NATURAL ENVIRONMENT RESEARCH COUNCIL

Science Theme Reports
NERC Strategy 2007 – 2012
Next Generation Science for Planet Earth

Sustainable Use of Natural Resources
November 2007

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Science Theme Report

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Living within the Earth's limits

1. Introduction

1.1 This report

Theme reports are the core of NERC Science and Innovation Strategy, which sits within the overall strategy for 2007 – 2012 *Next Generation Science for Planet Earth*. The reports are the culmination of consultation, advice and decision-making that took place over 2006 and 2007. They are working documents that provide the basis for implementation, informing Theme Action Plans. The NERC strategy document contains a summary of the information in the reports. The overall development process for the Sustainable Use of Natural Resources (SUNR) theme report is summarised below:

In November 2005 NERC Council identified seven strategic science themes, and a strategy development panel was set up for each theme. The panels' role was to recommend to NERC's Science and Innovation Strategy Board (SISB) NERC's future research priorities within each theme. The Sustainable Use of Natural Resources panel met on 10-11 May 2006.

Each panel prepared a report following a common format that was presented by the panel chair to SISB on 11-12 July 2006. At this meeting SISB provided its initial view on the relative priority of the challenges identified within each theme.

Following the SISB meeting some of the panel reports were updated. The conclusions from the SISB discussion together with a response from the panel chair were appended to panel reports and presented to Council on 26 - 27 September 2006.

The report was further updated following the discussions at both SISB and Council to reflect the overall priorities agreed at Council for this theme.

A draft NERC Strategy Document was developed from the panel reports and opened to public consultation on February – April 2007. A final version of the Strategy, incorporating recommendations from the consultation, was approved by Council in June 2007 and published in November 2007. In October 2007 the theme reports were updated to reflect this evolution of the strategy document.

1.2 Background

The HM Treasury set out five public policy challenges for the UK in July 2005. Of particular relevance is Challenge 5, relating to "increasing pressures on our natural resources and global climate from rapid economic and population growth in the developing world and sustained demand for fossil fuels in advanced economies."

NERC's role is in providing the foresight to understand these pressures in an integrative manner, given that use of one resource may adversely impact on another but also there may be environmental gains where more holistic thinking is applied to resource use. For example, whilst desalinisation enhances water availability it is energy-demanding but if it were coupled to renewable energy sources its benefits might outweigh its environmental costs. Similarly, unexpected environmental gains may arise from resource use such as offshore rigs providing 'artificial reefs' for marine ecosystems.

1.3 Scope

The broad scope of the theme is the sustainable use of renewable and non-renewable natural resources (e.g. fossil fuels, minerals, water, land) to meet long term societal needs.

A functional definition was used to help define the science challenges outlined later in this report; it was taken from the UK Government Sustainable Development Unit definition of Natural Resources (http://www.sustainable-development.gov.uk/key/whatare-natural.htm) and is given in the table below.

Raw materials such as minerals and biomass	Minerals, such as fossil fuels, metal ores, gypsum and clay, are non-renewable because they cannot be replenished within a human timescale. In contrast, biomass is in principle renewable within the human timeframe, and includes quickly renewable resources, like agricultural crops and slowly renewable resources like timber. However, both of these can be pushed beyond their limits of recovery if over-exploited
Environmental media such as air, water and soil	These resources sustain life and support biological resources on which we depend.
Flow resources such as wind, geothermal, tidal and solar energy	These resources cannot be depleted, but require other resources to exploit them. For example, energy, materials and space (land) are needed to build wind turbines or solar cells.
Biological resources include species and genetic information	Plants, animals and other organisms maintain the life-sustaining systems of the earth. Their variability (biodiversity) is also a resource and includes the diversity within species, between species and of ecosystems.

1.4 Key drivers

There is a clear and critical need to safeguard the environmental and economic security of strategic resources such as energy and water to maintain the wealth and well-being of UK plc. Globally, access to resources may become an increasing source of conflict in the future. The following key drivers were identified.

