ROTHAMSTED RESEARCH

2022 Yearbook

Fighting for the future

Professor Angela Karp
Director and CEO

Angela Karp

Russia's invasion of Ukraine in February shattered 80 years of peace in Europe, as the continent's worst nightmares were finally realised.

And whilst the fighting didn't spread beyond the borders of Ukraine, the impacts on global food, energy and financial markets were far reaching, nevertheless.

With Ukraine a major supplier of seed oils such as sunflower, Russia a major supplier of both natural gas and fertiliser, and the pair of them major wheat producers, it was inevitable that uncertainty and reduced availability of such staples would lead to turmoil as demand soared and prices skyrocketed.

For those of us Europeans fortunate enough to live beyond the borders of Ukraine, questions were soon asked of our own governments' food and energy security policies. Had we become too dependent on other nations to supply us with the most fundamental of all resources?

Here in the UK, first Covid, and now the war, have clearly demonstrated how access to affordable food also underpins our social cohesion. As inflation soared, the cost-of-living crisis fed into political instability and financial market uncertainty, as well as fuelling strikes by transport, healthcare, and other public sector workers looking for better pay and conditions.

But what – in the short and long term – can realistically be done to reduce dependence on imports? Bringing wholescale food and energy production back home is no simple task and would severely impact any nation's carbon emissions, land use, diets, and ultimately, its biodiversity.

There are no easy fixes but helping find solutions to these conundrums flies right to the very heart of Rothamsted's research agenda.

For example, shortages of wheat and seed oils led questions to be asked of which crops could and should be produced domestically. Studies by us over the year showed there is a genetic potential within wheat to better tailor varieties to local conditions – so much so that global yields might double; but we also showed how, using the example of OSR in Europe, the wrong public policies could deter farmers from even growing a crop, despite the demand.

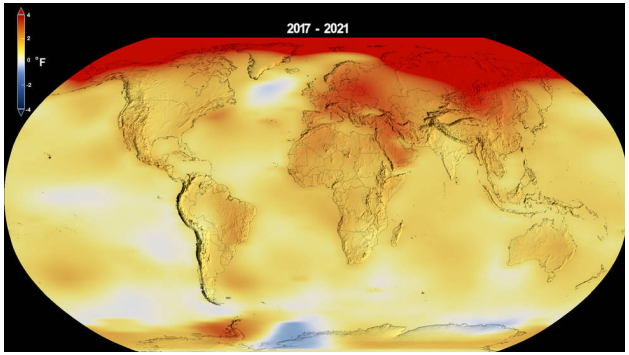
Similarly, the year's huge spike in fertiliser costs left struggling farmers searching for ways to use less of them – or to even explore the alternatives. A major Rothamsted study this year demonstrated for the first time that with the right combination of measures in place, reliance on fertilisers could indeed be reduced.

But what about the land use question? With a shift towards plant-based diets, many have suggested that the land currently used to rear cattle could instead be given over to crops, thereby reducing our reliance on imports. In fact, a study by us into one of the UK's key livestock regions showed any hopes of successfully replacing cattle with crops would be dashed under climate change – as rain-drenched fields made sowing and harvesting winter wheat near impossible.

And speaking of climate change…

2022 saw not only the UK break its highest daily temperature record, but 12 other European countries break their monthly records too. It was also the hottest year on record in the UK, with the top ten warmest years having all come this century. Famine returned to East Africa as it had its worst drought in 40 years (and Europe, its worst in 500 years). South Asia endured record breaking spring temperatures, and in Pakistan, the summer's heavy monsoon led to months of devastating floods. Australia, Europe and the United States suffered some of the worst wildfires seen in decades.

Around the world the cost of our climate inaction has meant millions have been displaced, and billions of dollars will be needed to put things right. I'd like to be able to tell you it's going to get easier this year, but in the UK, the Met Office is predicting 2023 to be even hotter.



Global five-year average temperature anomalies from 2017–2021 from the NASA GISS analysis. Credit: NASA

The challenges are immense, but we are responding. Much of 2022 was spent designing our new strategic research programmes, funded by the BBSRC. These are complex and detailed proposals that provide a solid intellectual framework for a new approach to agricultural science that we believe can deliver long-term sustainable progress.

