About us

The Natural Environment Research Council (NERC) is the UK's main agency for funding research, training and knowledge exchange in environmental science. Our work tackles some of the most urgent and fascinating environmental issues we face, including climate change, natural hazards and sustainability.

NERC research covers the globe, from the deepest ocean trenches to the outer atmosphere, and our scientists work on everything from plankton to glaciers, volcanoes and air pollution – often alongside other UK and international researchers, policy-makers and businesses.

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We often hear about ‘food security’ – the term appears in newspapers and magazines, in the science literature and on the lips of politicians. Research in this area has many aspects, but being ‘food secure’ is fundamentally about having access to the food we need for a healthy life. Alas, although the world produces more than enough food for everyone, a billion people are hungry; a billion more don’t have sufficient nutrients (especially iron) while a further billion eat too much! This means many of the issues surrounding food security fall within economic, social and political domains. These broad issues – together with others related to sustainable food production and supply, resource efficiency and sustainable, healthy and safe diets – therefore form part of the UK’s ‘Global Food Security’ programme, a partnership of major public funders of food-related research.

So what’s the role of environmental science in the complex food-security landscape? The answer becomes startlingly clear when we look at the activities we undertake for the sake of food security: producing food, processing and packaging food, storing and transporting food, selling food and – last, but by no means least – buying and eating it. Each of these activities is affected by changing environmental conditions (especially changes in climate, water resources and biodiversity), and each in turn affects the environment; it’s a two-way street. The very actions we take to satisfy our need for food risk undermining the natural resources and environmental conditions on which our food security depends.

This is true whether we’re catching fish in the oceans, hunting ‘bushmeat’ in the forest, livestock ranching on the grasslands or growing arable crops. Many of the issues revolve around converting ‘natural’ land to ‘production’ land, which affects soils, water resources, nutrient cycling, biodiversity and climate. Using fertilisers and other agrochemicals affects greenhouse gas (GHG) emissions and water quality. Changes in climate and other important considerations for farming, such as the availability of water for irrigation, influence food production both directly and indirectly. These are all areas where the environmental science NERC supports makes a vital contribution.

But let’s think beyond producing food – how do the rest of the food-system ‘activities’ affect the environment?

Food processing uses large amounts of water, and effluents from the industry often contain environmentally-damaging wastes which affect rivers and other water bodies. Food packaging requires massive amounts of paper and card, whose production affects forest cover, while plastics have substantial fossil-fuel content, and litter can harm wildlife. Transport raises the issue of carbon emissions from food miles; storms, floods, volcanoes and earthquakes can seriously disrupt food storage and transport facilities, and hence supply chains. Fridges and freezers are used in shops and supermarkets around the world to stop food going off, but they can release significant amounts of GHGs, and their use is likely to increase given the likelihood of growing economies – and more heatwaves. Food preparation, whether in homes or restaurants, uses lots of energy and water, and wastes range from GHGs from energy production for cooking to detergent- and fat-laden effluent. Environmental science is as relevant across these ‘post-production’ aspects of the food system as in the more obvious applications to what happens on farms.

This edition of *Planet Earth* explores a range of issues around these food-system activities, with examples of how research can help us understand the way they interact with the wider environment. NERC science is crucial in our quest for food security for all.

John Ingram
NERC Food Security Leader
Farmers bid to clean up rivers

Cornish farmers are benefiting from improvements to their farms that will also cut pollution in the River Fowey.

Soils, pesticides and manure can wash into the river and affect water quality and wildlife. Farmers lose out as topsoil disappears and crops are left unprotected from pests. Water companies have to spend more money cleaning the water, raising water bills for customers.

South West Water invested £360,000 in a pilot project that could be good news for everyone. They worked with the Westcountry Rivers Trust and academics from the University of East Anglia in the scheme, which puts a value on natural resources – in this case, clean water – and then pays to preserve them. The researchers designed and ran the UK’s first ever ‘valuing nature’ auction, with farmers with land close to the Fowey bidding for cash.

‘The auction approach hasn’t previously been used in the UK for schemes like this, so it was a bold move by South West Water to give it a go,’ says Professor Brett Day from the University of East Anglia. ‘An auction puts much more focus on farmers than other possible schemes.’

‘The scheme will reduce the amount of pollutants getting into the river, which will help reduce our costs of cleaning the water for drinking,’ Martin Ross, environmental manager for South West Water, explains – the savings could be around 20 per cent. ‘And the farmers are getting financial help with their farm improvements, so it’s a win-win situation.’

The auction attracted 41 bids from farmers in the region, and almost half of them succeeded in securing money to help with improvements. South West Water will contribute up to £50,000 a farm.

The initiative is linked to Defra’s Payments for Ecosystem Services projects and the Valuing Nature Network, part of the Living With Environmental Change partnership.

Ecological approach could help cystic fibrosis sufferers

Scientists more used to studying the communities of bacteria that live in rivers and soils are helping transform doctors’ understanding of a life-threatening illness, and could ultimately shed light on many other health problems.

Bringing the methods of microbial ecology to bear on lung infections in people with cystic fibrosis (CF) – a serious condition affecting 9,000 people in the UK alone – could radically improve their lives and help them survive longer. The idea is to look at the bacteria in patients’ lungs not as homogenous invaders but as a whole ecosystem.

‘Our starting point is to look at the lungs of CF patients as a functioning ecological community,’ says Dr Christopher van der Gast, a microbial ecologist at NERC’s Centre for Ecology & Hydrology (CEH) who’s working with medical researchers on the project. ‘We’ve found that a CF lung is a more diverse and complex ecosystem than previously realised, containing hundreds of unique bacterial species.’

This collaboration is already leading to exciting discoveries. For example, it turns out that as a patient’s lung function declines, the diversity of the microbial community in their lungs also drops. It’s possible that the latter is causing the former. Ultimately this may let doctors help patients using the bacterial communities as a marker for the state of the disease.

‘We’d like to be able to monitor these microbial communities and spot changes in their diversity that give us early warning of a drop in lung function,’ van der Gast adds. ‘In the future, we may be able to manage these communities of microbes in the lung to benefit the patient.’
Scientists have found tiny fragments of plastic in the digestive systems of fish pulled from the English Channel.

The discovery, by researchers from Plymouth University and the Marine Biological Association, highlights the growing problem of ocean plastic contamination.

Of 504 fish, more than a third contained pieces of plastic less than a millimetre across, known as ‘microplastics’.

We already knew they are widespread in the oceans. ‘Our recent research has shown that such fragments are also being ingested by fish,’ says Professor Richard Thompson of Plymouth University. ‘Laboratory studies on mussels have shown that some organisms can retain plastic after ingestion, so microplastic debris could also accumulate in natural populations.’

This could seriously harm fish, blocking their digestive systems or giving them a false sense of being full. It could also enable water pollution to make its way into organisms, as chemicals latch on to the plastic fragments.

Some fragments come from products like face scrubs and exfoliators, which contain microplastics as abrasives. Others come from the breakdown of larger items like bags and bottles.

Thompson thinks we can tackle plastic pollution without abandoning plastics. ‘We don’t need to have plastic debris in the sea. These materials are inherently very recyclable, but regrettably they’ve been at the heart of our throwaway culture for the last few decades.’

The study appears in Marine Pollution Bulletin.
New genetics project could help save the ash tree

Scientists plan to decode the ash tree’s entire genetic sequence in the hope of stopping Britain’s trees from being devastated by fungal disease.

A small percentage of ash trees in Denmark show some resistance to the ash dieback fungus. By decoding the tree’s genetic sequence, scientists will take a crucial first step towards identifying the genes that confer this resistance.

Together with field trials and breeding programmes, this could help produce a more resilient strain of ash.

‘Sequencing the ash genome is a foundational step towards discovering the genetic basis of resistance to ash dieback; the future of ash trees in Britain may depend on this,’ says project leader Dr Richard Buggs from Queen Mary, University of London.

The researchers expect to have a first draft of the tree’s genetic sequence by August 2013. Once sequencing is complete, they plan to make it publicly available for use by others.

