UNIVERSITY OF BIRMINGHAM | BIFOR

BIRMINGHAM INSTITUTE OF FOREST RESEARCH (BIFoR)

Report: Jan 2021 / August 2021

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Introduction

This 'annual' report spans just 8 months (January 2021 – August 2021), so that we can start to report by academic year (i.e., September-August) instead of by calendar year. Turns out everything is a lot easier if we sync with the university calendar rather than with forest phenology!

After the huge influx of new staff last year (see Annual Report 2020), it seemed timely to update the BIFoR Vision. BIFoR will be *an internationally leading Institute that will address fundamental and interrelated challenges*:

1. The impact of global change on forest ecosystems
2. The resilience of trees to invasive pests and diseases
3. The importance of trees and forests to humans and non-humans

We have now organised our research in four key themes:

1. **Climate** - The impact of climate and environmental change on woodlands
2. **Health** - The resilience of trees to invasive pests and diseases
3. **Global** - big data approaches across space and deep time
4. **Interdisciplinary** - Understanding the wider importance of trees and forests to human and non-human actors

Progress under each of these themes is presented in the pages that follow.

To draw out only four of many highlights… The first scientific results from FACE are published (page 21) … BIFoR is involved in fully half of the six interdisciplinary projects sharing £10.5 million from UKRI in its *Future of UK Treescapes* Programme (page 22)… Prof. **Frank Uekötter's** *The Making of Monoculture: A Global History* received a £1.74M Advanced Grant from the European Research Council (page 22)… BIFoR will feature prominently until September 2022 in the University's *The Air We Breathe* exhibition in its new city-centre location, The Exchange (page 19).

COP26 is a major event in the world's calendar, BIFoR included. We have worked hard to put our research in front of decision-makers and the public. The institute contributed to no fewer than 10 of the 23 COP-focused essays published by the University (page 31). A new film of BIFoR FACE has been produced with thanks to PR company Spoke; an image of BIFoR FACE will form part of the exhibition 'Images of Research' by the Universities 21 network; art by Ben Wigley will feature; and BIFoR FACE and Amazon FACE will be presented by colleagues from the Met Office.

We hope that the following pages make clear our commitment to fundamental research that emerges from engagement with all quarters of civic society, and inspirational education that reaches out inclusively.

The BIFoR Directors

Rob Jackson
Rob MacKenzie
Jerry Pritchard
Nicola Spence
Sami Ullah

Climate: BIFoR FACE - The impact of climate and environmental change on woodlands

The 2021 growing season (April-November) is the fifth in which we have immersed 30-meter-wide plots of mature oak forest with elevated CO_2 concentrations. Operations and science have continued successfully, with due regard to the COVID 19 restrictions in place.

The FACE infrastructure has continued to perform excellently, delivering on-target elevated CO_2 concentrations.

A new, published, sample storage protocol, along with data storage and analysis workflows ensure that we maximise the added-value emerging from our experiments. Our thanks go to **Adam Kiani,** who carefully curated 6 years' worth of leaf litter samples, and to the Ecological Continuity Trust and a private donor for helping to make this happen.

Six new publications (page 32) include the first scientific results from BIFoR FACE: Gardner et al. in '*Tree Physiology*'. Photosynthetic uptake of CO_2 by oak trees under elevated CO_2 is enhanced by ~33% max. As this report goes to press, the article is generating considerable media interest.

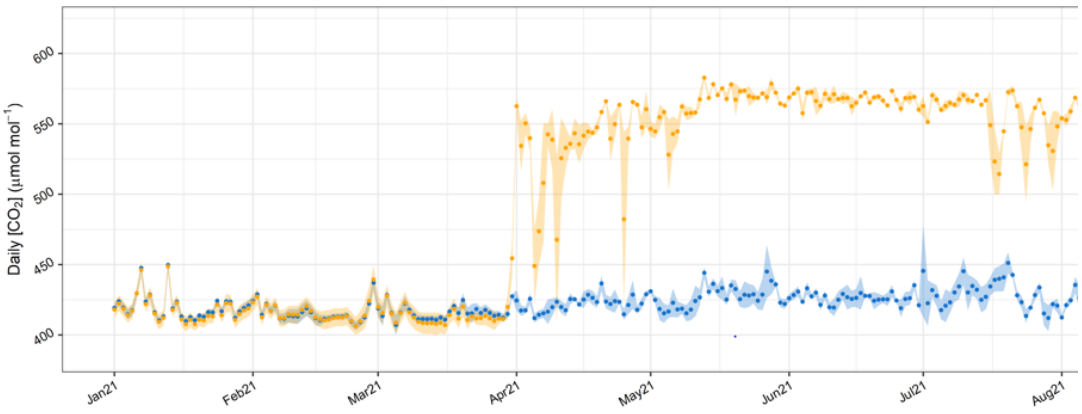
The NERC-funded QUINTUS project continues to **investigate** carbon and nutrient dynamics in our experimental temperate forest. Ably partnered by the Universities of Exeter, Bangor, and 10 other Institutes, the BIFoR team are focused on data gathering. This summer saw the first 1-metre cores taken for scientific analysis.