We know that science cannot provide all the solutions to the raft of challenges facing humanity, but I am hugely optimistic that our new research portfolio can have a significant impact in driving innovation and sparking new thinking in farming. We look forward to the next five years of research with renewed confidence and even greater determination to change agriculture for the better.

Death of HM Queen Elizabeth II

There was much sadness this year at the news of the death of HRH Queen Elizabeth II.

Rothamsted was always immensely proud to have the Queen as a patron. Our history is long, but the Queen has been an inspiring presence in our lives for as long as anyone currently at the institute can remember.

We have had the great pleasure of meeting many members of the royal family in person over the years, all of whom have shown great interest in our research as we strive for a more sustainable farming future. A highlight was the Queen's visit in 1993 to commemorate our 150th anniversary.

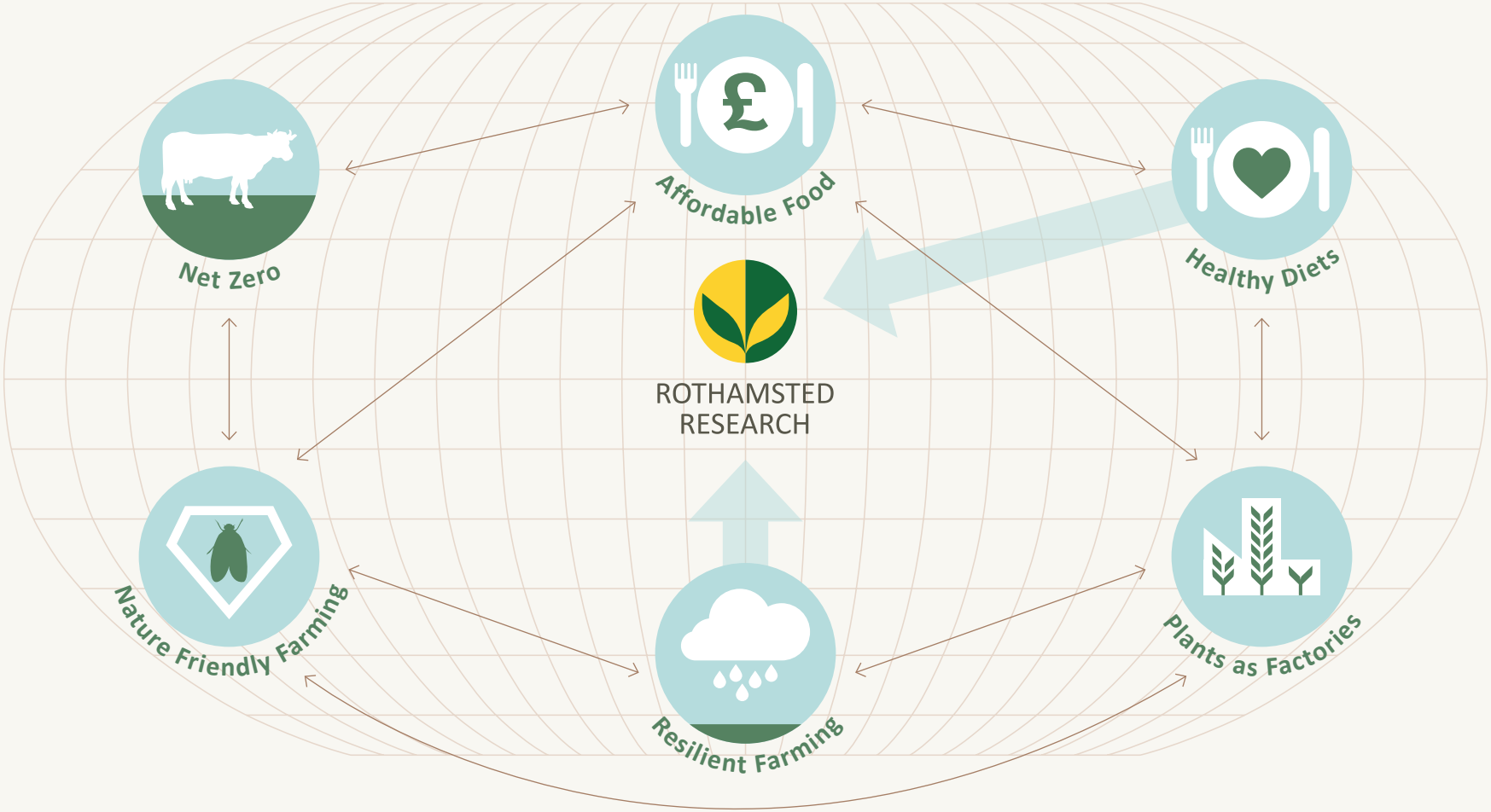
The excitement and pride such encounters generate is long-lasting and impossible to express adequately. They are highlights in our world of research that bring smiles and elevate spirits. What might in reality be a few moments of time, is remembered and talked about throughout people's lives. As our Patron, her Majesty has bestowed upon us the greatest honour, together with the royal family, of bringing such precious memories our way.