1.4.1 Economic

Some key resources are finite e.g. minerals including fossil fuels. There is a requirement to identify previously untapped reserves; to maximise potential available by increasing efficiency of mining/recovery processes; to reduce or change usage where possible; and to develop techniques for the effective and efficient recovery and recycling of resources.

Energy use is increasing globally. Sustainable methods of energy generation are needed as oil and gas reserves diminish in the coming decades. Renewable sources of energy are beginning to play an increasing part in the electricity mix, but are vulnerable to climate change impacts that are difficult to predict using current large scale models. As interest in nuclear power and coal-fired generation coupled with carbon capture and storage increases, it is likely that a variety of generation sources with very different environmental footprints will be deployed in the future.

1.4.2 Quality of life/Well-being

There is nearly as much urban land space in the UK as there is cropland. Urban encroachment and the move globally towards ever larger cities create resource use challenges. Large conurbations require adequate infrastructure (water, energy, transport, waste disposal). These infrastructure issues raise environmental challenges, including transport and distance of resources from source of supply. These challenges cut across rural-urban divides.

Valuing the natural environment – in a mature, developed society such as the UK, the public have an increased awareness, and place a greater value on the natural environment. There is a political and economic value in having high quality amenity areas.

1.4.3 Environmental

Globally, population is increasing. In the rapidly emerging and developing economies (e.g. China, India) the impact on natural resources of the population increase is magnified by the demand for consumer products that bring the benefits of a developed society. The environmental impact of this demand extends beyond developing countries, and when taken with the advanced economies sustained demand for fossil-fuels, has been identified by HMT as one its five public policy challenges.

Managing waste - greater consumption of raw materials leads to greater creation of waste products. Inefficient manufacturing techniques in developing countries may result in high volumes of high toxicity waste.

There are increasing pressures on water, both nationally and globally. Predicted climate change impacts will exacerbate these pressures. New technologies and altered water consumption patterns are likely to be part of sustainable water use.

1.4.4 Policy

This theme is closely aligned with government policy and will provide strategic knowledge to support evidence based policy development. Millennium Development Goal 7: ‘ensuring environmental sustainability' is pertinent, together with key areas of EU and UK policy including the Water Framework Directive requirement for integrated river basin management, the Habitats Directive and the UK Government's 2007 Energy White Paper.

The impact of climate change is an overarching driver, as it may act as a multiplier on the effect of the other drivers identified.

2. Key Outcomes

Four broad areas where environmental science should make a key contribution in delivering the foresight for the sustainable use of natural resources have been identified:

- Improved methodologies and technologies for quantifying and comparing ecosystem services;
- Improved knowledge (exchange, data, science into society) to inform policy and regulatory decision-making. The knowledge exchange is two-way: policy needs to articulate their needs to science community better;
- More informed choices by the public (individual and community) on use of resources leading to more equitable use and allocation of resources within the UK;
- Greater eco-efficiency in use of and waste from raw materials exploitation e.g. fossil fuels, minerals.

3 Science Challenges

The science challenges were developed within the framework of *"foresight built from strong science"*. Four high-level challenges have been identified for environmental science of international importance. These are further sub-divided where appropriate into science areas that it is feasible to deliver and where clear user relevance is identifiable.

1. **Extending the Resource Base**
This challenge focuses on fossil fuel sources of energy. It also includes other minerals and metals, and novel non-renewable resources. Key questions include: can society bury our way out of the carbon problem by through underground storage? Can society develop clean fossil fuels and/or alternative fuel source such as unconventional gas/oil; safe hydrate production. How does society lower the environmental footprint of resource use?

2. **Meeting the Renewables Challenge**
Can society meet the energy gap through renewables? What are the implications of biofuel production for UK land use? How can society ensure sustainable use of marine renewables?

