



# ANNUAL REVIEW 2021

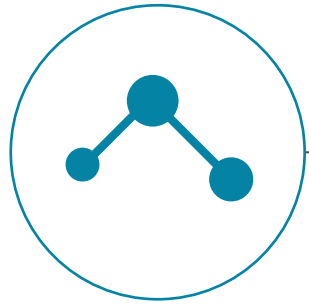


UK Centre for  
Ecology & Hydrology

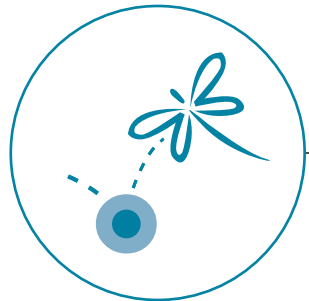


## 2021 THE YEAR IN NUMBERS

These numbers indicate the size, scale and excellence of the science we deliver in support of a world where people and nature prosper.



**1,400+** datasets (5.6 Tb) are now freely available via the Environmental Information Data Centre



**2 million+** records were received via iRecord to the Biological Records Centre, including **1 million+** images



The equivalent of **3,500+** years' worth of data in the National River Flow Archive were reviewed and improved



**31** early-career research associates joined UKCEH, giving us **92** research associates in total



Our annual turnover was **>£50 million**



We won **36** international bids across **27** countries



**3/4** of our outputs were rated world-leading or internationally excellent



**5** UKCEH scientists were named on the Highly Cited Researchers 2021 list



Our scientists jointly supervised **188** doctoral researchers



Our researchers published over **450** peer-reviewed journal papers

# 2021 THE YEAR IN PICTURES



Professor Chris Taylor speaks to Professor Dame Ottoline Leyser at the UN Climate Conference COP26 in Glasgow.



Presenter Liz Bonnin chairs a debate on 'the right and wrong routes to net zero' at our stakeholder event in Westminster.



Professor Alan Jenkins addresses delegates on the subject of nature-based solutions at the UN Biodiversity Conference COP15 in Kunming.



Our Auchencorth Moss Atmospheric Observatory was awarded prestigious Integrated Carbon Observation System (ICOS) labelling.



We upgraded instrumentation in the BT Tower Atmospheric Observatory for tracking London's emissions.



Dr David Fletcher participated in a Space4Climate / European Space Agency exhibition at COP26, focusing on Earth Observation.

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Cover: The restoration of the saltmarsh at Tollesbury, Essex, involving UKCEH scientists, was one of the first such projects undertaken in the UK. Credit: Aerial Essex





The largest survey of pollinator abundance in Wales to date, carried out by UKCEH and Butterfly Conservation Wales, found that woodland and hedgerow creation can play a crucial role in reversing declines in insects that are essential for crop yields and other wildlife.

# INTRODUCTION FROM THE EXECUTIVE DIRECTOR

PROFESSOR MARK J BAILEY



Welcome to our annual review for 2021, which was an exceptional year for us in many ways.

We participated in two key environment summits. At the UN Climate Conference COP26 in Glasgow, we joined forces with other leading climate science institutes to launch the UK National Climate Science Partnership, an alliance that will strengthen the UK's research capability and generate climate solutions for society. Meanwhile our Science Director Professor Alan Jenkins addressed delegates at the UN Biodiversity Conference COP15 in Kunming on the subject of nature-based solutions, stressing that the demand for informed, integrated, international environmental science is greater than ever.

During the year, we were successful in obtaining external funding to significantly strengthen our research infrastructure. Through the UK Research and Innovation (UKRI) World Class Laboratories programme, we invested in state-of-the-art field

monitoring equipment and laboratory facilities. This investment underpins our continuing role as a strategic delivery partner for the Natural Environment Research Council (NERC), part of UKRI, and will enable both UKCEH scientists and the broader research community to deliver innovative world-class environmental research for the future.

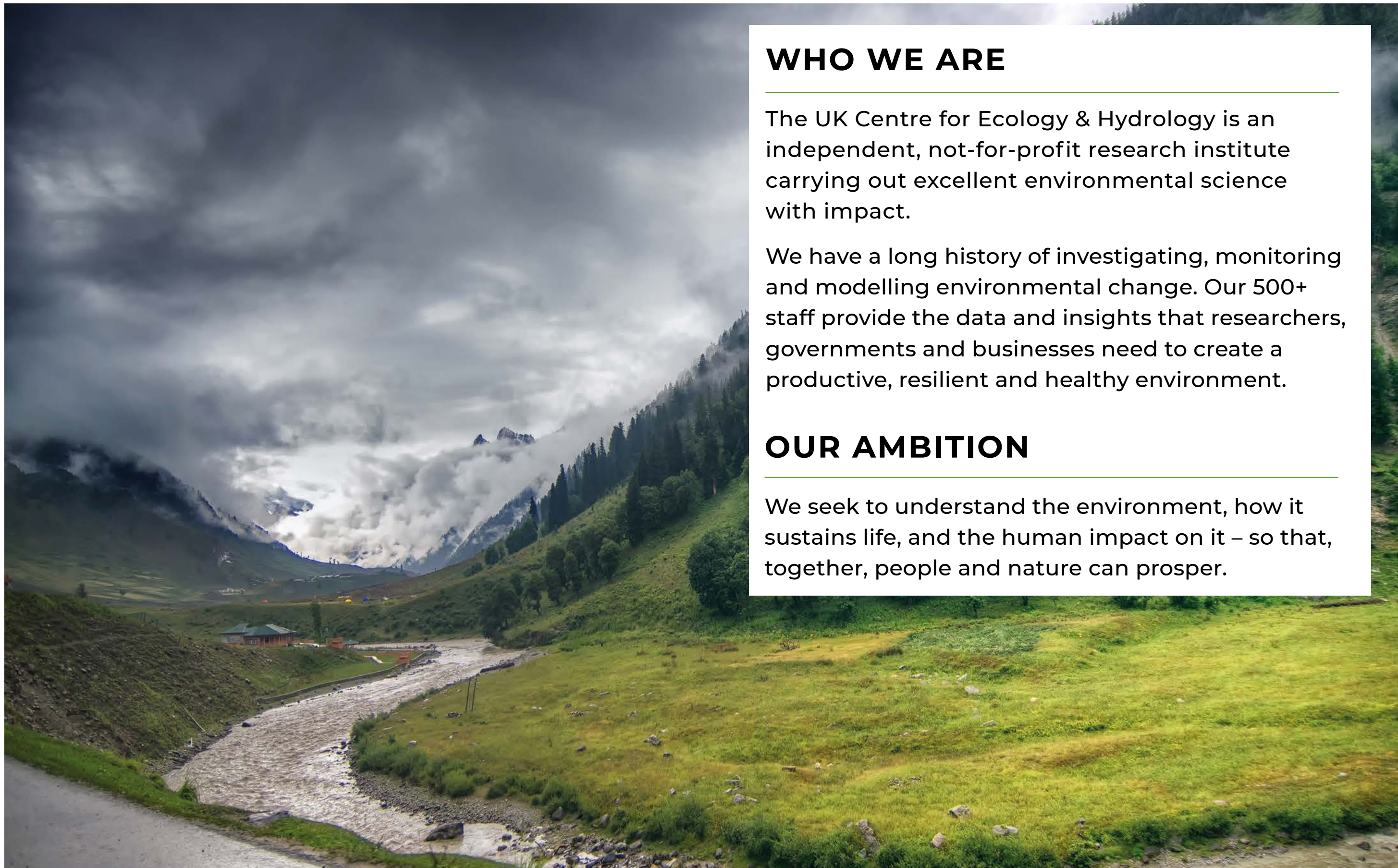
We also saw an increase in other sources of funding during 2021. To meet this growing demand for expert environmental science, in December we launched a recruitment campaign to hire 20 additional scientists.