We now look forward and pledge our support to a new monarch whose enthusiasm for environmental matters and sustainable farming is well known. We hope that our lasting relationship with the royal family can continue to thrive, even as we mourn the passing of the beloved Queen.

We're the centre of the food web

Rothamsted is the world's oldest centre for research into food and farming and we've been at the very heart of things for almost 180 years.

Whether that's been making farming more productive or more environmentally friendly, our work has helped ensure the food you eat is safer, healthier, and more sustainable than ever before.



Every end…

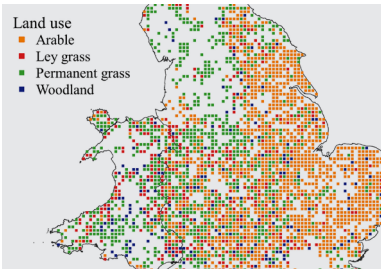
Our 2017–2023 research programmes have now come to a close. They resulted in many significant advances, spread over more than 1,200 peer-reviewed publications, of which more than 70% were open access.

Soil to Nutrition

Advanced the concept of soil health, by developing an understanding of soil-crop systems and their interactions with the environment across multiple scales.

We found that fertilisers reduce beneficial root bacteria

We showed why carbon is vital to how soil works

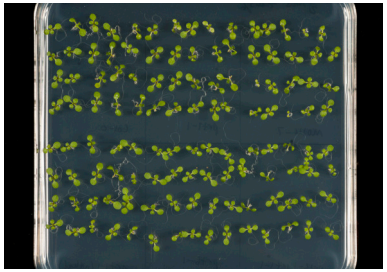


We developed an easy-to-use soil health measure

Tailoring Plant Metabolism

Redesigned chemical pathways in oilseeds and willow to develop sustainable production of high value products.

We showed plant produced omega-3 fats are just as nutritious as fish oils



We engineered plants to make human milk fat substitute

We discovered an anti-cancer compound in willow

Designing Future Wheat

Led to the development of genetic and genomic tools and resources that is benefiting researchers and breeders world-wide.

We developed technology to monitor crop growth 24/7

We made white flour high in fibre

We found natural sources of resistance to crop enemies

ASSIST

Delivered new evidence, models and tools for quantifying and enhancing the contribution of ecosystem services to sustainable agricultural systems and for mitigating impacts on the environment.

We calculated global wheat yields could be doubled

We demonstrated the potential for 'nature-based' solutions in controlling pests

We showed agri-environment schemes were better for incomes than the CAP

…is a new beginning

This year sees the Institute embark on an exciting set of five-year research programmes. Bold and innovative, they will help future-proof food and farming by embracing the very best nature-based, data-led, and green engineering approaches.

Growing Health

will harness nature-friendly farming practices to maintain yields whilst reducing reliance on agrichemicals. It will find ways to improve soil, water, and air quality whilst still tackling the major pests, diseases, and weeds that can decimate harvests.

Resilient Farming Futures

will call on AI and a century's worth of expertise in modelling and forecasting to forewarn and forearm UK farming against myriad threats, whether from the changing climate, pests, weeds and disease, or political upheaval – either solely or in concert with one another.