So far, ash dieback has been found at almost 300 places across the country. But with ash the third-commonest broadleaf in Britain’s woodlands, 80 million trees are at risk. The loss of Britain’s ash population would threaten the plants and animals that depend on the trees for survival.

Ash trees across continental Europe have already been ravaged by ash dieback, and it’s become clear it’s already too widespread to be eliminated from Britain.

in brief . . .

Open air labs boost citizen science
A new study based on the work of hundreds of thousands of amateur scientists has shed new light on what’s living in neglected corners of the urban landscape. Led by scientists from Imperial College London, the Open-Air Laboratories (OPAL) project has so far surveyed more than 25,000 sites, many of them for the first time. It’s also drawn in many people who’ve never before been involved with science. Coming soon is a project to monitor the spread of ash dieback disease. The report is available at www.opalexplornature.org.

NERC gets capital boost in data and for sea robots
Science Minister David Willetts recently gave details of the extra capital investment in science and technology that was announced in last year’s Autumn Statement. This will benefit the NERC research community in two areas. NERC will receive £13m of capital investment to help develop the computational capabilities to deal with so-called Big Data, helping it make the most of the enormous quantities of environmental information that are accumulating at ever-increasing rates. And a further £10m will support research and technology development in marine robots, an area where the UK already has a world-leading track record.

UK and US to collaborate on unmanned airborne science
British and American scientists are working together to use an unmanned robotic aircraft to gather high-altitude atmospheric data. The NASA Global Hawk drone will let them reach and sample some of the most climate-sensitive and hardest-to-reach parts of the atmosphere – in particular, the regions where the Earth’s air enters the stratosphere. The aircraft can remain aloft for 30 hours and travel 20,000km without refuelling, so it’s ideally suited to long-haul research missions; it can also reach twice the altitude of a commercial passenger jet. Also involved will be one of the UK’s dedicated atmospheric research aircraft, the FAAM BAe-146.
Scientists had fossil backbone backwards

Scientists have documented the structure of the backbone of the earliest four-limbed animals, known as tetrapods.

This could dramatically change our understanding of the early tetrapod fossil record and of how animals moved from water to land.

Dr Stephanie Pierce from the Royal Veterinary College and Professor Jennifer Clack from the University of Cambridge, who led the team, studied a 360-million-year-old extinct animal, Ichthyostega, thought to be the first species to have made brief trips onto land.

They had previously built up a 3D digital model of Ichthyostega’s skeleton but thought something was amiss with its backbone. They scanned three fossils using high-energy X-rays, produced by the ESRF synchrotron in Grenoble, to build extremely detailed 3D images of the spine.

Until now scientists thought early tetrapod vertebrae comprised four separate bones – one at the front, one above and a pair at the back. But the images showed that in Ichthyostega the rear bones are fused to the front one.

This means what was considered the first bone in the series of each vertebra was actually the last. ‘In evolutionary terms this discovery is extremely important. Imagine putting the forelimb of an animal where the hindlimb should be; this mistaken arrangement would completely change how the animal would move. The same principle holds true for the spine,’ says Pierce.

The study appears in Nature.

Cat survey reveals impact on birds

Some pet cats are killing a lot of birds around the UK, a new study shows. Most don’t do much harm, but millions of marauding felines could add up to a serious problem for the nation’s wildlife.

The PLOS ONE study’s authors say owners could do more to stop their pets scoffing increasingly-threatened bird populations. Sadly, they don’t seem keen to do so; conservationists have more work to do persuading pet lovers to act.

This subject was the basis of Dr Rebecca Thomas’s recent doctoral research paper at the University of Reading. She surveyed cat owners around town on the prey their pets brought home, as well as whether they were prepared to do anything about their predatory ways.

One finding is that cats’ hunting prowess varies greatly. Only 20 per cent brought back four or more dead animals a year; 22 per cent of owners had to manage with no prey gifts at all throughout the entire multi-year length of the study. It turns out that a minority of felines account for most of the havoc. They bump the average up to an estimated 18.3 kills per cat per year.

‘The density of cats in urban environments is the biggest issue,’ Thomas says. ‘Even if a cat isn’t killing often, there are so many of them in a small area that they can have a very serious impact.’

The team also found that many cat owners would consider mandatory bells or even neutering for cats, but that other measures like daytime curfews were deeply unpopular.
Climate models benefit from medical methods

Researchers have used mathematical techniques taken from the analysis of medical images to bring climate models into closer agreement. The breakthrough, described in Geophysical Research Letters, could enable better predictions of the future climate.

Climate models often disagree even over major climate features, like the location and timing of monsoons. They find it particularly hard to represent rainfall and other precipitation accurately, both in predictions and in simulations of historical climate.

So the search has been on for a way to bring their predictions closer to each other. Researchers at the University of Oxford realised the software used to process medical scans was already doing something similar. Doctors often want to compare the scans of several patients’ brains, for example, in search of common symptoms. To do this, they need to match up the various anatomical regions of the brain, which will be in different places in each patient.

‘When you scan different brains, you need to compare them all to a common reference brain,’ explains Adam Levy, an Oxford PhD student in atmospheric physics. ‘Here we need to get the outputs of climate models to match observations better, but the principles are similar.’

Using software designed to ‘warp’ medical scans enabled the team to get 14 climate models to agree better on how monsoons and other features will be affected by climate change, increasing confidence in the models’ predictions – the average improvement was around 15 per cent.

Soil science vital to food security

Protecting and growing the planet’s soil using the best research is essential if we’re to grow enough food for everyone and prevent famine, a new report argues.

It highlights several actions that are needed to make sure UK soil science remains at the forefront of advances in this area, calling for long-term investment in soil science. In particular, it suggests four key areas that will help increase crop production and cut resource use.

These are biosignalling and sensor technology to enable precision monitoring and control of crop conditions; systems for recovering plant nutrients like phosphorus from waste; computer models of plants, soil and water to help design new crop regimes; and new ways to make plants use water and nutrients more efficiently.

‘Advances like this are paving the way for precision agriculture, where crops and soil are managed together to gain a much more targeted and efficient uptake of nutrients,’ says Professor Steve Banwart of the University of Sheffield, the report’s co-author. ‘It’s exactly the type of science that the UK can use for new agricultural technology that increases production and reduces the demand for energy and chemical inputs to fields.’

Food security is likely to be one of the most important challenges of the 21st century; even as things are many people go hungry, and population growth is compounding the problem – by 2050 the global population is expected to reach nine billion.

Securing Soils for Sustainable Agriculture was produced by the Royal Society of Chemistry, NERC, the University of Sheffield and the Environmental Sustainability Knowledge Transfer Network.

Beetle declines add to insect concerns

Beetles don’t get as much attention as more glamorous insects. But a recent study shows that the populations of an important group are dwindling, and this could end up being just as problematic as the better-publicised problems of bees and butterflies.

The Journal of Applied Ecology paper found three quarters of beetle species examined had declined in number over the last 15 years. The abundance of half of the species had fallen by around 30 per cent per decade.

The study focused on ground beetles or ‘carabids’, the group most people will picture if asked to imagine a beetle. Many carabids perform valuable tasks in their ecosystems that we’d miss if they disappeared. More work is needed to link the declines in different areas to environmental conditions to unravel exactly what’s behind them. Yet, climate change and habitat loss and alteration are probably among the culprits.

There were clear differences between population trends in different habitats. Over ten-year periods, mountain-dwelling carabid beetles averaged declines of 52 per cent, while beetles at northern moorland and western pasture sites declined by 31 per cent and 28 per cent respectively. But woodland and hedgerow populations were mostly stable.
Cars could have a greater impact on kerb-dwelling plant life than previously thought.

A team of researchers has found new evidence that the slipstream behind a moving vehicle can blow seeds great distances, meaning some invasive plant species could thrive at the roadside.

Until now, the general view was that seeds scattered by cars tend to fall back into the middle of the road, where inhospitable conditions mean few grow into plants.

The PLOS ONE paper shows that when seeds are caught in the airflow behind a car, the turbulence eventually moves them to the roadside, where grassy verges and muddy banks let them germinate.