We would like to thank all our staff, partners and funders for their ongoing flexibility and support during the pandemic. Despite the difficulties, we have continued to deliver the data and insights that enable researchers, businesses and governments to solve complex, interrelated environmental, social and economic problems. This publication highlights some of the key contributions our science has made.



Professor Mark J Bailey gave the first international master lecture of the Chinese Academy of Environmental Sciences.





## WHO WE ARE

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The UK Centre for Ecology & Hydrology is an independent, not-for-profit research institute carrying out excellent environmental science with impact.

We have a long history of investigating, monitoring and modelling environmental change. Our 500+ staff provide the data and insights that researchers, governments and businesses need to create a productive, resilient and healthy environment.

## OUR AMBITION

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We seek to understand the environment, how it sustains life, and the human impact on it – so that, together, people and nature can prosper.

The Hydrological Status and Outlook System (HydroSOS), a global initiative led by the World Meteorological Organization (WMO) and coordinated by UKCEH, will enable communities across the world to better adapt to our changing water cycle.



# HOW WE WORK

Underpinning UKCEH’s research and innovation are large research infrastructures and our capabilities in monitoring, measuring and observation, experimentation, data science and modelling.



## Monitoring, measuring and observation

We provide flexible, long-term, large-scale monitoring and surveillance networks essential to identify and measure environmental change, and determine the factors that drive that change.



## Experimental platforms and research facilities

Our research facilities enable us to test the role of different drivers of environmental change and the outcomes of novel interventions to manage the environment. We provide and operate experimental platforms and research infrastructures supporting national and international collaborations.



## Data science and modelling

We have developed models to forecast and predict aspects of the environment at different spatial and temporal scales. They include: models of national and international importance for assessing air quality; GHG emissions inventories; land use and environmental impact modelling; the UK’s sole land surface model; nationwide, real-time flood forecasting; and water resource outlooks.

### Our charitable objects

- To carry out pure and applied scientific research in terrestrial and aquatic environments, including their interactions with the atmosphere.
- To advance education in the environment and environmental sciences, and sustainable development.
- To promote sustainable development for the benefit of the public by promoting the preservation, conservation, protection and improvement of the environment and the prudent use of natural resources.
- To promote sustainable means of achieving economic growth and regeneration.

# OUR STRATEGY

In April 2020, we published our Strategy 2025: Research and Innovation. Our strategy sets out the role of UKCEH in addressing three major environmental and societal challenges:



- **Creating and enhancing sustainable ecosystems**
- **Reducing and preventing pollution**
- **Mitigating and building resilience to climate and environmental change**

Our specific contribution to these challenges focuses on ten integrated issues:



**BIODIVERSITY**



**FLOOD AND DROUGHT IMPACTS**



**CHEMICAL RISKS**



**NET ZERO GREENHOUSE GAS EMISSIONS**



**CLEAN AIR**



**SOIL HEALTH**



**CLIMATE AND LAND**



**SUSTAINABLE AGRICULTURE**



**ECOSYSTEM RESTORATION AND RESILIENCE**



**WATER QUALITY AND RESOURCES**



## BIODIVERSITY

### THE CHALLENGE

Biodiversity is under threat with species declining at the fastest rate ever recorded. The biggest threats include habitat fragmentation and loss, climate change, pollution, invasive species and pathogens.

### OUR ROLE

Our flagship Biological Records Centre brings together the scientific capabilities and data resources necessary to assess the status and trends of species populations. Integrating work across monitoring, experimentation, and modelling gives us the capacity to deliver solutions for conserving and restoring biodiversity.

### HIGHLIGHTS



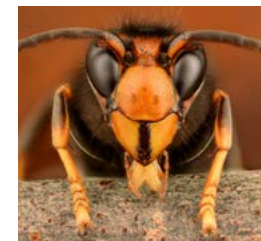
#### New biodiversity toolkit for housing developers

Urban development is one of the causes of habitat loss, deterioration and fragmentation of natural areas. Responding to this challenge, ecologists at UKCEH launched a biodiversity toolkit to enable housing providers and residents to support wildlife on their estates. The toolkit, developed in conjunction with Southern Housing Group and other partners, provides over 20 options to improve biodiversity on housing estates. These options can be tailored according to housing density, budget and the level of maintenance that is possible.