Green Engineering

will develop plants into 'living factories' that can deliver a sustainable supply of high value chemicals. These products will contribute to the health and nutrition sectors of the bioeconomy, the chemical and energy industries, and sustainable agriculture.

Delivering Sustainable Wheat

will help create new varieties of the world's most important crop. These will be ready for greener (less tillage – less fertiliser – less pesticide) farming, will help sequester carbon, and will be rich in minerals and dietary fibre.

AgZero+

will help farmers find routes to carbon neutral that are both productive and nature-friendly. Satellite imagery will allow the incredibly detailed analysis of individual study farms to be scaled up nationally – so we can thoroughly evaluate the net zero potential of innovative farming methods.

For more about each programme go to
www.rothamsted.ac.uk/institute-strategic-programmes

A new direction

The conflict in Ukraine has exposed the deep-rooted weaknesses within the global food system. Reliance on imports, especially of food, fertiliser and energy, has highlighted the extent to which many nations – including the UK – are at the mercy of geopolitical events.

In August, the United Nations World Food Program estimated that more than 345 million people were suffering from, or at risk of, acute food insecurity – double the number from 2019.

So far, the solutions suggested have spanned the spectrum – from having more international trade deals in place to sole reliance on domestic production.

> **"Even improvements in those countries with a medium genetic yield gap of 40 to 50%, but with a large proportion of global wheat harvest area – such as the leading producers India, China, USA, Canada, and Pakistan – would have a substantial effect on global wheat production due to the large wheat cultivation areas involved."**
>
> **Dr Nimai Senapati, study co-lead**

Whatever way forward we choose, the following five reports from this year highlighted just some of the challenges – and opportunities – we face in improving national food security.

1. Yields

One of the key agricultural commodities impacted by the war was wheat. Before the invasion, Russian and Ukraine grown wheat accounted for almost a third of all global exports. In the wake of the invasion of Ukraine, supply fell, grain prices surged and by the end of the summer wheat prices were more than 25% higher than they had been a year earlier.

Upping the yield from all existing wheat producing countries would help buffer against shocks affecting one or two of the major producers – and given growing political and climatic instability around the world, the spectre of failed harvests is an ever-increasing possibility.

So, there was some hope this year when a **Rothamsted led study** showed yields could increase markedly if varieties were better tailored to local growing conditions. The first-of-its-kind analysis of the untapped genetic potential of wheat showed global harvests are, on average, only half of what they could be.

By utilizing the vast genetic variation available in global and historical wheat gene banks with modern techniques such as speed breeding and gene editing, countries with the lowest yields could potentially increase their harvests by up to 70%.

2. Economics

A key food security issue to consider is the cost farmers face in getting the crop in the ground versus their return at market. Very simply, if the economics aren't favourable, the crop won't be grown. Fuel prices are a continuing barrier in this regard, but the Ukraine conflict added a new dimension through those eye watering increases in fertiliser prices.

These were mostly a result of increased energy costs for all manufacturers, but also because the hydrogen used to make ammonia fertiliser comes from natural gas. However, the lead author of a major study from the year says their findings could help reduce and rebalance worldwide fertiliser use.

Dr Chloe MacLaren and colleagues' **analysis of 30 long running farm experiments in Europe and Africa** showed that the high crop yields usually obtained using man-made fertilisers could instead be achieved through a combination of more environmentally friendly practices.

The report showed that low levels of fertiliser can produce high crop yields if supplemented by practices that support farmland ecosystems, such as growing a greater range of crops, growing plants such as beans or clover that enhance soil fertility, and adding organic matter in the form of manure, compost, or cuttings.

3. Government Policies

A further requirement for successfully maintaining domestic food security is a permissive and joined up policy environment. A Rothamsted report this year serves as a cautionary tale, however, as it shows very clearly how contradictory EU policies – one encouraging biofuels and the other banning neonicotinoid pesticides – ultimately led to the boom and bust of the oilseed rape industry in Europe.

After the EU implemented pro-biofuel policies, the area of oilseed rape harvested increased by 78% between 2003–2010. However, population booms of the cabbage stem flea beetle and another pest, the pollen beetle, led to increased use of pesticides, especially neonicotinoids, resulting in a ban on their use in 2013.