3. **Sustaining Water and Soil Life Support Systems**
Can we use emergence and complexity science to integrate and advance understanding at the air-soil-water interface? How important are atmosphere-vegetation-soil-water interactions at the abiotic-biotic interface as litmus tests of the state of the earth system? How can we improve predictive models that are currently either "too good to be real" or "too real to be good" through better monitoring, parameterisation, scaling and uncertainty estimation?

4. Valuing Environmental Services

Can we develop a common environmental metric for comparison and evaluation of the implications of natural resource use on the environment? Can market-based instruments (i.e. resource trading such as green water credits; diffuse pollution auctions; carbon trading) adequately protect environmental services? How do decision-makers account for the waste impacts of resource use? How do decision-makers incorporate uncertainty and risk in valuing resource supply and quality?

There are strong links between the fourth challenge, and challenge 5 within the Biodiversity theme – 'Developing integrated tools for assessing the benefits of biodiversity.' This area will need to be developed as a cross cutting challenge that reflects the overarching driver to enable society to account for the various values of the environment in decision-making.

Energy is the most important challenge in this theme, with the focus on clean energy and the environmental impact of new technologies. Energy is the key component of challenges 1 and 2 and needs to be addressed in conjunction with the other Research Councils. Within challenge 3, water was seen as being a higher priority than soils but they have been kept as a single challenge as an integrated approach to research in this area is required.

3.1 Challenge 1: Extending the Resource Base

What is it?

This challenge focuses primarily but not exclusively on the exploitation of energy from fossil fuels. However, it also considers novel non-renewable sources, metals and other minerals. There are three key strands: (1) making better use of existing resources e.g. by exploiting minerals survey data, (2) tapping new resources, and (3) predicting environmental impacts of the whole lifecycle of resource exploitation. Under (1) these might include enhanced oil recovery, zero-emission clean coal plants; under (2) unconventional gas/oil sources (e.g. tar sands); methane hydrates; underground coal gasification, and under (3) predicting potential for and monitoring carbon capture and carbon storage. Applied science challenges with strong human 'well-being' benefits highlighted energy efficient urban environments, and sustainable transport (aviation, surface) and waste management systems.

Why is it important?

NERC science is particularly well suited to facilitate the development of new, more sustainable approaches to the use of fossil fuels and non-energy resources. NERC science skills can provide sustainable waste management strategies for nuclear waste, carbon dioxide, other greenhouse gases and toxic materials.

NERC's contribution:

NERC's strengths lie in addressing impacts of extraction and generation, in long term environmental assessment and monitoring and the identification of ecosystem test sites for deployment. Evaluating the environmental implications of changes to the fuelling infrastructure is critical as we move towards a low carbon society. There are several areas where NERC has a critical role:

- Initial surveys for sub-seabed hydrates around the UK using seismic data have not indicated the presence of significant quantities of stored methane. More certainty is needed using novel seismic and remote sensing, linked to seabed monitoring or borehole tests; 3D/4D modeling of resource distribution and its change with time;
- Monitoring to predict the environmental feedbacks of underground carbon storage proposals. Enhanced 3D and 4D modelling of demonstration projects will be crucial to

understanding the geochemistry and fluid movements in the subsurface, and reduce the risks associated with underground storage. Addressing the geotechnical uncertainties associated with use of saline aquifers for CO_2 storage to ensure that estimated long-term geocapacities can be realised;
- Forecasting the waste and recycling requirements of new forms of energy generation, including from low exposure nuclear sources;
- Predicting the impacts on the environment of trends towards increased vehicle use but with changed fuels (e.g. high efficiency petrol/biofuel models; hydrogen fuel cells);
- Predicting how the out-sourcing of gas supplies (e.g. shipping of super cooled LNG) may put pressures on land and coastal environments;
- Enabling better use of existing raw materials by e.g. micro-correlation techniques to enhance the geological input into reservoir modelling; characterisation of fracturing at a variety of scales; use of new non-seismic techniques for lithology and fluid prediction.