#### Latest technology to improve biodiversity alongside thousands of miles of rail track

Our scientists used high-resolution satellite imagery to produce a detailed national map of all the habitats found alongside Britain's 20,000-mile rail network, as part of Network Rail's new action plan for sustainable vegetation management. By combining this information with millions of records of species, they predicted what animals and plants are likely to be present in these lineside habitats including grasslands, heathlands and woodland. This initiative is part of Network Rail's new Biodiversity Action Plan, drawn up in collaboration with UKCEH.

#### Preventing the spread of the Asian Hornet in Europe



The Asian hornet is a highly aggressive predator and poses a significant threat to honey bees and other pollinators across Europe. We produced an IUCN (International Union for Conservation of Nature) report for the European Commission on the effectiveness of rapid eradication attempts in preventing the spread of the Asian Hornet in Europe. IUCN provides technical and scientific support to the EC for the implementation of the EU Regulation on Invasive Alien Species. The report will inform future approaches to managing this invasive species.

#### Research into insect populations leads to changes in street lighting

Research into the impact of low-energy LED streetlights found that the lights were more harmful for insect populations than the traditional sodium bulbs they replaced. Almost all previous research on light pollution has focused on adult insects, but by studying moth caterpillars, which are a lot less mobile, researchers were able to get more precise estimates of the impacts of street lighting on local populations. The large diversity of moths means they are broadly representative of nocturnal insects. Widespread media coverage of the study contributed to some councils changing their street lighting.



### ▶▶ FORWARD LOOK

- UKCEH scientists will join partners in a new project called TickSolve, which will determine whether climate change and woodland expansion are likely to increase tick-borne infections in the UK.
- A multidisciplinary research team, led by UKCEH, will investigate how quickly tree species can adapt to environmental pressures, specifically changing climate, pests and diseases.
- A separate project involving UKCEH will improve our understanding of the value of trees to society, including benefits for people's wellbeing, cultural heritage and wildlife.





## CHEMICAL RISKS

### THE CHALLENGE

Chemicals are integral to human life and generate billions of pounds for national economies. However, chemical discharges can degrade the environment, having an adverse impact on ecosystems, and thereby affecting the health of humans and wildlife.

### OUR ROLE

We investigate the dispersal, fate and behaviour of chemicals and polluting substances in terrestrial and freshwater environments. Priority pollutants include radionuclides, pesticides, organic pollutants, toxic metals, nutrients, and manufactured nanomaterials and plastics. We seek to determine the effects of these pollutants across multiple scales, ranging from genes to populations.

### HIGHLIGHTS

#### Improved methods for assessing the environmental safety of nanomaterials

UKCEH researchers streamlined the testing requirements for assessing the environmental risk posed by nanomaterials. Through EU-funded projects and work with the OECD (Organisation for Economic Co-operation and Development), we delivered several key pieces of science to improve the methodology for assessing the risk of these substances causing harm to the environment. This work will reduce testing requirements significantly, including the need for animal testing.

#### Bloomin' Algae app helps public and pets enjoy the environment safely

We released a new version of the Bloomin' Algae app, which enables UK and Irish citizens to submit photos of possibly harmful algal blooms, so that the risk from hazardous toxins to people and animals can be gauged. The new version enables users to see records for their area, and provides a quick notification service to local authorities. We worked with regional media to increase public engagement with the app, and targeted dog walkers and wild swimmers who are among those likely to contribute.



#### Estimating the number and spread of COVID-19 cases from wastewater

Our scientists led the research community in the UK in developing and optimising wastewater-based epidemiology (WBE) in order to improve the four nations' responses to the COVID-19 pandemic. We contributed to an innovative investigation into the feasibility of conducting WBE within specific locations such as primary and secondary schools, prisons and care homes; and we chaired the Home Office's Accelerated Capability Environment Expert Advisory Group, which led the creation and scaling up of WBE capability.

#### Updated tool for assessing the risk of radiation to wildlife



UKCEH and its predecessor institutes have carried out research in the Chernobyl Exclusion Zone for 30 years.

The ERICA Tool is the most widely used model for evaluating the risk of anthropogenic ionising radiation to wildlife. In 2021, UKCEH released the most significant update to the tool since its launch in 2007. The new version has updated parameters, new functionality, and now applies the International Commission on Radiological Protection's latest approach to dosimetry. We also provided training for regulators, industry and other assessors on how to use the updated tool to estimate risks to selected animals and plants.

### ▶▶ FORWARD LOOK

- In 2022, we will report to UKWIR (UK Water Industry Research) on micro- and nanoplastic contamination of the whole drinking water system, from treatment works through to service reservoirs and household taps.
- We will develop a model to describe and predict plastic fragmentation and degradation in the environment, applied across a broad range of polymers and environmental conditions.
- We will produce long-term time series data (1750-2100) of nitrogen and metal inputs to soils from atmospheric deposition and agricultural activities in the UK. We will use a range of shared socio-economic pathways to model these into the future.





## CLEAN AIR

### THE CHALLENGE

Air pollution is a major risk to human and environmental health. Around the globe, the adverse health effects of air pollutants are most prominent in urban areas, notably in African and Asian megacities. Air pollutants also have adverse effects on our natural environment, contributing to ecosystem damage and biodiversity loss, and impacting food security by reducing crop yields.

### OUR ROLE

Through our groundbreaking flux measurement techniques and our field experimentation facilities, we generate long-term, high-frequency time series data of atmospheric composition change and identify the sources of emissions. This delivers vital data needed to inform the development and evaluation of effective clean air policies around the world.

### HIGHLIGHTS

#### Identifying the sources of Delhi's poor air quality

Delhi continues to rank amongst the most polluted cities for which measurement data exist. In 2021, we co-published seven papers that analyse the sources of air pollutants in the city, the origin of particulate matter, and predict the responses of pollutants to emission changes. The work put regional agricultural residue burning, often blamed for Delhi's poor air quality during the post-monsoon period, in the broader context of urban emissions from vehicles, and the burning of solid fuels and municipal waste. This research was carried out as part of DelhiFlux, a collaborative project led jointly by UKCEH and the Indian Institute of Technology Roorkee.