With no way to control them, widespread crop failures and significant yield losses for farmers have become commonplace. Since 2018 the area of oilseed rape grown in Europe has collapsed to 2006 levels.

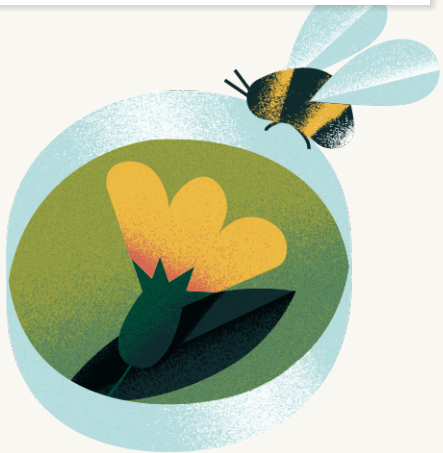
These well-meaning environmental policies have led to the collapse of the continent's oilseed rape cultivation and a reliance on imported oils – including palm oil, the growing of which is often responsible for tropical deforestation, and oilseed rape from countries still using pesticides banned by the EU.

4. Land Availability

Increasing food security will often mean increasing the land given over to food production, and for many densely populated or highly biodiverse countries, this would likely prove a stumbling block. With the recent trend towards plant-based diets, many have suggested turning over traditional livestock areas to crops instead.

However, this study showed that converting farms in Cornwall from livestock to arable would lead to regular crop failures. The chances of successfully growing winter wheat on fields once used to raise livestock could be as little as 28% in future, as increased rainfall will make sowing the crop impossible in some years.

Forecasts show when the near certain impact of increased future rainfall on sowing and harvest dates were included in the simulation, yields were sometimes a measly 3 tonnes per hectare, as farm machinery struggled to access waterlogged fields.



5. Diversification

In addition to increased output, achieving greater food security inevitably means farming a wider range of plants and animals – but as we know, the economics might not always support it.

In fact, poor farmers can achieve similar or higher incomes than farmers with greater access to resources if they farm a wider variety of crops and livestock, according to a study of more than 1,000 African farmers.

The same is also true for their food security, and the authors say it indicates a strong potential for diversification to improve livelihoods amongst the continent's smallholders.

The study found that, in general, farms with access to greater resources – in terms of land, inputs, and incomes – did better than those with access to few resources. However, farms raising the greatest variety of plants and animals could achieve similar, or sometimes greater levels of food security, dietary diversity, and incomes, as better resourced but less diverse farms.

Edited highlights

2022 was the start of a new era for precision breeding in the UK

New UK legislation – announced by DEFRA in January and in effect from April – removed much of the red tape around the research and development of improved crop varieties using precision breeding techniques such as CRISPR.

The new rules – which mean that genome edited, or GE, field trials will now no longer have to be run under GM regulations – are already making it much easier for scientists to do their research and test new GE varieties in the field.

In May, our farm staff notched up a UK first by sowing seeds of genetically edited camelina just weeks after the regulations were eased.

Under the previous rules, trial sites had to be specifically identified and permission sought from DEFRA following a detailed application procedure.

Under the post-Brexit non-GM classification for GE crops, plants can now be sown anywhere on Rothamsted's farm.

For the camelina trial, the approval process took just a few minutes as opposed to the months required under the older pre-Brexit regulations which lumped GM and GE crops together.

Rothamsted Research Director and Chief Executive, Professor Angela Karp called the easing of regulations very welcome news.

> **"It will significantly speed up our ability to test enhanced crops in the field. With the triple threats of climate change, a burgeoning human population, and widespread biodiversity loss hanging over us, the sooner we can get more resilient, more nutritious, nature-friendly crops to market the better."**

Her remarks were echoed by two the UK's leading GE experts.