‘The fact this process takes the seeds to the edge of the road, to somewhere that they can germinate – known as effective dispersal – that’s the important part of the process,’ says Professor James Bullock of the Centre for Ecology & Hydrology, a co-author of the study.

There has been much previous research into the dispersal of seeds by natural processes such as wind, animals and even gravity, but scientists realised that lorries, cars and other motor vehicles can carry seeds much further than animals can.

The study was conducted in the glamorous surroundings of the CEH car park. It involved lining up fluorescent-paint-sprayed seeds – naturally dispersed by wind or gravity – across the car park, then getting cars to drive across the line. The scientists then waited until darkness to venture out with UV lights to find where the seeds had ended up.

Estimate of polar ice loss is most accurate yet

UK-led scientists have made the most accurate estimate ever of how much ice has been lost from Greenland and Antarctica since 1992, by combining data from ten satellites.

The Science study shows that from 1992 to 2011, melting polar ice added just over a centimetre to global sea levels.

This amounts to a fifth of all sea-level rise over the period. The rest comes from melting mountain glaciers around the world, and from water’s increased volume at higher temperatures.

This is the first time data from so many satellites has been combined in this way, with the resulting figure ending 20 years of uncertainty around ice loss from the poles.

Scientists need to know this so that they can accurately predict future sea-level change. This is one of climate change’s biggest threats, because so much of the world’s population lives in cities around the coast.

Before this study, estimates of polar ice loss were typically based on data from just a few satellites. Indeed, the Intergovernmental Panel on Climate Change used only a handful in its 2007 report, leading to a spread of estimates, ranging from a drop in sea level of 0.2mm per year to a rise of 1.9mm a year. It wasn’t even clear if Antarctic ice was growing or shrinking.

The new combined estimate is two to three times more accurate than previous ones. Around two thirds of the melt came from Greenland, with the rest from Antarctica. Both are losing more than three times as much ice as they were in the 1990s, but the speed of loss from Greenland has surged five-fold since the middle of that decade.
Irrigated farmland along the banks of the Orange River on the border between Namibia and South Africa, not far from the margins of the Namib Desert. The projects use water from the river to grow produce, turning parts of a normally beige, rust and tan-coloured landscape emerald green. Grapes are the main crop, and the climate here means they are often ready two to three weeks before those of the main grape-producing areas of South Africa’s Cape region.

Namibia is Africa’s driest country south of the Sahara, according to the United Nations Environment Programme, and 65 per cent of South Africa is too arid for agriculture. Irrigation projects like this enable food production in areas where rainfall alone couldn’t sustain farming. But if not properly managed, they can also deplete scarce water resources.

earthobservatory.nasa.gov/Feeds/GoogleEarth/ge_43035/ge_43035.kml

NASA Earth Observatory
Nature’s harvest

We live in a hungry world, and this will only increase. By the middle of the century, scientists estimate that global crop yields need to rise by 70 per cent. How can we do this in a way that’s environmentally and socially sustainable but also economically viable? Richard Pywell and Ben Woodcock argue that supporting native wildlife on farms is part of the answer.

Population growth and changes in diets mean we urgently need to produce more food. The farming methods we already rely on may not be able to achieve this. The UK has signed the Convention on Biological Diversity, which requires that ‘by 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity’.

But many native species have the potential to increase crop yields, so supporting biodiversity on farmland has more to offer farmers than simply beautifying the countryside. For example, bees pollinate crops, predatory beetles eat pest aphids, and wildflowers mean there’s more and better grass for livestock without the need for environmentally-damaging nitrogen fertilizers. Yet for biodiversity to benefit agriculture, our native plants and animals need careful husbandry within farmed landscapes.

Farmers have always been in a running battle with pests. We estimate that in 2010, UK crops worth £715 million were lost to insect pests. Pesticides are crucial to controlling them, but the development of pest resistance, key products being withdrawn from sale and fears about human and environmental health mean that alternative methods are increasingly important. One solution is to promote native biodiversity that will kill pests within crops.

A flower-rich field margin. The flowers provide food and shelter for bees and butterflies, as well as other insects such as spiders, predatory ground beetles and parasitic wasps that are involved in natural pest control.

A solitary bee covered with oilseed rape pollen that will subsequently result in increased pollination and crop yield.
NATIVE SPECIES CAN INCREASE CROP YIELDS, SO SUPPORTING BIODIVERSITY HAS MORE TO OFFER FARMERS THAN SIMPLY BEAUTIFYING THE COUNTRYSIDE.

So-called 'natural pest control' can cut crop losses by 65 per cent, and is worth an estimated £1.3 billion a year to UK farmers. £432 million of this comes from invertebrates like parasitic wasps or predatory ground beetles. Invertebrate communities that control pests are diverse in the UK – for example, we have identified nearly 60 species of predatory ground beetles that feed on pests in wheat, barley and oilseed rape.

However, most invertebrates that help control pests cannot remain in fields throughout the year – ploughing and harvesting will kill them. To keep large numbers of predatory invertebrates in the fields, we need to sow new habitats where they can shelter before moving back into the crops. One of the best ways of doing this is by managing field margins for biodiversity. This involves sowing seed mixtures that provide crucial habitats for pest-eating invertebrates in thin strips around the field edges.

For example, sowing tussock-forming grasses like cocksfoot will benefit beetles and spiders that hide and overwinter in them. Creating these habitats is an important part of European agri-environmental schemes, of which field margins represent one of the most widely-implemented approaches. The principle behind these field margins is simple, but how they are established and managed will determine what predators are present, how common they are and how well they can move into the centre of fields to feed on pests.

A helping hand

Insects play other roles in food production by pollinating flowering crops like oilseed rape and soft fruits. In the UK this is worth an estimated £400 million a year, and worldwide its value could be as high as £150 billion. Yet we know very little about the role our native bee species play in this pollination. In recent surveys we were surprised to find that as well as the well-known honeybee (Apis mellifera), more than 30 species of native bees were pollinating oilseed rape crops. Native bees can account for at least as many flower visits as honeybees, so they are crucial in crop pollination, particularly where colony collapse disorder means there are no longer enough honeybee hives.

Observations we are making suggest that native solitary bees may be particularly efficient in pollinating crops as they don’t clean pollen off their bodies to the same extent that bumblebees and honeybees do. By being messy eaters, the solitary bees are more likely to transfer pollen to the female reproductive part of the flower (the stigma). It is by gaining a more detailed understanding of which insects are pollinating crops that we can map their UK distribution using data collected by the volunteers of the Bees, Wasps and Ants Recording Scheme and the Biological Records Centre. This lets us identify crop-growing regions that support limited numbers of native bee species. This kind of information is likely to be increasingly important in the future for policy-makers who need to target land management to promote beneficial insect pollinators – for example, by sowing wildflowers on unproductive field edges and awkward field corners to support large numbers of these helpful insects.

Farm-management techniques that enhance biodiversity need to develop in a way that is compatible with real-world agriculture, and increasingly must deliver a wide range of benefits including pollination, pest control, water protection and even locking up greenhouse gases in the soil. The most successful approaches rely on communication between scientists, farmers, the agricultural industry and the government.

For example, a partnership with the agro-chemical company Syngenta helped create wide-reaching benefits for bees under the ‘Operation Pollinator’ programme by planting field margins rich in flowers that helped support greater abundances of pollinating bees. Future increases in crop yields will almost certainly not be achieved in isolation from consideration of the role played by ecosystem services that are provided by native biodiversity. This means that promotes biodiversity to benefit crop production will be vital to the UK’s long-term food security.

MORE INFORMATION

Dr Richard Pywell is the Biodiversity Section Head at NERC’s Centre for Ecology & Hydrology (CEH). Dr Ben Woodcock also works at CEH, where he is an ecological entomologist.

Dr Mike Edwards of the Bees, Wasps and Ants Recording Scheme and Dr Marek Nowakowski of the Wildlife Farming Company also contributed to this article.

Operation Pollinator farmland biodiversity programme – www.operationpollinator.com

Bees, Wasps and Ants Recording Scheme www.bwars.com

Biological Records Centre – www.brc.ac.uk
You know the feeling – the end of a hard day at work, no time (and, in my case, no inclination) to cook. So you do what 30 per cent of Brits normally do: stop at a supermarket on your way home and buy a ready meal. What is it going to be? Tonight I fancy lamb curry. Mmm – looking forward to it.