#### Informing the development of England's new air quality targets

The UK Government's Department for Environment, Food & Rural Affairs (Defra) is developing new targets for reducing PM<sub>2.5</sub> (fine particulate matter) for England, which will transcribe the ambitions of the Clean Air Strategy and Environment Bill into secondary legislation. UKCEH supported this process by modelling future PM<sub>2.5</sub> concentrations that would be expected under a range of emission scenarios, and their response to meteorological year-to-year variability. UKCEH also fed scientific evidence into a number of outputs from Defra's Air Quality Expert group, providing independent advice to government.

#### Upgrade of the BT Tower Atmospheric Observatory for tracking London's emissions



UKCEH, in collaboration with the Universities of Reading and York, has been measuring London's emissions from a unique installation on top of the BT Tower since 2006. In 2021, NERC's World Class Labs infrastructure investment programme enabled us to upgrade the core measurement on the tower to a new state-of-the-art analyser for carbon monoxide, nitrous oxide, methane and ethane. In addition, we conducted intensive measurements of the fluxes occurring at specific times of year, generating data that will shed light on the quality of emissions inventories and help to identify underestimated sources.

#### New research shows reducing ammonia emissions to improve air quality is cost-effective

New research published in the journal *Science* showed that action to reduce ammonia emissions would be a cost-effective way to improve air quality and health. The study estimated the global impact of nitrogen air pollution and also the potential economic benefits of implementing measures to reduce emissions. The international research team, which was led by Zhejiang University and included UKCEH scientists, calculated that, on a global scale, every US\$1 spent reducing ammonia emissions would result in preventing US\$4 of health damage, and in the UK this ratio rose to 23:1.

### ▶▶ FORWARD LOOK

- In 2022, we will build the first UK Community Emission Modelling System funded by the UKRI Strategic Priority Fund on Clean Air, working with the Met Office and research partners.
- We will quantify the impact of emission control measures in agriculture and changes in diets on UK emissions of atmospheric pollutants and benefits for human health.





## CLIMATE AND LAND

### THE CHALLENGE

Changes in climate, involving interactions of physical, chemical, and biological processes of the atmosphere, ocean, and land surface, are having widespread impacts on societies and ecosystems. Understanding how the land surface interacts with the atmosphere is therefore critical for climate change prediction, adaptation and mitigation.

### OUR ROLE

Our land surface science is underpinned by detailed process understanding in hydrology, ecology, micro-meteorology, biogeochemistry, and, critically, their interactions. These processes are modelled within the Joint UK Land Environment Simulator (JULES) system, coordinated by UKCEH and the Met Office, which provides the community with a unique UK land surface model for accurate weather and climate prediction.

### HIGHLIGHTS

#### Launch of new UK National Climate Science Partnership at COP26

During the UN Climate Conference COP26 in Glasgow in November, we announced that we were joining forces with the Met Office and other NERC-supported research centres to develop a new national alliance focused on climate solutions for society, called the UK National Climate Science Partnership. The Partnership will support the UK Government in developing solutions to the challenges of mitigating and adapting to climate change, and will work with the public and private sectors to make sure they have access to the climate information they need.

#### Contribution to IPCC report on climate change impacts

UKCEH scientists contributed to a hard-hitting IPCC report on Climate Change 2021, which showed how climate change caused by human activities is having many unprecedented effects globally, including intense heatwaves and rainfall, Arctic melting and sea level rises. The report presents an impartial summary of what climate data, simulations and theory from across the world currently tell us.

#### New integrated water cycle model to underpin future hydrological research

We released the first version of the Hydro-JULES modelling framework. Hydro-JULES is a five-year national capability programme to develop an integrated water cycle model, which will underpin future hydrological research in the UK. The model will contribute towards better early warning systems for floods and droughts and ensure reliable water supplies. The first version of the new open-source software platform is now available to the entire hydrological community. We also delivered training and internship programmes to support the use of the new framework.

#### New research improves early warning of megastorms

New knowledge on how the surface temperatures of the land affect storms was used to co-develop satellite-based tools with African meteorological agencies to help predict where rainfall is likely in the next six hours, helping communities protect themselves from flooding. In 2021, our partners in Senegal used the tools to issue a severe weather warning to two million people by text message.



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#### Climate and socio-economic scenarios support future projections

UKCEH launched a unique set of climate and socio-economic scenario products in 2021, developed with partners. Drawing on the most recent set of widely applied scenarios for investigating climate change risk and resilience, we developed downscaled and enriched climate and socio-economic datasets and products specifically for the UK. These will be used in 2022 to create consistent projections of land-use change, pollution and biodiversity risk.

### ▶▶ FORWARD LOOK

- We will develop new attribution tools to improve understanding of the influences of climate and human drivers on the occurrence of extreme wildfire events around the world.
- We will produce new field datasets to establish nutrient fluxes and fates from various land-based sources to the sea to better inform land surface models.





## ECOSYSTEM RESTORATION AND RESILIENCE

### THE CHALLENGE

The UN Decade of Ecosystem Restoration to 2030 recognises that ecosystem degradation undermines the well-being of 3.2 billion people. The resultant loss of species and ecosystem services across the world equates to a 10 per cent annual reduction in gross productivity.

### OUR ROLE

Our multidisciplinary science enables us to develop innovative approaches to sustaining healthy ecosystems and restoring degraded ecosystems at landscape scales. We provide the evidence base to restore degraded ecosystems in such a way that they are resilient to climate change and extreme events, particularly where societal and environmental pressures are in conflict.

### HIGHLIGHTS

#### Passive rewilding can expand UK woodland rapidly at no cost

A long-term passive rewilding study at Monks Wood in Cambridgeshire showed that natural regeneration could make a significant contribution to meeting the UK's ambitious woodland expansion targets – potentially at no cost and within relatively short timescales. While natural regeneration is not suitable for all sites, the study shows that incorporating passive rewilding into national planting targets could result in significant cost savings.