> **"I am genuinely excited by the opportunities this shift in the classification of genome editing in plants will bring. I strongly believe that genome editing can contribute to making crops to be more nutritious, more sustainable and more resilient, and this change to how field trials are regulated is a welcome first step in liberalising how the UK regulates new genetic technologies like GE and GM. I look forward to being part of this exciting new chapter, one where the UK can better realise its potential as a world leader in plant biotechnology to deliver food security."**
>
> **Professor Johnathan Napier**

> **"Great news", and the "first positive step" in crop biotechnology regulation for two decades. "It will make it much easier for us to test the low acrylamide wheat lines we are developing in the field, which is essential if we are to find out if they could be suitable for wheat breeders to use. The possibility of low acrylamide wheat products being available to consumers in the future has moved one step closer."**
>
> **Professor Nigel Halford**

Plastic fantastic and a new turn on!

Green engineering feats tease potential of new gene tech.

Back in the lab, Professor Pete Eastmond and his team were making genetic breakthroughs of a different kind this year.

Firstly, they engineered camelina to produce a range of vital chemicals used in the manufacture of common everyday items, the majority of which are usually obtained from fossil fuels.

The class of chemicals – a group of molecules called 4-VPs (vinyl phenols) – are widely used in the manufacture of products such as food and make up – and even includes a plastic used in television and mobile phone screens.

The researchers inserted a gene into the camelina plants so they expressed a tailored bacterial enzyme in the developing seed. This redirected the plant's usual metabolic pathways so rather than producing sinapine from the chemical, hydroxycinammic acid, they instead produced the 4-VP molecules, either in a free form or attached to plant sugars.

Using crops to produce the raw materials for industry could reduce our reliance on petrochemicals, which would help the move to net zero, the study's lead author, Dr Guillaume Menard, said.

A few months later the team also announced they had found a way to switch on a dormant gene without inserting foreign DNA and creating a GMO, as would usually be the approach.

Demonstrating the concept in the model plant species, Arabidopsis, the team fused the promoter of a non-essential gene that's usually switched on in leaves, to a gene called DGAT2 that's involved in vegetable oil production and is normally switched off – resulting in leaves accumulating vegetable oil.

This is the first such demonstration using a gene editing 'deletion' approach in any organism, with previous methods not managing this feat in such a precise and predictable way. The hope is this technique could be adapted to a variety of situations where plant breeders want to turn genes on, rather than just turning them off, as is often needed for crop improvement.

> **"It's amazing just how many everyday products are made from, or contain, chemicals extracted from crude oil and its derivatives. We all know the issues around the continued extraction and use of fossil fuels, but turning plants into 'green factories' to make substitutes for these petrochemical compounds is a great sustainable alternative."**
>
> **Dr Guillaume Menard**

Stark reality

Climate change inevitably dominates when discussing current environmental issues, but this year, weather related events took us to a whole new level

All indications are that humanity is passing a threshold, where climate change goes from being an occasional inconvenience to the fatally disruptive norm scientists have long feared.

There was a time when record breaking heatwaves were an anomaly; a 50- or 100-year blip. Instead, long term forecasts suggest that 2022's high temperatures will be surpassed within just the next year or two.

Farming is clearly not blameless when it comes to carbon emissions, but it also suffers the consequences along with everyone else.

For example, a study of **long-term data from the famous Park Grass experiment** suggests that spring hay yields in southern England have already been reduced by more than a third due to changes to our climate. The study forecasts that climate change will reduce them by a further 20-50% between 2020 and 2080.

That's potentially devastating as managed grassland is the UK's largest crop by area at over 12 million hectares and underpins a livestock sector worth over £13 billion each year.

Whilst many would welcome the demise of the livestock industry due to its major contribution of climate changing emissions, another study from the year demonstrated things may not be that simple.

Nitrous oxide is roughly 300 times more potent that CO2 as a greenhouse gas, and fertilized soils are its major source. The gas also contributes to ozone depletion, and human-induced emissions of the gas have increased worldwide by 30% over the last forty years – mainly through an increased use of chemical fertilisers.

However, emissions from soil of nitrous oxide can be **drastically reduced** just by adding carbon-rich manure, the research shows, as doing so essentially 'locks-in' nitrogen as it is no longer turned into the gas by microbes such as fungi and bacteria.