But because of my research on environmental impacts of food, I know my lamb curry has the carbon footprint of around 6kg of carbon dioxide equivalent (CO2 eq.) per person*. So it may be tasty and convenient, but by choosing and eating this curry I will have contributed to climate change, through the greenhouse gases emitted on its journey to my plate.

But so what? Should I worry about it? Probably not, if I was the only person in the country favouring convenience. But I’m not, and the lamb curry ready meals eaten in the UK every year – just lamb curry, not the many others – have an annual carbon footprint equivalent to 140 million car miles – that’s 5500 car trips around the world.

We’ve estimated this based on the figure of 30 per cent of adults in Britain eating ready meals at least once a week. Curry, as one of the nation’s favourites, accounts for up to 10 per cent of ready-meal sales, which have soared during the recession.

Every stage of the meal’s life cycle emits greenhouse gases. Rice paddies and sheep give off methane, a greenhouse gas 25 times stronger than CO2. Sheep (and cows) also emit methane because of their digestive systems. Fertilisers used on land emit nitrous oxide, which is 300 times more potent than CO2. The vehicles that transport the ingredients to the manufacturers and take their

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**Fancy a curry?**

Curry is one of the nation’s favourites but the price we pay for a ready-made plateful isn’t just the one on the carton. Adisa Azapagic unpacks the carbon footprint of her evening meal and asks if we should be worried about it.

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products to the retailer, burn fossil fuels, which in turn produce CO₂. And that’s before you’ve even driven to and from the shop and cooked your meal.

The main contributors to the carbon footprint are the meal’s ingredients, which emit around 70 per cent, with the lamb alone contributing more than half of the total. Meal manufacture adds a further 10 per cent and packaging 5 per cent.

Despite popular belief, the contribution of transport is relatively small, adding less than 2 per cent to the total. In contrast, refrigeration of ingredients and the meal contribute around 10 per cent, largely due to leaking refrigerants which are powerful greenhouse gases. You get a similar picture for most meat-based foods.

So, what could we do to reduce the carbon footprint of the food we eat? Our research shows there are at least two things: eat less meat – particularly red meat – and cook more at home.

For example, if we were to eat the same ready-made curry made with chicken instead of lamb, the total carbon footprint would go down from 6 to around 3kg CO₂ eq. per person – simply because sheep and cows emit methane, while chickens and turkeys don’t.

The same lamb curry prepared at home would have a carbon footprint up to 15 per cent lower, mainly because you cut out meal refrigeration at the retailer, but also because you’ll typically waste less food.

We have found that even more elaborate meals made at home, such as a traditional Christmas dinner, have a lower carbon footprint than ready-made lamb curry, coming in at only 2,5kg CO₂ eq. per person.

We are currently researching how we can reduce the environmental impacts of our food and diet across the whole of its life cycle, from agriculture to food processing to the way we prepare food at home. We have developed a free tool, CCaLC, to help the food industry and consumers find out the carbon footprint of hundreds of different food items.

You can use the tool to look up different meal ingredients, or to prepare your own meal virtually by adding the ingredients of your choice, ‘transporting’ and ‘cooking’ them. You can compare the carbon footprint of different meal options to help you choose the lowest carbon alternative. We have also developed a simplified version, CCaLC Lite, for android tablets and mobile phones, which is fun to play with (we think!). It includes the carbon footprint of lamb curry.

Which reminds me – I can hear the microwave beeping so I’d better go back to my dinner. Tomorrow, I may cook at home – just food for thought...

PS. Even the French are at it. Apparently, the largest M&S store in Paris sells more chicken tikka masala than any UK branch. Bon appétit!

* This measure includes all greenhouse gases, such as carbon dioxide, methane and nitrous oxide, emitted in the life cycle of this meal, from farm to plate. Some of these are stronger greenhouse gases than others, so they are scaled to give an equivalent measure in CO₂.
Our crops are under attack from pests and diseases, weeds, fluctuations in rainfall and temperature, and other climate extremes; all of this results in troughs and peaks in the availability and value of food. But few people realise that many of our most important crops are also sensitive to air pollution, with ozone being the most damaging kind. We all know about the important role that ozone plays in the upper atmosphere protecting us from harmful ultraviolet radiation from the sun, but when the same chemical is present in the lowest few kilometres it becomes a damaging pollutant that harms human health and the environment.

At ground level, ozone is a secondary pollutant – it forms in the air when gases emitted by burning fossil fuels and some industrial processes react in the presence of sunlight. Ozone concentrations are strongly influenced by the weather. They are highest on warm, sunny days in spring and summer, especially in rural areas downwind of major cities. There is always some ozone in ground-level air (the so-called ‘background’ concentration, partly influenced by pollution from other continents). Yet ozone concentrations can rise to a higher level for several days when conditions are right for it to form – during so-called ‘ozone episodes’.

Although international agreements in Europe have succeeded in reducing the highest peak ozone concentrations, current background and episodic ozone levels remain high enough to damage human health, natural vegetation and crops. Ozone enters plants through the small pores on the leaf surface, known as stomata. Once inside the plant, ozone reacts to form oxidising chemicals that can damage cell membranes and key processes such as photosynthesis.

In crops, this leads to reduced growth and smaller, lower-quality seeds and tubers with less oil or protein. If ozone episodes last a few days, visible damage to the leaves of sensitive species can appear. This can be seen as pin-head-sized pale yellow or brown blotches, below which the cells have died. It can reduce the value of leafy crops like lettuce, spinach and herbs.

Some of the world’s most important staple food crops are sensitive to ozone, and how scientists are responding.
including wheat, maize, rice and soybeans. Several studies have shown that crop varieties grown in south-east Asia may be at least as sensitive as those in Europe and North America. Ozone concentrations are rising here, partly due to rapid industrialisation, and alarm bells are beginning to ring about current and potential future ozone impacts in the region, where food security is precarious.

Focusing on wheat and tomatoes, we calculated the production of ozone, and the economic losses it causes, in the 27 EU countries plus Norway and Switzerland. We looked at whether current European policies to reduce emissions of the chemicals that lead to ozone pollution will reduce ozone damage by comparing data from 2000 with predictions for 2020.

Using a recently-developed modelling method that calculates the amount of ozone plants take up through their stomata over a whole growing season, we predicted that around €3.2 billion was lost in 2000 due to ozone effects on wheat yield. Even with current legislation to reduce ozone pollution in Europe, we predict losses will still be €2 billion in 2020.

These numbers are based on wheat prices and production in 2000; given the rising price of wheat, economic losses could end up substantially higher. The biggest impacts were predicted in areas of France, Germany, the UK and Italy. Losses for tomatoes, an important crop in southern Europe and the Netherlands, are estimated at more than €1 billion in 2000, and predicted to fall to €0.63 billion in 2020.

In a more detailed study looking at smaller geographical areas, we investigated the effects of ozone on eight UK crops in 2006 – a hot, dry summer of the kind that’s expected to happen more often in coming decades – and 2008, a more typical year for the UK. Ozone-sensitive wheat is grown on some 2 million hectares in the UK, especially in the south and east where some of our highest rural ozone concentrations occur. So it’s not surprising that more than a third of the total losses in monetary terms for the UK could be attributed to effects on wheat yield.

What was surprising, though, was that estimated losses for wheat were the same (5.6 per cent of economic value) for both 2006 and 2008. Although ozone concentrations were higher in 2006, the drier conditions in that year meant that stomatal pores didn’t open as much – a defence against water loss which also reduced the amount of ozone uptake. There were also differences in the UK regions most likely to have been affected.

Protecting our crops from ozone pollution in the future will require a multi-faceted approach. Firstly, we need international effort to reduce the emissions of the chemicals that lead to ozone pollution. The results presented here have fed into United Nations negotiations for the Convention on Long-range Transboundary Air Pollution via ICP Vegetation, an international programme coordinated by the Centre for Ecology & Hydrology at Bangor.