#### Woodland and hedgerow creation will be crucial to support pollinators in Wales

The largest survey of pollinator abundance in Wales to date found that woodland and hedgerow creation can play a crucial role in reversing declines in insects that are essential for crop yields and other wildlife. UKCEH and Butterfly Conservation Wales carried out the survey, in conjunction with the Welsh Government and more than 1,000 landowners across the country. The findings show that carefully managed woodland and hedgerow creation could play a key role in land management incentive schemes, alongside other actions such as restoring wildflower meadows, organic farming and planting mass-flowering crops.

### Zoning of Lake Victoria is key to its sustainable use

Lake Victoria, the largest lake in Africa, is an important source of food, energy and income security for local people. To feed growing numbers of people, cage fish farms are being developed on the lake. However, these can cause environmental damage by polluting the water and damaging the breeding grounds of the natural fish population. Working with the Kenya Marine and Fisheries Research Institute, UKCEH developed a map of the Kenyan part of Lake Victoria, which indicates the levels of suitability of different areas for developing cage fish farms. Fish farmers can access the map via a mobile phone link.

### Decline in seabirds' breeding success indicates deteriorating ocean ecosystems



The first global analysis of seabird breeding success in relation to climate found many species are struggling to produce offspring as ocean temperatures rise. The study, published in the journal *Science*, was carried out by an international team, including UKCEH scientists. Seabird breeding success depends on the availability of food sources, which is being affected by rising ocean temperatures.

### ▶▶ FORWARD LOOK

- A series of pilot projects led by UKCEH will pave the way for investment in restoring the UK's saltmarshes in order to mitigate climate change and reduce flood risk.
- We will explore, demonstrate and promote innovative approaches to restore, or protect from further degradation, valuable freshwater ecosystems such as lakes, rivers and wetlands.





## FLOOD AND DROUGHT IMPACTS

### THE CHALLENGE

Floods and droughts have the potential for immense destruction of homes, crops, wildlife and infrastructures. Since 2017, water crises and extreme weather events have been consistently identified in the World Economic Forum's top five global risks by impact.

### OUR ROLE

Combining expertise in hydro-meteorology with data derived from national monitoring networks, we measure and model water to accurately predict, mitigate and manage the impacts of floods and droughts. We work in partnership across the world to build local capacity in monitoring, analysis and modelling, supporting planning, response and recovery.

### HIGHLIGHTS

#### Scoping a new flood and drought research infrastructure for the UK

UKCEH led the scoping and consultation phase of a new transformative Flood and Drought Research Infrastructure (FDRI). The FDRI team sought views from a broad range of stakeholders across research, business, major landowners, government departments and regulatory agencies via a series of surveys, webinars and workshops. We prioritised the requirements of this community, which then formed part of the business case submitted to the Department for Business, Energy & Industrial Strategy (BEIS) to support future FDRI investment. The primary objective of the FDRI is to increase the UK's resilience to floods and droughts through a transformational research capability, which will dramatically improve the UK's flood and drought forecasting, planning, incident response and management.

#### New guidance on global drought monitoring

UKCEH developed Good Practice Guidance for monitoring drought hazard, exposure and vulnerability. The guidance was published by UNCCD, the UN Convention that brings together 197 signatories to address desertification and land degradation and mitigate the effects of drought. The Guidance balances state-of-the-art methodologies and data availability with the need for simplicity and global applicability.



#### New global system will enable communities to adapt to our changing water cycle

Following the successful completion of a UKCEH-led pilot, The World Meteorological Organization (WMO) approved the global implementation of the HydroSOS initiative, a system for assessing hydrological conditions. The system will provide regular data on the status of water resources – including groundwater levels, river flows, reservoirs, lakes and soil moisture – in local catchments across the world. It will also assess whether these measurements are normal for the time of year and predict whether the situation is likely to get better or worse over coming weeks and months, supporting effective management of water supplies, guiding farming practices and helping countries prepare for natural disasters.

#### Improving projections of extreme tropical rainfall

Our scientists devised new methods for predicting extreme tropical rainfall as a result of climate change, in order to better protect vulnerable communities from future flooding. A study led by UKCEH found that traditional climate models used to inform international research and policy could be underestimating the hourly rainfall during extreme weather events in the coming decades by up to 25 per cent. Reliable information is essential to guide the planning of urban development, water and energy infrastructure, flood resilience measures and sustainable agricultural practices.

### ▶▶ FORWARD LOOK

- UKCEH will work with the WMO to assess the needs of countries who would like to implement the HydroSOS system and design projects that can meet such need.
- We will develop a hydrological module within the UKCEH City Explorer tool that will simulate the local and downstream effects of nature-based solutions in urban areas on runoff and peak flows, facilitating urban planning.





# NET ZERO GREENHOUSE GAS EMISSIONS

## THE CHALLENGE

Many countries, including the UK, have committed to a net zero emissions economy. To drive down greenhouse gas (GHG) emissions, we need to identify where they come from, how they can best be reduced, and ensure we fully understand the processes involved.

## OUR ROLE

We undertake long-term national surveys of GHG emissions in both natural and managed environments, focusing on carbon dioxide, methane, and nitrous oxide. We make a major contribution to national and international GHG emissions inventories, providing GHG flux measurements, and improve understanding of the role that land use has on emissions.

## HIGHLIGHTS

### Landmark report outlines how greenhouse gas removal could help UK achieve net zero

The UK Government's Department for Business, Energy and Industrial Strategy (BEIS) commissioned UKCEH and low carbon energy consultants Element Energy to analyse the costs and deployment potential of engineered and land-based greenhouse gas removal options in the UK. Our assessment, published in October 2021, sets out different scenarios that would enable the UK to reach net zero by 2050.

### Improved management of farmed peatlands could cut 500 million tonnes of CO<sub>2</sub>

Substantial cuts in global greenhouse gas emissions could be achieved by raising water levels in agricultural peatlands, according to a new study published by UKCEH scientists in the journal *Nature* in April 2021. Concerns over the economic and social consequences of rewetting agricultural peatlands have prevented large-scale restoration to date, but our study shows that the development of locally appropriate mitigation measures could deliver substantial reductions in emissions.