Contribution of others

The research is timely given the recent Government Energy Review and the science challenges share common opportunities (primarily the need for a multidisciplinary approach) and linkages to other aspects of the NERC areas of responsibility, such as Biodiversity and Pollution. There are opportunities to exploit knowledge through working with developing countries.

Deliverables

- Models to forecast the environmentally sustainable energy mix of the future;
- Methods to demonstrate how sustainable technologies can reduce the environmental footprint of existing raw material use e.g. life cycle analyses (LCA);
- Methods for environmentally safe production from methane hydrate resources in the UK continental margins. This would present the opportunity to link with existing data obtained by oil exploration industry, or data about to become available;
- 3-D/4-D techniques to inform decisions about managing energy wastes;
- A knowledge base about properties of seabed and associated habitats. This would provide a toolbox/decision support for marine developers;
- Evidence on the viability and long-term safety of carbon capture and storage to inform regulatory practice and public acceptance.

3.2 Challenge 2: Meeting the Renewables Challenge

What is it?

Renewable energy structures need to be placed in the most effective sites for maximum extraction of energy while minimizing environmental impacts. This challenge seeks to raise the profile of both the climate change and environmental implications of renewable energy in all its forms and to explore the multiple uses of sites as a method of enhancing their sustainability.

Why is it important?

Renewables are beginning to play an increasing part in the UK electricity mix. The UK Government will continue to encourage the future development of renewables as part of its energy portfolio. So far, most investment has been in onshore wind, but if long-term goals are to be met, then less mature technologies, such as offshore wind, marine renewables and bioenergy will need to be deployed. Marine renewable energy is not yet well developed but UK plc has tremendous potential owing to its extensive coastline, high winds and relatively high tides. Understanding the complex interactions between the hydrodynamics, morphological, environmental and ecological parameters resulting from renewable devices is a key science challenge that NERC is well-placed to address.

NERC's contribution:

- Provision of robust, reliable and independent evidence on the future location and sustainable use of renewables to enable business, policy and society to make informed choices;
- Sustainable use of marine renewables through the development of wave and tidal power with minimal environmental footprints (e.g. improved wind and wave climatology is needed to improve understanding of these energy sources; through optimising the location of generators; and through developing appropriate technologies for the operation of inshore wave fields);
- Forecasting climate change impacts on the security of renewable energy supply, including better climate predictors of tidal and wind parameters;
- Understanding how changes to household power sources (e.g. ground source heat pumps; low-head hydro power) may change the environmental footprint of urban areas and new housing developments in peri-urban areas. Although the engineered technology is mature there is poor take up in the UK due to lack of awareness and lack of a domestic service industry; this is likely to change;
- Establishing the net carbon footprint of biofuel commercialisation. With a finite area of land available in the UK there will be competing priorities (fuel, urban, food) particularly as biorefineries are likely to be located in rural environments. The challenge is to develop appropriate models to predict the catchment to regional scale impacts of bioenergy and determine appropriate crops or waste feedstocks in different regions;
- Developing approaches to minimise the environmental impact of structures, rotors and antifouling compounds; improved understanding of interactions between hydrodynamics and upstream morphological, environmental and ecological parameters resulting from renewable energy turbine devices. Could offshore wind-farms become havens for fish species (as have oil platforms), due to the lack of commercial fishing in the immediate vicinity?

Contribution of others.

Collaborations with the Hadley Centre in terms of future climate scenarios; Defra for fisheries and marine spatial planning plus UK environmental agencies such as EA, Natural England, Forestry Commission, SEPA, SNIFFER have interest in impact or sustainability issues. Links with BBSRC on biomass/energy crops with NERC focus on landscape and spatial land use change impacts.

Deliverables.

NERC's major contribution would be in providing foresight and solutions for the future location and sustainable management of renewables to allow business, policy and society to make informed choices.

- An evidence base to inform the future development of societal energy needs;
- Sustainable, environment-enhancing and CO_2-free supply of energy from the marine environment;
- Life cycle analysis of renewable energy, leading to decision support systems in priority areas such as the environmental impacts on marine environments, and an integrated 'field to generation' evaluation of bioenergy;
- Achieving added environmental benefits e.g. offshore wind farms and artificial reefs;
- Protecting estuaries e.g.' London Array' offshore wind project proposed for Thames estuary.