We also need more research to develop ozone-resistant varieties of staple crops, to investigate farming practices that might reduce ozone uptake during episodes, to gain further insight into how ozone damages crops and to investigate chemicals that could be used to protect against damage.
The term ‘food miles’ was coined to represent the complexity of the whole food system. But the media soon turned it into a simplistic measure of distance alone. Do lots of food miles mean a higher carbon footprint? What is a carbon footprint, anyway, and can it help us make better decisions?

We can calculate a food’s carbon footprint (CF) using Life Cycle Assessment (LCA). It is the sum of all greenhouse gas (GHG) emissions produced by making and delivering that food. For much industrial or domestic activity, the CF depends largely on fossil-fuel use – burning fossil carbon emits CO$_2$. But in agriculture, two major gases change things: nitrous oxide from artificial fertilisers and manure management, and methane from animals’ digestive systems and manure. Further along the food chain, refrigerants can leak from sources like mobile chillers on lorries and in shops.

To find a product’s carbon footprint, we need to trace its GHG emissions all the way back to natural resources in the ground. So a lorry’s carbon footprint must include emissions from extracting, refining and delivering the diesel, not just from burning it. Similarly, for crops we include the energy used in making fertilisers and pesticides, vehicle fuel for cultivation and harvest, the energy cost of making farm vehicles and other capital items, drying and storage energy and even the energy used to produce seeds.

Is local always best?
‘Local is always best’ is a commonly-heard mantra, but is it true? There is no single answer. Crops – including grass – vary in yield because of soil, climate, water availability and management approaches. Some crops are perishable, while others have long storage lives, though some of these need refrigeration and other preservative processes. So we can only start to answer ‘local is best’ in the context of our demands for different kinds of food.

If a crop’s carbon footprint is the same at the farm gates of locations A and B, then moving the crop from A to B and consuming it there must be worse because of the transport emissions. But life is rarely so simple!

Take tomatoes. We can grow them outdoors in the UK, but with a small yield and very limited season; most commercial production needs heated greenhouses with extra CO$_2$ to boost photosynthesis. We can grow tomatoes all year, but need extra energy for lighting in winter. Or we can buy tomatoes in winter from, say, Spain. There, little or no heat is needed and the cheapest tomatoes grow in simple plastic-covered structures.

Overall, producing tomatoes in the UK emits more GHG than transporting them from Almeria in Spain, but again the truth is complex. Tomato quality may not be the same, and production techniques are improving all the time; an increasing proportion of UK tomato-growers use combined heat and power – that is, they generate their own electricity and use the ‘waste’ heat that would otherwise go into the atmosphere to warm their greenhouses – or they import waste heat and CO$_2$ from elsewhere, instead of using stand-alone heaters. This can mean their products emit less than they would if grown in Spain – provided both heat and CO$_2$ would truly otherwise go to waste.

The comparison makes clear that being
transported a long way does not contribute as much to GHG emissions as a heated production system. But for outdoor crops, the differences are smaller. For potatoes, the comparison is more about importing the crop from abroad versus storing those grown in the UK. The eastern Mediterranean is a common source, but here the emissions from transport outweigh those of storage, and the emissions from potato farms there and here are similar.

So, these two examples show there’s no simple rule – more food miles isn’t always a bad thing. Of course, the method of transport is crucial. Air emits most GHGs – about 10 to 25 more than heavy lorries for a given weight.

**Beyond carbon footprints**

Agriculture’s environmental burdens go beyond GHG emissions alone, and the concept of the carbon footprint doesn’t address this. Other burdens such as energy and resource use, land occupation and potential for water pollution are commonly included in wider LCAs. This makes comparisons more complex, but also possibly confusing. For example, beef from Brazil may have a higher carbon footprint than UK beef, but it uses less energy.

One area of increasing concern, though, is the amount of water that different foods consume. The subject has been raised by the Water Footprint Network and much has been made of the water footprint of, say, bread (1.6m³ per kilo) and beef (15.4m³). But these stark numbers alone do not address the real problems.

The crucial difference is the need for ‘blue water’ taken from rivers or aquifers for crop production, and what conflict there is for that water, which is also needed for human health and industry. If crops are watered by the rain, there is no conflict; if many users are competing for too little water, the conflict can be intense. So depending on demand, the same water footprint can cause much more harm in one place than in another. For a water footprint to be valuable to decision-makers, we need to find out how much stress the relevant water supply is under, and our methods to do this are still developing.

Other factors also need considering to put a water footprint figure into context, such as how quickly aquifers recharge. Current work towards an international standard on water footprints aims to use such an approach.

This brings us back to Spanish tomatoes. Almeria has winter sunshine, so we can have tomatoes – and other fresh vegetables – in the winter with lower GHG emissions than we could get by growing our own. But the water stress of growing tomatoes in Spain is very high. Rainfall is low and both horticulture and humans demand a lot of water. A recent national debate was resolved by opting for local desalination rather than a long pipeline from Catalonia.

Our future use of these precious resources must be managed with care to extend our sustainable life of the planet. Food miles do not tell the whole story, but they lead us to the methods that do – methods which we must develop and apply better: Life Cycle Assessment and impact-weighted Water Footprinting.

**Comparison of growing and storing main crop potatoes in the UK with importing them from Israel.**

**Comparison of the carbon footprint of tomatoes grown in the UK and Spain, up to when the tomatoes are delivered to a regional distribution centre (RDC) in the UK.**

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**MORE INFORMATION**

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Life Cycle Assessment
www.cranfield.ac.uk/sas/cerf/lca.html
Cheesed off with hunting and gathering?

We take our morning milk for granted but how did it become such a staple? In a muddy farmyard in Somerset, Richard Hollingham meets Julie Dunn, an archaeological scientist from the University of Bristol, and Wyndhurst Farm manager David Hitchings, to find out how the dairy cow has influenced human civilisation.
Richard: Julie, you found the first direct evidence in Africa of prehistoric people rearing cattle for milk?

Julie: Yes, in the Libyan Sahara. Around 8000 BC, so 10,000 years ago, people started dairying in Eurasia, and moved from the Near East down into Africa with their cattle. We looked at lipids in ceramics excavated from a rock shelter in the region [the Takarkori rock shelter in Libya’s Tadrart Acacus Mountains]. These told us that people were processing milk products and animal fat products in their pots.

Richard: And they were using this milk for what?

Julie: Probably for making butter, cheese and yoghurt. Most humans then were lactose intolerant, in other words they couldn’t drink milk, it would have made them quite ill. Processing milk reduces the lactose content so they could have eaten the products without becoming ill.

Richard: And since that time we’ve evolved the ability to digest milk?

Julie: Yes, it’s a very good example of selection in action. Around about 10,000 years ago when people started dairying and settling down, as opposed to being hunter-gatherers, nobody could tolerate milk. But then this new technology comes in, these wonderful creatures called cows and they’re walking larders. Obviously everyone wants a bit of this new technology and within a thousand years of processing milk and using milk products a gene evolves which allows people to tolerate milk. So we’ve become lactose persistent.

Richard: How do you know it was the milk they wanted from the cows, that it wasn’t just a by-product?

Julie: We can tell whether they were processing milk or fats from the flesh of the animal, in the pots. Our lipid analysis showed 50 per cent of the pots had milk processed in them. Bear in mind that this region, although it had been quite green and wet in the last 10,000 years, was beginning to dry up, and cattle are important because they’re a source of liquid, on the hoof as it were.

Richard: And so the cattle became much more valuable for producing milk than they did for meat or by-products like skins?

Julie: Yes, we think so. We think the secondary products, milk, cheese, butter, yoghurt, were much more valuable to ancient people than the actual flesh of the animal. Why would you kill something that is going to give you food every day?

Richard: This was happening in Africa – but how did we end up here farming cows and making cheese?

Julie: When cattle were domesticated they moved into Africa but they also moved with people the other way and spread out right across Europe and into Britain and Ireland, finally getting here round about 4000 BC, so 6000 years ago. And pretty much across Europe people settled down, became farmers and started using milk and its products.

Richard: So cattle turn out to be incredibly important for these ancient people and for human civilisation?