### UKCEH's greenhouse gas monitoring network extended

UKCEH, together with partner organisations, operates a network of greenhouse gas monitoring sites across the UK. During 2021, we extended the network to comprise around 35 sites, establishing new sites in Northern Ireland for the first time. In November, our flagship site at Auchencorth Moss, became the first such monitoring station in the UK to receive Integrated Carbon Observation System (ICOS) labelling, having passed a rigorous quality assurance process.

### Lake restoration could reduce greenhouse gas emissions

Lakes are important sources of greenhouse gas emissions, with polluted tropical and subtropical lakes being particular hotspots. UKCEH research into specific urban lakes in India suggests that restoration of these lakes has the potential to reduce methane emissions significantly.



## ▶▶ FORWARD LOOK

- We will work with partners to investigate large-scale nature-based removal of GHGs through four new projects funded by UKRI.
- Using new data science methods for integrating computer models and data streams, we will scale up our greenhouse gas observational network to cover the whole of the UK.
- We will provide the first national-scale estimates of GHG emissions from inland waters, and of fluxes of carbon dioxide, methane and nitrous oxide across the land-ocean-atmosphere continuum.





# SOIL HEALTH

## THE CHALLENGE

Healthy soils and peatlands are critical for life. They produce 95 per cent of our food and are the source of many of our antibiotics. They store more carbon than the world's forests, mitigate climate change, recycle nutrients and waste, and clean our water. Yet, they are vulnerable to pollution, unsustainable exploitation and erosion.

## OUR ROLE

Our multidisciplinary, integrated soils research spans physical, biological and chemical soil processes and investigates their interaction with the biosphere. This research enables environmental risk assessment and predictions of how soils may change under future land use and climate change scenarios.

## HIGHLIGHTS

### Evidence to underpin EU transition to healthy soils

A review of evidence on soil health across Europe, led by UKCEH, concluded that 60 to 70 per cent of soil is currently unhealthy. The review supported the adoption of the EU mission 'A Soil Deal for Europe', which presents an ambitious vision for delivering healthy soils by 2030. In support of this mission, UKCEH also collated evidence on effective soil management practices that could be adopted more widely across Europe.



### Quantifying and understanding soil carbon

Our scientists continued their work to quantify and understand how soil carbon stocks are changing across the UK, and created the first ever national inventory of saltmarsh soil carbon stocks. A new study explored how current models differ in their predictions of soil carbon across the landscape. The study highlighted that the greatest uncertainty surrounds carbon rich soils, and identified these as a target for improving monitoring and assessment in future.



## New remote sensing approaches for tracking soil erosion and damage

A new report for Welsh Government, delivered in collaboration with the British Geological Survey, demonstrates the potentially powerful use of remote sensing for assessing the extent of soil erosion and damage across the landscape. The report shows how remote sensing can identify numerous features indicating threats to soil from inappropriate management and breaches of current regulations. This approach has the potential to provide real time alerts, providing a potentially cost effective approach to improving regulatory monitoring.

## New approach to tracking global land degradation

A new study proposed a 'debt-based' global approach to tracking land degradation. The approach provides more robust and equitable ways to recognise long-term historical degradation in areas such as Europe and North America, as well as in areas where rapid change is occurring such as Southeast Asia. The method uses recent advances in remote sensing, machine learning, and computational resources, which can now be implemented in a straightforward manner at a global scale.

## ▶▶ FORWARD LOOK

- We will work with partners to develop a new national soil classification scheme and guidance on how to assess soil structure, to support critical soil functions such as plant growth, drainage and nutrient cycling.
- We will release a new dynamic soil carbon model to explore carbon storage and change at a national scale. The model will be based on understanding built up through our 40-year rolling soil monitoring programme.
- A further model currently in development will facilitate prediction of the impact of land use and soil type on earthworm populations.





# SUSTAINABLE AGRICULTURE

## THE CHALLENGE

Population growth, changing diets and urbanisation are driving ever-increasing intensification of agriculture and land-use change. Meeting the need for increased food production and nutrition without degrading our environment is one of the greatest challenges facing society today.

## OUR ROLE

We work with farmers to monitor the impact of agriculture on the environment, understand the limitations of food production, and develop new sustainable farming systems that are resilient to climate change and protect biodiversity.

## HIGHLIGHTS

### Supporting the development of a new agri-environment scheme in Wales

UKCEH led the creation of a set of reports for Welsh Government, applying the newly developed ERAMMP Integrated Modelling Platform (IMP) to explore environmental and economic impacts of various designs of the new Sustainable Farm Scheme in Wales.

### Free E-tools support sustainable farming

UKCEH has created a series of free digital tools (E-Tools) to support farmers and land managers in planning and delivering environmental management actions. The E-Planner, E-Surveyor and E-Viewer will help farmers maintain efficient food production while delivering increased environmental benefits. The BASF Group's xarvio Field Manager app was also enhanced with functions from UKCEH's E-Planner tool to enable farmers to improve biodiversity and crop yield.

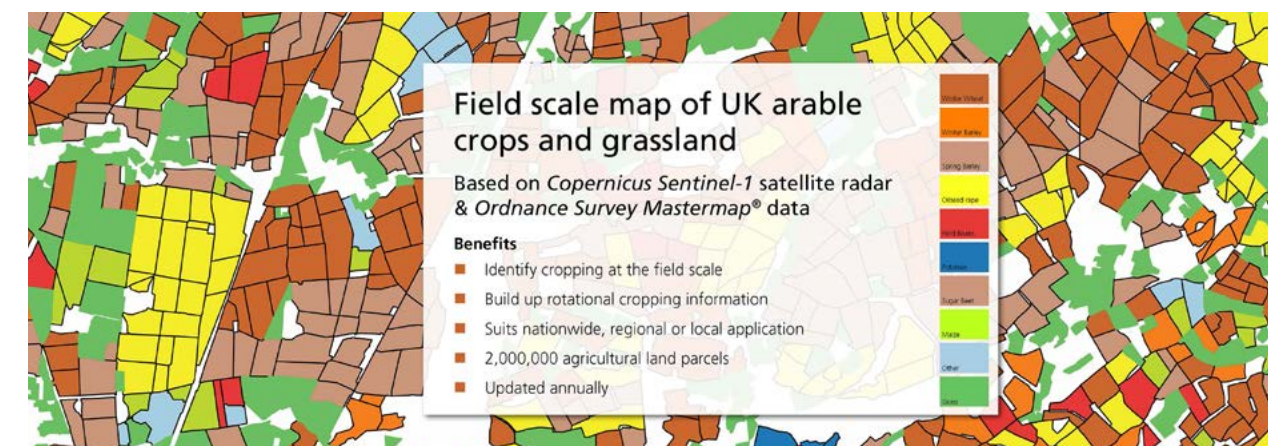


Exploring future farming in virtual reality.