3.3 Challenge 3: Sustaining Water and Soil Life Support Systems

What is it?

Advances in Earth System Science have generated knowledge on large-scale interactions and fluxes and have demonstrated the coupling of human and environmental systems. This challenge focuses on interactions from the hillslope to regional scale appropriate for sustaining the quality of air, soil, water interchanges that sustain life and support the biotic resources on which we depend. The challenge is to build integrated understanding across different space and time scales of the relationships between air/soil/water to sustainable use of this resource. There are strong political and legislative drivers in this area at UK and EU level.

Why is it important?

Field and modelling research in atmosphere/vegetation/ soil//water spheres takes place at a range of space-time scales but is rarely joined-up; yet critical interactions or 'tipping points' may occur at e.g. the atmosphere-vegetation-soil and soil-water interfaces. A cohesive and multidisciplinary approach is needed to ensure resource protection and sustainable use. The importance of this challenge has worldwide recognition: the NSF in the US fund a consortium of >100 Universities to advance integrated hydrologic research via the CUAHSI programme (www.cuahsi.org); in Australia a $35M AUD initiative funds 3 environmental research hubs: the Landscape Logic hub focuses on linking land and water management to resource condition targets (www.deh.gov.au/minister/env/2006/mr06july06.html).

NERC is strategically well-placed to lead UK research in this area. This challenge seeks to ensure that the risks to air/soil/water resources are based on integrated knowledge of the processes and interactions across media and properly incorporate the uncertainties in current data and knowledge. Adopting this challenge would enable NERC to maximise data and monitoring to address the current (and future) legislative framework. This would be a big step forward from the compliance monitoring currently undertaken. Technology in this area is advancing rapidly, especially with regard to sensors, data-handling and software. This challenge has the potential for NERC to create flagship 'outdoor laboratories' for UK and European networks to match those being developed worldwide.

NERC's contribution.

This challenge fits wholly within NERC's remit and can be 'owned' by the NERC community – unlike other science challenges such as renewable energy, where there are many 'big players'. Building appropriately scaled models of the interactions between air/soil/water requires new understanding using data derived using new network systems approaches and incorporating non-linearity and emergent behaviour and complexity science. We have yet to find out if these interactions are non-causal: we do not know whether with the same starting conditions the patterns of interaction would repeat. This is important because we need to predict the impact of climate change dynamics on these resources. NERC could contribute to this challenge by establishing outdoor 'laboratories' with long-term security of tenure for integrated air/soil/water research that enable (1) development and application of new technologies (e.g. networked arrays of state-of-the-art sensors (using ground-, air-, and space-based platforms) for measuring states and fluxes in critical zone at point, hillslope, catchment, and regional scales and at critical time-steps (e.g. *in situ* real-time soil moisture sensors, optical and microwave imagery, radiometry, hyperspectral imagery);(2) experimentation (manipulation) to determine process linkages); (3) development and application of non-invasive tools (e.g. computing tomography, geophysical tools, remote sensing) to characterise air/soil/water structures across multiple scales; and (4) appropriately scaled models that incorporate uncertainty. There are parallels in the US where the National Ecological Observatory Network (NEON) is establishing a continental-scale, distributed research platform to advance understanding of how ecosystems and organisms respond to variations in climate and land use change (www.neoning.org).

The two sub-challenges below are a response to both the science need and to the strong political drivers in these particular areas. The water sub-challenge is seen as being a higher priority than the soils sub-challenge.