Julie: Absolutely. Cattle are one of the things that drive humans, part of the beginnings of our civilisation, and they were clearly just as important then as they are today. For a start they created the most remarkable rock art which shows how much they clearly thought about and relied on their animals. The transition from being hunter-gatherers to settling down enabled the development of much bigger communities, which eventually led to the establishment of things like city states and so on, and finally to where we are today.

Richard: David, how important is milk and cheese to us now?

David: It’s a huge industry. Unusually in the UK we value fresh milk to drink, so it’s got to be transported within a very short time and because it has a short shelf life it’s also got to be kept refrigerated. Elsewhere in the world if they do drink milk it is usually UHT, which is heat-treated, has a much longer shelf life and doesn’t need to be refrigerated.

Richard: Noone likes UHT milk!
Calling all foodies

Doing great science is all very well, but it’s all academic if the people who can put it to use don’t get to hear about it. Hugh Wright and Lynn Dicks tell us more.
We naturally tend to work in a comfort zone: collaborating with like-minded colleagues, presenting to people in the same profession and heading to the bar afterwards with only our closest peers. Stepping outside these cushy surroundings to interact with outsiders feels much harder, especially where interests diverge. Finding different stakeholders in the same venue, let alone around the same bar table, is all too rare.

Yet finding common ground and sharing information is precisely what’s needed to ensure that science is directed at the most important issues and that policy decisions are well informed. And identifying shared interests and collaborating across sectors needn’t be arduous. Once different professions come together, new opportunities arise quickly and spontaneously.

One NERC-funded project recently brought together 50 people interested in conserving the UK’s wild pollinating insects, from scientists and farmers’ unions to conservationists and retailers. Among these stakeholders was the Bee Guardian Foundation. They had funding to plant trees to feed bees, but needed to know which trees are best for the job, and how they compare to the wildflowers that are more often planted for pollinators.

Scientists responded to this need immediately via the network of contacts that had already been established, providing the project designers with data on the pollen and nectar resources of UK trees. “This evidence enabled us to make informed decisions about the most appropriate planting plans,” says Jessie Jowers of the Bee Guardian Foundation. “To be effective it is essential that we can access the latest research. Through the pollinator group we can tap into this and ask specialists the questions that we are repeatedly being asked on the ground.”

This is the kind of collaboration that NERC’s Knowledge Exchange Programme on Sustainable Food Production is nurturing. It aims to give the food sector the science it needs to become more environmentally secure. Task forces for agriculture and aquaculture are bringing together businesses, grower and trade associations, civil society and scientists to identify priority areas for further research.

Subjects vary from the very small – such as how to provide food and shelter for natural enemies of pests – to the very large, such as how to stop non-native species, and their diseases, from spreading between fish farms. European aquaculture has to tackle new viruses transmitted via contaminated water. Monitoring and controlling their spread is a major challenge, as wild fish may carry the disease without any symptoms. Once the existing science on these topics is identified, the task forces set an agenda for future research, spawning new project ideas and partnerships.

The programme is also evaluating what food producers, whether they farm on land or in water, can do to maintain biodiversity, enhance ecosystem services – that is, the range of benefits that nature provides us with – and improve environmental conditions. Scientific evidence around three main themes – pest control, soils and aquaculture – is being collated and condensed, highlighting key results, especially effects on yield and profit, to demonstrate the effectiveness of different actions.

This is important, as many actions become popular without much attention to whether they really work. Increasing crop diversity on farms to enhance biodiversity is widely advocated, yet the effects of rotating crop types from season to season are surprisingly understudied. The evidence we have points to contrasting effects, suggesting we need more research before we can advise farmers to do this.

The new synthesis of evidence for sustainable farming practices will provide a quick way for practitioners and decision-makers to find out what they could do, and what the evidence says about its effectiveness.

Our new NERC sustainable food website is a valuable resource offering free access to summaries of the scientific evidence for and against many different measures taken to enhance ecosystem services, boost farmland biodiversity or improve soils. Thinking of improving the cycling of organic waste on a fish farm, or creating beetle banks to encourage natural predators of pests, or reinstating hedges to prevent the loss of soil organic matter? The website lets everyone see what the science says – what works, and what doesn’t.

MORE INFORMATION
Dr Hugh Wright is a research associate at the University of Cambridge assessing the science and research needs in pest control and food security. Dr Lynn Dicks is a NERC Knowledge Exchange Fellow, also at Cambridge, working with practitioners and scientists interested in pollination and sustainable food production. Email: lvd22@cam.ac.uk.
www.nercsustainablefood.com
Turning down the heat on farming

Farms produce a lot of greenhouse gases (GHGs) – in 2011, the Carbon Disclosure Project estimated the agriculture sector was responsible for some 14 per cent of global emissions. Like most people, farmers burn fossil fuels for lighting, heat and transport. But there’s also methane from manure and composting, and nitrous oxide from nitrogen-based fertilisers.

Many farmers want to do better. And the big companies that buy their produce are often even keener; they now routinely plan for tightening regulations on greenhouse-gas emissions, and want to get ahead of the game. So they’re leaning on farmers to cut their emissions.

But for farmers, acting on a desire to improve isn’t always easy. There are hundreds of changes they could make around the farms, with varying costs, and it’s not obvious which would bring most improvement for least money. What if they were to adopt a new mixture of crops? Change how they plough? Or should they invest in precision-fertilisation technology? (This lets them apply nutrients exactly where they’re needed and nowhere else – it’s costly, but can boost yields as well as saving chemical fertiliser and cutting emissions.)

For farmers without scientific training, evaluating the options can be near-impossible – scientific models of carbon emissions take specialised knowledge to use, and need to start with carefully-tailored parameters if they’re to represent a particular situation accurately.

The Cool Farm Tool (CFT) aims to help. Launched last summer, it’s already being adopted enthusiastically by farmers all over the world and is helping bring them together with food processors, scientists and environmentalists. It gives them a simple but accurate way to estimate a farm’s GHG emissions. Farmers enter some simple information about their land, its soil type and what they do on it; they are then presented with a summary of emissions and potential steps to cut them.

The CFT doesn’t just calculate total emissions; it breaks them down so the farmer can see where their emissions are greatest and where they can make the biggest difference most quickly. If it turns out that the main problem is carbon loss from the soil, there’s not much point spending a fortune on fuel-efficient tractors. And while it’s based on the best available information, it’s designed to be used by non-specialists. It’s early days yet, but so far the response has exceeded its creators’ expectations – it’s now being used...
by groups from Indian cotton growers to the Americans who produce the tomatoes that end up in Heinz soup. And their feedback is enthusiastic.

‘The industry saw the need for a tool that was driven by real data from farms and that packages good science in a way farmers can access,’ says Dr Jonathan Hillier of the University of Aberdeen, the CFT’s creator. ‘Before this, there wasn’t much that was helpful for them; what’s best for each farmer depends on what they are producing, where they are and how the costs and benefits balance out. It’s all about trying to find the low-hanging fruit, and this will be different in each situation.’

The project got started when the sustainability team at Unilever, the Anglo-Dutch consumer-goods giant, approached Hillier asking for something simple that could help its farmers understand their emissions and what they could do about them.

Since then, other big players in the food and drink industries have joined the project, including PepsiCo, Marks & Spencer, Tesco and Heineken. They have a common interest in emissions-cutting, which means working with the farmers who supply them – researchers think up to 80 per cent of the average fresh foodstuff’s total emissions happen before it leaves the farm.

Everyone gains from using the CFT. Farmers and food companies get to cut emissions as efficiently and painlessly as possible. Scientists get to spread their knowledge about the most effective ways to do this, with big companies carrying the word to hundreds or thousands of small farmers and working with them to put theory into practice – something the researchers would struggle to do themselves. ‘The great thing of being a big company with a short supply chain is that you can work directly with farmers to do this kind of thing,’ Hillier says.

One such company is PepsiCo. It owns Walkers Crisps and is making it a condition of its contracts that potato growers set out rigorous emissions-cutting plans. It’s set itself a target of halving carbon emissions over five years. ‘When I first heard about that, I thought it was incredibly ambitious,’ Hillier admits. ‘But we’ve now shown this kind of collaboration works; it cuts emissions in a cost-effective way. So I now think the target is achievable.’

