring the pollution of air, water, soil and biota; risk assessment of chemicals and radionuclides; drought and flood forecasting and management; the environmental significance of unusual and extreme events - we will address the overarching question of:

12 How do we estimate chemical, ecological and hydrological hazards and risks and develop mitigating measures?

Pollutants are released into the environment by many human activities. They can pose a risk to the functioning of ecosystems and to the health of living organisms, including people. Part of CEH's core business is to improve understanding of the sources, transport, chemical transformation, fate and effects of chemical and radionuclide pollutants. Thereby, CEH helps provide the essential scientific underpinning of UK, European and international laws, policies and initiatives on pollution control and chemical regulation. This knowledge will be integrated to provide tools and techniques by which ecosystem health can be measured and effective mitigation of hazards, risks and impacts achieved.

CEH will further develop its long-term, national monitoring of pollutants in the air (e.g. sulphur, ozone, particles - including deposition effects), water (e.g. endocrine disruptors, algal toxins), biota (e.g. organics, metals) and in soils and vegetation (e.g. acidity, heavy metals, radionuclides). The new challenge will be to combine our understanding of biogeochemical cycles with temporally- and spatially-explicit monitoring, experimental ecotoxicological studies, predictive modelling and diagnostic tools to assess the behaviour and effects of contaminants (single and mixed species) to generate more realistic and ecologically relevant risk assessment systems and mitigating measures.

Our contribution to avoid and mitigate problems will focus on two areas. First, CEH will devise semi-automated biological and chemical monitoring systems that respond sensitively and diagnostically to pollution, and which can be used in early-warning mode to provide forecasts of longer-term impacts at the population and community levels. Second, we will exploit natural processes to enhance the rate at which chemicals are broken down (e.g. through use of innovative multi-taxa bioreaction systems) so that key waste streams are managed more effectively and opportunities for re-use increased.

Floods and droughts. Fluvial and coastal flooding is of major national concern. CEH has proven expertise in the development of flood forecasting and flood frequency estimation procedures (e.g. the Flood Estimation Handbook), and expertise in managing coastlines to counter sea-level rise driven by global change. CEH has proven expertise in developing water resource decision support systems ranging from software to estimate the frequency of low flows in UK rivers (Low Flow 2000) to the analysis of the spatial development of drought at the continental scale.

Working from its recognised scientific strengths, CEH will improve knowledge of hydrological risks, including floods and droughts, by developing new analytical methods and modelling techniques for applications in risk analysis and the assessment of environmental change and mitigation options. We will focus on three key areas (i) the development of innovative approaches of hydrological analysis and modelling, together with the new methods of both strategic and operational benefit to hydrological practice, (ii) hydrological modelling and forecasting, including real time flood forecasting, hydro-meteorological interactions and generic modelling methodologies appropriate to hydrology and ecology, and (iii) flood frequency and uncertainty analysis, including current practice and next-generation flood frequency estimation methods, quantitative estimation of uncertainties and detection of trends in environmental variables.

Ian West/Oxford Scientific Films

Delivering the science strategy

CEH's greatest resource is the know-how and skills base of the people who work within the organisation. Success in delivering this ambitious Science Strategy will depend on strong support for our staff, including continuing development and training, and setting out a clear and exciting agenda for the future in which staff can identify their role. We will improve communication and interactions within the organisation to facilitate knowledge transfer and team building, including opportunities for short- or long-term transfers of staff between CEH sites.

Much of the CEH Science Strategy is geared towards knowledge transfer and technology transfer, either to underpin policy development or provide solutions to environmental problems. CEH will improve the vehicles used for communicating the results of our research in ways meaningful to decision/policy makers, maximizing the potential of modern information communication technology. CEH will also aim to exploit the added benefits from its core business (in partnership where appropriate) to underpin development of a thriving environment industry for the UK. The commercialization of outputs can in turn generate new scientific questions and provide new opportunities for research. We will contribute to the corporate approach to exploitation in order to maximise the commercial value of NERC intellectual property where appropriate.

Full details of the delivery of this strategy will be given in the CEH Implementation Plan currently being developed. The plan will prioritise and allocate resources to the science areas described in this Science Strategy.

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