3.3.1 Specific sub-challenge relating to water.

Water has been described as the “new oil” – the challenges pertaining to its sustainable use are timely and have international relevance. The House of Lords Select Committee report on water management in the UK (June 2006) raised many challenges that NERC should address in relation to the conservation, efficiency of use and the potential for substitution of this critical resource. Many of the challenges identified in the report (e.g. leakage, water demand in SE England) focus on end-of-pipe solutions that may not be sustainable in the long-term. This challenge seeks to optimise the demand for water and cope with projected water shortages through integrated measures that may adopt ‘green water’ principles to conserve water. Particular issues that might be addressed include:

- Water-soil interrelationships at different scales for both water resource and water quality protection;
- Water conservation measures within river basins that avoid costly and unsustainable end-of-pipe solutions;
- Protecting groundwater resources through integrated measurement and modelling of abstraction, quality and habitat needs; developing aquifer recharge and recovery technologies;
- LCA of water substitution measures e.g. the environmental benefits and costs of desalinisation using non-renewable energy sources;
- Maintaining effective water resources to support essential ecosystem services (e.g., wetlands, riparian buffer zones, floodplains).

3.3.2 Specific sub-challenge relating to soils:

Soils are the buffer between water and air, and a medium for biotic/ abiotic interactions; soil function and quality is intrinsically linked with water status and air quality and is threatened through erosion, decline in organic matter, decline in biodiversity, salinisation, contamination and pressures on land from new crops such as biofuels. Soils may play a critical role in carbon sequestration. The UK has a strong position in soils research and mapping but the discipline needs investment and energising through interdisciplinary challenges similar to the CUAHSI initiative in the US. There are two key challenges: (1) soils as a resource (ecosystem services, resilience, diffuse pollution impacts, attenuation potential), and (2) soils as a mediator of climate change impacts (gaseous emissions, carbon flux and sequestration potential). The overriding challenge is to manage soils to deliver multiple functions under multiple drivers/pressures across multiple scales from micro to macro and from local to global. Specific challenges relate to:

- Understanding how soil microbial processes, vegetation, soil carbon storage and release and water flux are linked in catchments[1] and whether it is possible to maximise C and water

[1] Taken from the BBSRC-NERC Soil and Water strategy development workshop, Bristol 22-23 March 2006

retention in catchments through conservation or land management actions without generating other pressures e.g. flooding?
- Evaluation of whether integrated atmosphere-soil-water studies can identify whether larger scale (e.g. stream drainage) fluxes are the linear expression of finer scale processes (e.g. soil ion exchange) or is there an emergent complexity that cannot be predicted?
- Building understanding of biotic/abiotic interactions and the tipping points in terms of soil resilience and risk associated through non-sustainable use of land.
- A better understanding of how interactions with vegetation affects soil function with a view to predicting and mitigating impacts of environmental and climate change.
- Understanding the importance of landscape fragmentation in addressing land conflicts e.g. biofuel demands on available land area.

Contribution of others
An interdisciplinary and cross-Council approach would be possible (notably; BBSRC, EPSRC) together with government bodies (Defra, DfID, Environment Agency). The challenge goes beyond an understanding of the physical, chemical and biological sciences as it is driven by pressures from finance, planning and policy. It needs to incorporate social science understanding, and requires input from a wide community of water interests, notably environmental agencies, private water companies and NGOs.

Deliverables
- A functional audit of environmental media (soil, water – air covered by another theme) and assessment of future resilience;
- Science input to decision support for optimal management of resources with multiple objectives (e.g. water for consumption as well as a medium for supporting environmental services);
- Collaborations to generate new visualisations of resource planning and environmental evaluation (e.g. with computer scientists);
- Enhanced and synergistic land/water 'outdoor laboratories' monitoring networks from which new approaches to modelling and assessment may develop that further understanding of the scale dependencies in the water, soil, biochemical and sediment cycles and their impact on terrestrial and aquatic ecology in the context of multiple human use.