Hillier’s team is now using NERC funding to put together an extended version of the CFT that will go beyond GHG emissions to show other aspects of farms’ performance, ranging from water quality to harder-to-quantify measures like biodiversity. The idea is to give farmers a better sense of the big picture and how different goals can conflict – so that in trying to cut GHG emissions they don’t do something to harms rare birds living on their land, for instance. ‘There’s also a new web version of the tool on the way. At the moment it works in Excel; it does the job but is hardly a thing of beauty.

Hillier argues that this sort of collaboration between scientists and industry is vital if we’re to cut emissions as much as we need to. Hearteningly, the industry now needs little persuading to get involved. ‘Many farmers are genuinely concerned about the environment, but without some external pressure the farming industry as a whole isn’t likely to take much action,’ he says. ‘That pressure is now coming from big food companies like the ones we work with. For them, it’s just long-term strategy; they see more policy, regulations and consumer pressure on the way, and they want to get in early and be seen as pioneers. We’re not talking about some fluffy green mindset – it’s in their interest to be prepared.’
Shellfish could provide the UK with much more healthy, cheap food than they do at present, but concerns about pollution and its possible impact on people’s health stand in the way, and environmental change could make the problem worse. Shelagh Malham and James McDonald explain how their research will help.

Mussels and other bivalve shellfish are a nutritious food source. They are high in protein, low in cholesterol and fat, contain numerous vitamins and minerals and are a rich source of Omega-3 fatty acids – an important part of a healthy diet that is linked to better cardiovascular health. Shellfish have been hailed as a sustainable and valuable food source for the future, as the land’s capacity to feed our population falls and the world’s population increases.

Shellfish farming is also an important commercial activity in estuaries and coastal waters. The UK is a major producer of shellfish, harvesting more than 39,000 tonnes of mussels in 2011. Most of these are exported, with only about 20 per cent eaten in the UK. With better water quality, better site provisioning and more financial support for the industry, the UK could double aquaculture production, boosting this affordable and sustainable supply of nutritious food as well as local industry and livelihoods.

On top of the health benefits of eating mussels, growing and eating more mussels would create jobs harvesting and preparing seafood, as well as distributing and selling it. This would also help make the UK’s food supply more secure and less dependent on other countries. Mussels are also important and beneficial members of the marine ecosystem, recycling nutrients, regulating phytoplankton blooms and improving water quality.

But one problem is that shellfish absorb pollutants from the water around them, and if they’ve grown in the wrong conditions they can cause food poisoning. Environmental change could make this problem worse. Coastal environments will face increased temperatures, heavy rainfall and storms, compounded by coastal development and increased population size, as well as emerging infectious diseases of both shellfish and humans. There are significant challenges in understanding and managing microbial contamination, shellfish safety and future food security.

Bivalves are collected from the wild or from cultivated stocks; they can be grown either on the seabed or on ropes in the water. But there are restrictions on shellfish farming and harvesting due to public health concerns around eating them. Bivalves get food by filtering particles from the water, and some of the coasts and estuaries where they live have poor water quality, containing contaminants that can infect humans such as bacteria and viruses.

People can catch these harmful microbes from eating raw or undercooked shellfish, ending up with food poisoning. Pathogenic bacteria and viruses get into freshwater, estuaries and coastal waters via surface run-off, wildlife excrement, septic tank outputs and storm and sanitary sewer overflows. Once on the loose, they can attach to sediment particles, known as ‘flocs’ – these are aggregates of organic and inorganic material – which are either deposited in the estuary or are washed down to the coast.

Flocs aren’t just isolated reservoirs containing higher concentrations of harmful microbes than the surrounding waters – around seven times more, in some cases. They are also reserves of macro-nutrients – compounds containing carbon, nitrogen and
phosphorus that humans need in large quantities. We know very little of what ultimately happens to these nutrients, flocs and associated microbial pathogens in the environment, or how they affect water quality and interact with sediments. Nor do we know how the nutrients affect the viability of microbes as they move through the estuary before reaching the shellfish.

Bivalves’ filter-feeding nature means that contaminants, including pathogens, can build up in their tissues, potentially endangering public health. The survival and persistence of microbial pathogens from catchment to coast could be a threat to shellfish food safety.

Many food poisoning cases are caused by water-borne pathogens, including E. coli 0157. This can damage both food security and the local economy, whether by harming the fish and shellfish industry’s sales, affecting workers’ health, causing beaches to lose their blue flag status, or simply generating negative publicity that makes tourists stay away.

Securing safer shellfish
Food safety is strictly regulated, and mussels must be harvested from areas classified under the Food Hygiene Regulations, which use the number of faecal indicator bacteria such as E. coli to assess whether an area of shellfish can be harvested. But E. coli numbers are only an indicator of microbial pollution; many E. coli are harmless to humans, so we need to know more about how many of the bacteria detected in shellfish waters are actually dangerous to us. It’s possible we could be safely eating shellfish from areas that are currently considered too polluted.

A new NERC-funded project on macronutrients will let us investigate the impact of pathogens that come from river catchments on human health, tourism and food security, and how these are affected by changes in available nutrients and the weather. Recently Bangor University, working with organisations like the NERC Centre for Ecology & Hydrology and stakeholders such as Conwy County Borough Council, the Environment Agency and Welsh Water, have shown that E. coli are found in muddy sediments in rivers and estuaries, and survive up to 6cm deep in the mud. There are also fewer potentially pathogenic bacteria in faster-flowing water.

The research also shows that flocs have higher general bacterial and potential pathogen numbers than either the water or the mud, perhaps because their macronutrient levels increase the chance that bacteria survive the journey from the land to the mussel beds.

Our work will focus on pathogenic microbes. This will involve taking samples of water, flocs and sediment from several places in the river and where the river meets the sea, both from boats and from river banks and other access points. We will then analyse these samples for macronutrients, bacteria and viruses as well as floc size, salinity and the speed of the water.

These field measurements will also be reproduced in the laboratory under controlled conditions to provide more insight into how macronutrients, floc size and salinity affect pathogenic bacteria. Our research will let us estimate how many potential pathogens are going from the land to the river to the mussel beds at the coast. We will investigate these interactions in relation to changing tidal states, nutrient availability and environmental conditions such as rainfall, so that we can produce new policy guidelines on public health risk.

Understanding the effect of macronutrients and flocs on the survival and transport of potentially pathogenic bacteria, both in current conditions and after future environmental change, will lead to more effective regulation, protect commercial food production and contribute to food security. Our project is a major first step in uncovering the interaction between macronutrients and pathogens as they move from fresh river water to estuarine salt water, and will help us sustain this important food resource for the future.

More Information
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An estuary full of mussel beds.
Checking water quality on a mussel farm.
Food is not just something we eat. Its fluctuating price and availability mean it will be one of the main ways many of us will interact with the environmental issues of our time: climate change and competition for water, land and energy. Tim Benton explains why.

By the middle of the century, global demand for food is projected to grow by about 60 per cent, as population rises, and the burgeoning global middle class develops more sophisticated tastes and devotes more money to satisfying them. But how easy will it be to increase supply? Climate change is already affecting crop yields, through an increase in extreme weather, and this is only likely to get worse. Even if conditions were more favourable, most of the land available for agriculture is already in use; at about five billion hectares, agriculture effectively covers most land not occupied by rainforests and deserts.

Land availability isn’t the only constraint. Agriculture already uses about 70 per cent of the world’s available fresh water resources: with other demands on water likely to grow too, this means we have to find a way to meet the projected increase in demand for food using the same amount of water. Energy is another big issue, affecting the costs of food transport, fuel availability for agricultural processes and the production of synthetic fertilisers.

How do we considerably increase food production, using less land, less water, less fertiliser and in the face of climate change? And, at the same time, how do we reduce its environmental impact?