> **"This means wider application of organic matter in arable systems has the potential to reduce nitrous oxide emissions and agriculture's contribution to climate change."**
>
> **Professor Andy Neal**

We should of course remember, it's not just the extreme temperatures – terrible as they are – that await us. Increasingly wet winters will also be a feature from now on and a Rothamsted paper on river water quality during one of the UK's wettest ever winters gave a glimpse of what is to come.

It showed a massive increase in agricultural pollution occurred within the upper catchment of Devon's River Taw during the winter of 2019/20, with the amount of soil washed off arable fields – and the associated environmental clean-up costs – **showing a twenty-fold increase on average**.

Large pulses of such sediment pollution harm both aquatic wildlife and drinking water quality, and sadly, are set to be more common in the future.

Researchers + Farmers = Climate Friendly Food

Rothamsted is a major partner in a new £13 million programme that will work with UK farmers to produce low carbon, environmentally friendly food.

The five-year project will find ways to balance the need to produce nutritious food with reducing greenhouse gas emissions and pollution, while at the same time enhancing biodiversity and soil health – an approach known as 'net zero+'.

AgZero+ will bring together researchers and farmers to test ideas – not just in a lab or a few fields – but across whole farms and farming regions.

The programme will utilise data from national sensor networks, satellites, and a network of commercial study farms and study catchments to help scale up the on-farm results. These will also be made available to the research community and other stakeholders to support their environmental planning and management.

Some of the 'smart farming' ideas being tested include targeted fertiliser application, nature-based solutions, such as agroforestry, and new innovations, such as how biochar can affect carbon storage.

Roth weather data for 2022

19th July was the hottest day ever recorded at Rothamsted (38.4 ºC)

The joint warmest year, with 2014, since our records began in 1878 – the overall mean for the year was 11.2 ºC (average is 10.2 ºC)

The second sunniest year recorded at Rothamsted since 1890 when sunshine recording began (after 2020) with 1912.5 hours of sunshine (259.9 hours above the annual average).

Note: The average refers to the 30 year means 1991–2020.

Insects on the move

Moth declines have uncertain cause – but 'moth motorways' could help them move north

Moth numbers have declined more in UK woodlands over the last half century than in any other habitat, according to a recent study.

A team of scientists led by Rothamsted Research found that populations have more than halved in broadleaf woodland, compared to average losses of 34% across the rest of the country.

Habitat loss, pesticides and urban light pollution have all been implicated in insect declines, but these results show the greatest losses are occurring in broadleaf woodland, a UK habitat type that in fact increased in area during the study period and is relatively shielded from the effects of chemical and light pollution.

The authors – who also looked at the possibility that over-grazing by deer and less woodland management might be responsible – say the reasons for the declines are still unknown, but climate change may play a role.

Meanwhile, moths struggling to move north to adapt to climate change in the UK could be assisted by pinpointing areas where habitat restoration can give them a smoother journey – so called 'moth motorways'.

A new study from Rothamsted with the University of Liverpool, Butterfly Conservation and the University of Reading combined data gathered in part from the Rothamsted Insect Survey with new computer simulations to predict the movement of different moth species in a changing climate.

The research, published in the journal *Global Change Biology*, revealed that some moth species were only moving northwards across certain British landscapes, putting them at greater risk.

Farmland and suburban moths in particular, which are crucial for both pollination and as food to support birds and bats, struggled to move across landscapes.

International activities

China & Europe

The Transformation for Sustainable Nutrient Supply and Management (TRANS4NUM) project, supported by Horizon Europe, will focus on nutrient management and will substantiate and promote nature-based innovations to support sustainable agriculture in Europe and China.

Brazil

A Rothamsted International Fellowship project, hosted by David Withall, is developing new control methods for Fall Armyworm using gene silencing and bespoke designed chemical inhibitors of key detoxification enzymes.

France

A project supported by the British Council and led by Dr Christophe Lambing, is working with the Centre National de la Recherche Scientifique to examine whether silencing/overexpression of genes in wheat and Arabidopsis can support the breeding of wheat varieties that have better resistance to stress.