3.4 Challenge 4: Valuing Environmental Services

What is it?
This challenge focuses on the need to make choices regarding the sustainable use of natural resources in terms of affordability, environment and security. The environmental services that natural resources provide have no common metric from which to assess the impact of their use on the environment and on ecosystem quality. For some services (e.g. carbon) particular markets for the ecosystem functions they provide have begun trading but the ground rules are economic not environmental. The scope of this challenge is cross-cutting and interdisciplinary – it covers terrestrial and marine sciences; finite, renewable and biotic resources. The science challenge is devising new and innovative methodologies to achieve parity for environmental services alongside readily quantifiable economic indicators.

Why is it important?
This challenge seeks to improve decision-making through scientifically-informed choices. The overall aim would be to provide common source of knowledge for decisions by policy makers and regulators. Countries such as Australia are leading the way in developing market-based

instruments (MBIs) as policy tools to influence human behaviour to natural resource use (www.ecosystemservicesproject.org) but markets for ecosystem services are few; and in economic terms, the risk of 'market failure' is high and the consequences for resource protection are far-reaching.

NERC's contribution.

Modelling environmental risk is a NERC strength and can help meet the strong global focus of this challenge and the need to incorporate issues such as well-being and health, together with alternatives to financial or market solutions (especially for poor countries). Key questions this challenge would answer include:

- How do we arrive at weights for different types of environmental impact?
- How can we incorporate environmental risk within an accounting or market framework?
- How do we incorporate different means of accounting within decision making?
- Evaluating the risks and outcomes of market-based solutions for environmental services and derivation of new innovative approaches grounded in environmental science.

These questions might be addressed by:

- Millennium Assessment comparisons of development vs. ecosystem value based on scientific principles and modelled risk evaluations;
- Developing approaches to enable trade-offs in development decisions to be properly evaluated e.g. trading carbon storage; evaluating diffuse pollution auctions; achieving land use optimisation through 'green water' credits; developing measures for sustainable waste recycling. This may mean exploiting methods developed in other disciplines for valuing the environment.
- Integrating uncertainty in the decision-making process; developing appropriate models of environmental risk; incorporating spatial planning indices such that the source of a problem (e.g. headwater land use) and its potential impact (e.g. downstream flooding) may be understood better.

Contribution of others.

This science challenge provides a number of exciting opportunities to strengthen interdisciplinary skills and networks. Opportunities exist for partnerships with other research councils and with policy makers. In particular, there are opportunities to engage economic and social scientists to build on successful partnerships between environmental and engineering scientists. Tackling this challenge would bring NERC science into mainstream policy. There are some obstacles which NERC would need to consider – while there is an obvious need for interdisciplinary approach, currently there is no effective RCUK infrastructure in place to facilitate this and the RAE structure does not engender it. Currently, policy – particularly market-based solutions - in this area is moving faster than the supporting science, and there is a lack of a developed skills base.

Deliverables

The outcomes of this challenge could include:

- Development of integrated methodologies for proper accounting at all levels of decision making to compare different types of ecosystem values and ensure more effective resource use.
- Better articulation of future research needs from a science and policy community using a common information source and through the establishment of effective and inter-disciplinary collaboration networks;
- More robust values (reduced uncertainty) in valuing the environment and improved frameworks for handling environmental risk.

4. Meeting the Challenges

The published NERC Strategy highlights some of the ways in which the NERC will be "Meeting the Challenges" for each Theme. These are essentially some of the potential key deliverables. They often cut across several of the Theme's challenges. For consistency, we have included those for the Sustainable Use of Natural Resources theme below, against the challenges that they most strongly relate to. They are not exclusive and may evolve during the Strategy's lifetime.