Globally, agriculture has probably the greatest environmental impact of any human activity. Some 25 per cent of global greenhouse gas emissions are associated with agriculture and the conversion of land to it; up to a quarter of the soils used for agriculture around the world are degraded, and over 12 million hectares have to be abandoned every year because the soil can no longer support crops. And the loss of global biodiversity, with all the benefits it brings us, is probably incalculable. In our eagerness to turn the world over to agriculture over the last 50 years, we have not paid due regard to the natural resources that are critical both for agriculture and for our survival.

With no more land available to meet increasing demand for agricultural produce, our only option is to produce more food on the land we do have. But if we are going to intensify agriculture in this way, we have to ensure we do it with the minimum environmental impact. We need intensification, but we also need to improve and protect ecosystem services – we need ‘sustainable intensification’, with equal emphasis on both. But intensification
here is not a clarion call for greater industrialisation of farming: sustainably producing more food can come about by increasing our knowledge, labour or technological inputs. An allotment gardener or smallholder can produce far greater yields per unit area than large-scale agriculture, by applying their knowledge of the land and more labour-intensive land management (constant weeding, dynamic pest control).

**Intense, but sustainable**

One important change that is already happening is in the scale of our thinking about ecology and landscape management. An agricultural landscape is not just a collection of individual farms: the pollinators a farmer relies on for one field of crops don’t come from that field, but from the population of pollinators supported in the wider landscape. So the sustainable intensification challenge is not to think about sustainable agriculture per se, but the sustainable management of whole landscapes that provide many, connected, ecosystem services.

An agricultural landscape produces food but it also provides water, requires biodiversity to underpin soil function, pollination and other useful services, and also has value to society in terms of aesthetics and recreation. Rather than think about fields producing food, and the rest of the land producing everything else, we need to think about managing integrated, multifunctional, landscapes.

It’s a neat idea but what does it really mean? How, in practice, can we manage the trade-offs between the different things we want from the land: food, water, biodiversity, recreational value? What is the best way to maintain biodiversity and other services in agricultural landscapes, whilst recognising that there is a growing demand for food? How should the non-cropped land, the hedgerows, the field margins, the coppices, the water courses, be laid out and managed to create the best connected network allowing animals and plants space to live and move? How should the best management vary from place to place? And how do we encourage land managers to put all this in place?

As well as these local considerations we must also recognise the wider context of the agricultural market. The market is a mechanism which connects changes in land use across the globe. If less food is being produced in one place (because land has been set aside to regenerate biodiversity, for example) the market signals the need to replace the ‘lost’ yield – as prices for that commodity rise and farmers elsewhere increase their own production of it to take advantage.

We’ve seen the potential for this to happen in Europe, with the spread of wildlife-friendly practices like organic farming. These more sustainable practices produce lower yields, and when demand is growing that shortfall has to be made up by increasing food imports. The overall effect is therefore to shift some of the environmental costs of our food elsewhere – or perhaps even to increase it if it contributes to intensification in the more biodiverse tropics. This doesn’t mean organic food is a bad thing – it simply shows the huge challenge of understanding how decisions taken in one place can have global consequences, and of working out how to manage the whole system to get the balance as good as it can be.

Climate change makes this need all the more pressing. The impact of extreme weather on global food production is increasingly creating shortfalls in supply, raising food prices and sending short-term signals to further intensify production. So we must also understand the links between climate, weather, production, environment and economics – the entire food system – and how changes to any of those variables affect the whole system. Only by understanding how changing production practices in one place works through the market and impacts land-use in another place, will we really be able develop truly sustainable food systems.

This is a real interdisciplinary challenge, spanning the biological, environmental and social sciences at least. Collaborative research like the Rural Economy and Land Use (RELU) programme and Biodiversity and Ecosystem Service Sustainability (BESS) have made considerable progress in working out how we can better organise our agricultural landscapes. Meeting the global challenge of sustainable intensification of agriculture will call on even broader partnerships, of which the Global Food Security programme is one.

**MORE INFORMATION**

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More than four million people in sub-Saharan Africa are currently malnourished. Rapid population growth, poor infrastructure, weak governance, recurrent conflict, environmental degradation, low food production and high dependence on rain-fed agriculture all threaten food security.

Lurching between floods and drought, the weather is another significant factor for food security. Our understanding of weather and climate is improving all the time and, as a meteorologist, I wanted to turn these scientific advances into practical solutions for African communities, to help them survive and even thrive despite the uncertain climate. But my colleagues and I were unsure what weather information people needed, or what channels to use to exchange expertise. So in 2010 I secured a travel scholarship to go to Africa and start to find out.

I quickly discovered the communication gap wasn’t confined to the UK: there were limited opportunities for climate scientists, decision-makers and farming communities to talk together too. Without mechanisms in place for effective dialogue, the latest climate science is not getting through effectively to inform policy. Sudan, for example, has no climate-related policies while climate research in Senegal is limited by weak links between the national meteorology services, universities and user communities. Many talented and motivated meteorology students have little prospect of using their skills in the long term because of severely limited funding.

The stark reality of what this really means hit me in Senegal last year when I saw the large ditches criss-crossing villages where communities lose not just crops but their children, as flash floods carve the ground into ravines of fast-flowing water. If only the villagers knew the storms were coming, children would be called back in from the fields in time.

Poor communication has two outcomes here: people are suffering because they can’t access the relevant information at the right time; and countries are not investing in the capacity and expertise needed to build long-term resilience.

Importantly, the communication barriers and institutional links are different for each country, so solutions have to be tailored – but coordinated. I started the Africa Climate Exchange, AfClix, to find ways round these barriers and strengthen these links, so our science could make a difference on the ground in a number of strategically-targeted countries.

Working mainly in Senegal, Sudan and...
Ghana at first, my role as AfClix director is to understand the existing communication structures and listen to the needs on the ground. My own climate research helps me stay in touch with the latest science and take ideas from Africa back to the research bench. AfClix takes me outside my comfort zone as I work with users from different sectors and disciplines, but this means we can improve communication and information exchange at every level.

For example, in the absence of better forecasts for farmers at the weekly to seasonal scales, AfClix has helped establish innovative low-cost early warning systems based on monitoring, ‘nowcasting’ and good communication across communities. In one pilot project funded by the Climate & Development Knowledge Network, the Senegal Met Service, working with the Red Cross and community leaders, relays weather information to a designated village contact by mobile phone. The news is then posted on a blackboard in the village and picked up by contacts from other villages or spread through local markets – simple but effective. AfClix will support an extension to this pilot over the summer and through AfClix connections, will help extend its reach and learning to other targeted countries.

At the other end of the spectrum, AfClix is helping government policy-makers understand the importance of climate science for improving food security. By demonstrating the economic benefits of relevant weather and climate information, we hope to encourage decision-makers to engage with the issue and put money behind useful initiatives.

Activities on the ground are supported by the AfClix web portal, by helping maintain relationships between the UK and sub-Saharan Africa and signposting access to expertise, data, education resources and news – a facebook for the climate science and humanitarian-policy community.

AfClix projects are now evolving across the continent. We have plans to forewarn coffee cooperatives in Tanzania about extreme weather events which can seriously damage their crops. Farmers will be able to call into a daily radio programme to ask questions such as what seeds to use, when to plant or when the monsoon is starting. These will be answered by climate and agricultural experts from two NGOs, the local university and the national Met Service among others. The farmers will also receive information via a new SMS platform already trialled successfully by the Kenya Met Service. This lets the farmers plan ahead and take action now to deal with approaching weather; heavy rainfall can damage drying coffee beans or even wash away whole crops.

This work relies on building personal relationships and it can’t be done from the UK. I travel to Africa every eight to ten weeks, juggling my own research with AfClix work. Although the work is demanding, there is nothing more motivating than sitting down with the village chiefs, NGO practitioners, fellow African scientists and government advisers and ministers, to realise how even small changes can make big differences. Over two years in Senegal, I’ve seen significant improvements thanks to the energy and willingness of a committed group of people. Here, in the last year, AfClix has become a sort of ‘African response unit’, with people from many disciplines coming to us for help shaping their own decisions and solutions.

It’s fantastic to see AfClix grow in this way. But it’s even better to see how, through simple connections and taking time to listen, our science can make a difference to people’s lives.

An aerial view of the landslide which hit the area of Bududa in Uganda.
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