## Land Cover Maps provide greater detail about the British landscape than ever before

UKCEH has used high-resolution satellite technology to map the landscape throughout Great Britain in more detail than ever before. We have produced the first land cover map to identify broad habitats at a resolution of 10 metres across the UK. The latest UKCEH Land Cover Map, based on data from the year 2020, identifies 21 types of broad habitats, including grasslands, arable, water, woodlands, urban and suburban. These maps inform policy, research, planning, land use, agriculture and forestry, among other uses.

## Crop map data and crop yield models will inform future farming



Since 2015, UKCEH has used satellite-derived imagery to identify crop types grown across 1.7 million agricultural fields in Great Britain each year, producing annual UKCEH Land Cover® plus: Crop maps. With six sequential years of the crop map now available, we have a unique and highly informative dataset for exploring changes in cropping patterns over time and space, which can inform future farming policy and research. We have now also linked the Met Office future climate change scenarios (UKCP18) to our crop yield models for winter wheat, which is the dominant UK crop. This has enabled the production of national, high resolution predictions of future crop yields to 2080 to inform climate change risk assessment and adaptation strategies.

## ▶▶ FORWARD LOOK

- Working with the farming industry and research partners, our scientists will assess the trade-offs between GHG emissions, food production, biodiversity and the wider environment, through a new programme of work.
- UKCEH's work linking the Met Office's UK Climate Projections 2018 future climate change scenarios to our crop yield models will be extended to cover other major arable crops, such as oilseed rape and grass.





# WATER QUALITY AND RESOURCES

## THE CHALLENGE

Water is a resource on which all life depends. Yet, across the planet, 30 per cent of people do not have access to reliable supplies of clean water. Efficient management of water is critical to addressing the competing demands of industry, agriculture and energy production while sustaining flows and quality for natural ecosystems.

## OUR ROLE

Our research integrates ecology and hydrology in the evaluation of water availability and demand. We seek to understand the complex interactions that affect the availability and quality of water resources now and into the future, from local to global scales.

## HIGHLIGHTS

### Data to support the resilience of the UK water sector to drought

The enhanced Future Flows and Groundwater (eFLaG) project delivered a high quality, accessible, nationally consistent dataset of river flow projections for 200 rivers and 54 groundwater boreholes using the latest UK Climate Projections (UKCP18). The project also created water industry demonstrators to support use of the new dataset. As well as being valuable to the water industry, the data have a wide range of applications in research and in sectors such as farming, energy and transport.

### Mitigating the threat posed by climate change to the UK's upland drinking water sources

Rising concentrations of dissolved organic matter (DOM) in upland drinking water sources due to climate change are a major concern for the water industry, since DOM concentrations can lead to the production of toxic substances if not treated. Through the UKRI Climate Change Resilience Programme, UKCEH, in collaboration with researchers at the University of Leeds and the water industry, detailed the threat that climate change poses to upland drinking water supply, and reviewed a range of potential options for mitigating or adapting to this threat.

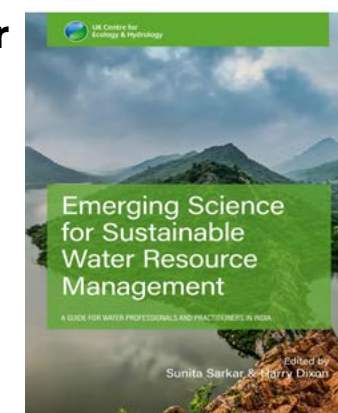


### Lake heatwaves will be hotter and longer by the end of the century

Lake ecosystems, and the organisms that live within them, are vulnerable to temperature change. UKCEH and partners used satellite observations and a numerical model to investigate changes in lake heatwaves – prolonged periods of warm surface water temperature – for hundreds of lakes worldwide from 1901 to 2099, showing that these events will become hotter and longer by the end of the twenty-first century. The research, published in *Nature*, highlights emerging water pollution in some of the world's least disturbed lakes on the Qinghai-Tibetan Plateau.

### New science to support sustainable water resources management in India

A new book published by UKCEH shows how emerging scientific knowledge and new technologies can support sustainable management and use of freshwater resources. Called 'Emerging Science for Sustainable Water Resource Management', the book is written for water professionals and practitioners in India, and is the result of research collaboration between scientists in India and UKCEH.



## ▶▶ FORWARD LOOK

- We will advance national and global capabilities in seasonal hydrological prediction, working on climate services initiatives such as the UK Hydrological Outlook and the WMO HydroSOS framework.
- We will improve resilience to extreme droughts by providing evidence-based guidance to policy- and other decision-makers, through our involvement with the WMO-GWP Integrated Drought Management Programme and the UNCCD, among other initiatives.
- A proof-of-concept monitoring innovation project for the European Space Agency will test the possibility of measuring river flow velocities from space using high-resolution video.



# NATIONAL CAPABILITY

As a strategic delivery partner for UKRI-NERC, UKCEH delivers impartial environmental science to benefit the UK research community, governments, businesses, and wider society. UKCEH's portfolio of programmes supported by national capability funding provides underpinning science to facilitate cutting-edge research into the integrated land, air and water system on which life depends. The work delivered through these programmes enables UK researchers to deliver excellent research, and puts the environment at the heart of critical policy and business decisions.