"Meeting the Challenges" (From NERC Strategy)	**SUNR Theme Challenges**			
	1	**2**	**3**	**4**
Create new tools and techniques to quantify the environmental impact of the whole life cycle of resource exploitation	X	X	X	X
Forecast the environmentally sustainable mix of renewable and non-renewable energy sources for the future	X	X		X
Provide predictions for the long-term sustainability of capturing carbon from the atmosphere and storing it	X			X
Provide scientific expertise on unconventional energy sources and their environmental impacts. Examples include tar sands, methane hydrates and gas from coal deposits	X			X
Use environmental science to help develop methods for enhancing oil recovery and developing economically viable coal power stations with lower emissions	X			
Evaluate the physical and chemical behaviour of materials in potential storage sites for waste from nuclear power generation	X			
Develop an integrated approach to understanding air, soil and water processes, recognising their interconnections			X	
Predict how alternative fuels will affect the environment, including changes to the landscape, soil and bioresources	X	X	X	X
Understand how soil microbial processes, vegetation, soil carbon storage and release and water movements are linked in catchments			X	
Understand how the biological, physical and chemical interactions in soils determine the extent to which people can use the land sustainably			X	

5 Links and interface issues with other science themes.

There are close links between this theme and the Biodiversity theme and issues relating to the diversity of life as a sustainable resource have been picked up within the Biodiversity theme. SUNR Challenge 4 is closely related to challenge 5 within the Biodiversity theme 'Developing integrated tools for assessing the benefits of biodiversity'. This will need to be developed as a cross cutting challenge as it also has links with Natural Hazards, Environment Pollution and Human Health and Climate System themes. There are linkages between SUNR science challenge 3 (Sustaining Water and Soil Life Support Systems) with the Environment, Pollution and Human Health theme, and between SUNR science challenge 1 (Extending the Resource Base) and the Hazards theme. The Earth System Science and Climate Systems (Variability and Change) themes provide overarching context for the sustainable use of natural resources.

6 Implications for the Science Base

There is a need for NERC to review its existing monitoring arrangements with a view to determining whether the rationale for each is still appropriate and whether the most up to date technology and methodology is being applied. Effective monitoring is an essential foundation for much of the science that NERC undertakes and should be seen as a hugely positive activity. Unfortunately, monitoring standards are not consistent across the UK and practical challenges exist in e.g. Scotland given the diversity and vulnerability of Scotland's habitats and species. By reviewing all existing NERC-funded networks and identifying where they sit compared to each other and other funder's networks, any gaps or overlaps can be identified, allowing better targeting of resources. There is potential for improvements in monitoring as a result of improvements in sensor technology, improved remote access arrangements, and a greater integration between modelling and monitoring. Investment in these areas may pay dividends. This evaluation should sit alongside other initiatives such as the UKTAG guidance on WFD standards that will influence what is measured and where in the UK by the relevant bodies.

Improvements are needed in the management and accessibility (to the whole research community) of environmental data and data management, especially that relating to soils where there is a particular problem in scientists accessing soils data from across the UK. Monitoring of soils data is sparse and collection of biological data from soils is almost non-existent.

7 Synergies and Partnerships

Delivering the challenges will require interdisciplinary research and for NERC to work with other UK funders. The following bodies have been identified as being key partners who NERC should continue to engage with wherever possible: other Research Councils, Defra, RERAD, DARDNI, DfID, the Environment Agency, SEPA, HM Treasury, and data suppliers, such as the Meteorological Office.

8 Knowledge

NERC generates knowledge which potentially has significant impact. In order to maximise this potential, the following is proposed:

- NERC should take full responsibility for the final step in knowledge exchange, i.e. getting products to the end-user. This is perceived as a weakness at present;
- There are some exciting new opportunities afforded by new technology – NERC should investigate the possibilities of extending the reach of knowledge exchange through the novel use of new platforms such as computer games and next generation mobile phones;
- Public participation in environmental matters is rising up the agenda – this is partly driven by legislation, and partly by increased education and awareness. NERC must embrace these developments;
- End-users should be more fully engaged in developing knowledge exchange strategies – differing user groups (commercial, research community, regulators, the public/society) have different needs, and different communication methods will be needed in order to be fully effective. It is essential that information is 'packaged' in a way that the users can understand.

9 Links and interfaces with organisational themes

Sections 7 and 8 above set out specific opportunities for partnerships and knowledge exchange within the Sustainable Use of Natural Resources theme. At a strategic level, these have been incorporated into the corresponding organisational themes of the NERC Strategy.