Argentina

Supported by a Royal Society travel grant, Jozsef Vutz is collaborating with the Instituto Nacional de Tecnología Agropecuaria to exploit the insect gut microbiome as a novel sources of semiochemicals to develop push-pull (repel-attract) pest management systems for South American fruit flies.

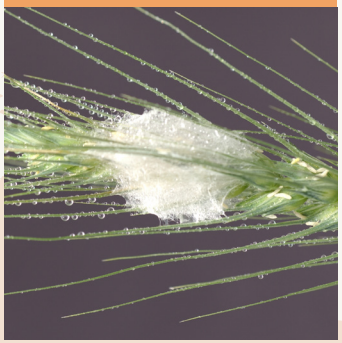
Southern Africa

CropGas is a unique collaboration between scientists in the EU and in Malawi, Zambia, Zimbabwe and South Africa to study the effect of conservation agriculture interventions on greenhouse gas emissions.

International activities

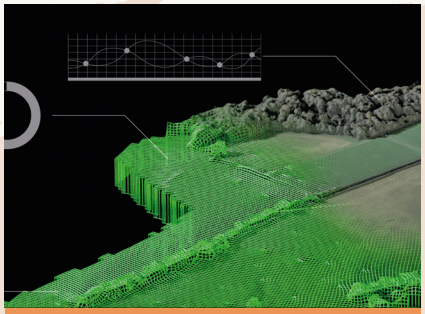
USA

Working with Indiana University and the US Department of Agriculture, Dr Kim Hammond-Kosack has begun a long-term project use genome editing to generate wheat and barley varieties with enhanced resistance to Fusarium.



Spain

Fred Beaudoin has begun a partnership with the Instituto de la Grasa, studying the synthesis of waxes in sunflowers to understand their relationship in the processing and quality of sunflower oil.



Europe

Rothamsted together with 70 other institutions is a partner in the Agroserv project which aims to deliver a European-wide data ecosystem of customised and integrated research and innovation services that will grow the agroecology research community and knowledge exchange.

Nigeria

Funded by the Stapledon Memorial Trust, Jordana Rivero Viera is working with the University of Jos to assess the impact of contrasting grazing management strategies on environmental outcomes and animal performance.

Saudi Arabia & UAE

Funded by the UK Government FCDO, Rothamsted is developing collaborative programmes of research and capacity building to provide a bridge between agri-tech researchers in the UK and the MENA Region.

Our year

As global travel re-opened post pandemic and the public flocked back to live events, we welcomed new overseas visitors and shared our science at multiple venues including Cereals 2022, Groundswell, The British Science Festival and New Scientist Live.

Clockwise from above

US Deputy Secretary of Agriculture, Dr Jewel Bronaugh visited the Harpenden site in June 2022

Harvest of GM Camelina field trial

Staff at the New Scientist Live Event in London

Dr Anneke Prins explored the history of wheat for the Linnean Society seminar, *Stories from Plant Collections*

Professor Angela Karp received an honorary degree from Cranfield University

Rothamsted celebrated 100 years of beekeeping with a special edition of our home produced honey

Dr Rob Dunn and filmmaker **Tom Law** survey a Silvopasture site in Devon

By the numbers

ROTHAMSTED RESEARCH

537
colleagues

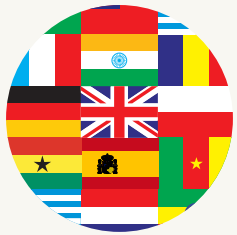
43%
female

57%
male

40
PhD students

63%
female

37%
male



48
countries

United Kingdom, France, Venezuela, Ireland, Slovakia, Australia, Hungary, Germany, China, Mexico, Malaysia, Spain, Italy, Netherlands, Pakistan, St Vincent and the Grenadines, Brazil, Uruguay, India, South Korea, Romania, United States, Nepal, Colombia, Peru, Portugal, Argentina, Uganda, Russia, Kenya, Thailand, Lithuania, Greece, Morocco, Nigeria, Denmark, Tunisia, Zimbabwe, South Africa, Guinea, Chile, New Zealand, Iran, Bangladesh, Taiwan, Poland, Malta, Ghana, Indonesia, Senegal, Ethiopia, Costa Rica, Cameroon, Philippines, Canada, Romania

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