## HIGHLIGHTS

### ASSIST: Achieving sustainable agricultural systems

The ASSIST programme partners created a forum for the research and farming communities to work together to address critical issues relating to sustainable agriculture in the UK. A new commercial study farm network enabled the testing of innovative farming systems that benefit soil health and support natural processes underpinning food production, such as pollination and pest control. Working with the farming industry, ASSIST produced planning tools to target the most suitable sites for the creation of a range of habitats on farms (see page 28).

### Hydro-JULES: Next generation land-surface and hydrological predictions

Hydro-JULES delivered UK open-access data sets on rainfall, water flows and abstractions for current and future climates. Working with the UK-wide hydrological modelling community and diverse stakeholders, we co-designed a modelling framework of the terrestrial water cycle. Outputs from the HydroJULES programme have been used by the wider UK research community in proposals that have generated over £10 million in funding for new science. The programme team engaged stakeholders and the public by running a series of community workshops and webinars, hosting winter and summer schools, and producing enrichment materials for schools.

### LOCATE: Land ocean carbon transfer

The LOCATE programme, led by the National Oceanography Centre, brought together the freshwater and marine community, and established a unified approach to assessing flows of carbon from the land, through freshwater to the ocean. As a result, the international scientific community now has access to a single model that represents land-freshwater-ocean carbon transfer and processing, addressing an important knowledge gap identified by the IPCC. In addition, the UK water industry is now better equipped to respond to rising dissolved organic matter concentrations that threaten drinking water quality and increase treatment costs (see page 30).

### SUNRISE: Sustainable use of natural resources to improve human health and support economic development

This four-year programme, which concluded in 2021, contributed to the UK's Overseas Development Assistance efforts by conducting research to reduce vulnerability to environmental risk, improve environmental quality and provide more reliable sources of food, water and other ecosystem services. Our scientists worked closely with local stakeholders in sub-Saharan Africa, South Asia and South-East Asia to generate solutions to complex regional-scale problems.

The programme's many achievements in 2021 included: the delivery of the new WMO HydroSOS system, which provides short- to medium-term seasonal predictions of floods, droughts and water resources globally and regionally, enabling better early warning and emergency response; new methods to improve smallholder land, crop and forestry management practices in Indonesia, Malaysia and Kenya; and remote training to health practitioners in India on participatory approaches, policy analysis and earth observation methods to help tackle problems associated with zoonotic diseases.

### UKESM: UK Earth System Model

The UKESM programme, led by NERC and the Met Office, worked with the UK land surface and Earth system modelling community to enhance the representation of complex interactions of the land system in the next generation of UK climate and Earth system models, developed jointly with the NERC-supported research centres and the Met Office. In particular, the UK Earth System Model (UKESM1) provided outputs to the sixth World Climate Research Programme's Coupled Model Intercomparison Project (CMIP6), which underpins the IPCC's sixth assessment of how climate change is impacting the world.

### UK-SCAPE: UK status, change and projections of the environment

During 2021, the UK-SCAPE programme continued to provide insight into the status and dynamics of the natural environment through long-term monitoring. Using our sensor networks and surveys, both experts and citizen scientists contributed to monitoring over 20 different aspects of the terrestrial system, from biodiversity to air quality, and from land use to soil moisture. We used models and methods to interpret the data generated in order to drive increased integration across science disciplines. We also made substantial progress in making this information more readily available to the UK research community through the production of new resources such as catalogues, maps, data portals and phone apps. Over 150 digital assets from the UK-SCAPE programme are now available online.





# OUR PEOPLE

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## New directors and trustees

We welcomed two new directors to the organisation in 2021. Sam Bullen joined as Director of Finance and Gill Lay as Director of People and Operations. Lynette Eastman and Professor Sir Charles Godfray were appointed Trustee Directors of UKCEH, while Ian Reid took up the position of Non-Executive Director of UKCEH Enterprise, our trading subsidiary.

## Enhancing our capabilities

We invested in new posts to meet the rising demand for our science and to augment our scientific and technical capabilities for the future. This included the appointment of a new Head of Environmental Digital Strategy, whose role is to define and deliver a vision for data across the organisation. In total, over the course of the year, we recruited over 100 new employees across our science and professional services teams.

## Postgraduate and early career research

UKCEH plays a prominent role in training the next generation of environmental scientists. In 2021, our scientists supervised 188 postgraduate researchers, who benefited from access to our laboratory facilities, field sites and data centres. We also put in place training plans for 92 research associates, delivering 64 specific coaching interventions. Around 10 per cent of our research associates' time is dedicated to professional development.

## Learning and development

We launched a new online learning management system to deliver training to all staff and students. Initial content included 29 people management modules. In addition, over 200 of our staff completed training courses provided by over 70 different organisations.

## Equality, diversity and inclusion (EDI)

In order to minimise barriers to accessing our science online, we carried out accessibility audits of key digital assets, including our corporate website, reviewing them against the WCAG AA standard and putting in place action plans for improvement. We commissioned guidance for staff on best practice in web accessibility, and delivered training for all staff on improving EDI in communications more broadly. In 2022, we will launch a review of all our EDI practices to ensure that we maximise opportunities to promote and support equality, diversity and inclusion in our workplace.



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## Employee experience

In 2021, we started to develop our employee value proposition to ensure we are offering a great employee experience and supporting all our employees and students throughout their whole career journey. This work, which will continue into 2022, includes a holistic review of how we reward and recognise our employees. 2022 will also see the launch of our wellbeing strategy with a series of online and in person events.

## Environmental sustainability

UKCEH sets high organisational standards to reduce the environmental impacts of our activities, underpinned by our ISO14001:2015 certified Environmental Management System. Key actions we took in 2021 in support of our strategic environmental objectives included:

- Investing in more efficient IT and science equipment.
- Identifying and bidding for opportunities to expand our on-site renewable energy generation.
- Including sustainability criteria within procurement tenders.
- Making improvements to our Edinburgh and Wallingford sites to support biodiversity.





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The Centre owns a registered trading subsidiary, the UK Centre for Ecology & Hydrology Enterprise, a Company Limited by Shares (number 12251749), which supports our charitable purpose.

The registered office of the UK Centre for Ecology & Hydrology is at the Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire, OX10 8BB, UK.



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