Closely integrated with QUINTUS, the NERC-funded FACE-Underground project investigates whether mature trees gain greater access to limiting nutrients in soils under eCO_2 and, if so, which strategies they employ. Prof. **Sami Ullah,** Dr **Michaela Reay** and **Iwan Evans** have worked tirelessly in difficult conditions. First results are not yet peer-reviewed but indications are that there has been: enhancement of and changes in the composition of root exudates; and changes to soil gross nitrogen mineralisation. Such changes pointing to important shifts in nutrient acquisition strategies of plants under eCO_2.

Pages 5 to 8 showcase just some of the research underway and the core measurements being taken. Our re-designed website showcases the breadth of research underway.

We are committed to communicating the science emerging from the FACE experiment. Our team have presented the early results from BIFoR FACE to national and international stakeholders (page 29). A recording of one of the presentations is available online. Details of some of our public engagement activity is included in page 19 with detailed information available in Appendix 3.

The BIFoR Annual meeting 2022 will have a session at which research from the three global FACE experiments set in mature forests (Amazon FACE, BIFoR FACE and EucFACE) will be presented.

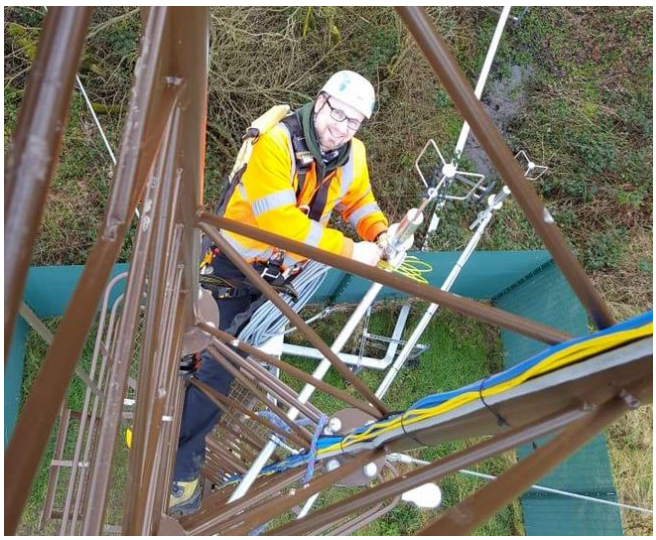


BIFoR FACE performance

BIFoR Professional Services Team

Once again, in 2021 our Professional Services staff have gone over and above to keep the facility running. They even found time to write an article for World Environment Day for the *Technicians Make it Happen* website (Part 1/ Part 2)

Research Technicians, **Gael Denny** and **Robert Grzesik** have worked tirelessly and flexibly throughout the pandemic. Gael has responsibility for collecting many of the core measurements at BIFoR FACE



In addition to keeping the CO_2 flowing the FACE Operations team Dr **Kris Hart, Peter Miles** (pictured) **Thomas Downes** and **Nick Harper** have taken excellent care of the instrumentation on the met masts and flux tower.

Atmospheric Processes Research

Example core measurements and images of some project specific measurements

- Wind speed
- Air temperature and relative humidity profile
- Solar and net radiation
- CO_2,H_2O,CH_4, fluxes

Senior FACE Engineer, **Nick Harper**, helps set up the Proton-transfer-reaction mass spectrometry (PTR-MS) for monitoring of volatile organic compounds (VOCs) released by the forest.

Laura James is investigating the impacts of ozone and elevated CO_2 on chemical communication networks. Pictured here are **Mark Raw** and Emma Platt who ably assisted Laura with Winter Moth pupa which will be grown to adulthood and used in her experiment.

Belowground research

This summer saw the first 1-metre cores taken from the FACE patches for scientific analysis. Over 80 kg of soil was meticulously sieved and sorted in order to make well over 3,000 measurements of root and soil properties.

Example core measurements and images of some project specific measurements

- Fine Root development
- Soil CO_2, H_2O Fluxes
- N mineralization and N_2O source partitioning
- lab analysis for nutrients (cations, anions), particle size distribution at least three times a year
- Leaf litter
- pH, soil type, organic matter content, CEC, bulk density
- Soil Sampling and Lab analysis
- Hyphal growth and turnover

Manon Rumeau soil labelling with ^{15}N isotopes. Manon is studying soil gross N transformation processes for her doctoral research.

Tubes ready to be inserted into the ground to allow images of fine roots to be captured - to measure root productivity. Our thanks go to the **Woodland Trust** (page 36) who have funded part of this research.

Forest hydrology

Example core measurements and images of some project specific measurements

- Throughfall precipitation (ground level
- Groundwater levels
- Field precipitation (ground level)

Sue Quick fits small Tranzflo compensated heat pulse probes to Hawthorn trees measuring xylem sap flows for her BIFoR FACE tree-soil-water relations research.

JABBS Foundation funded research project – Nutrient Uptake and GHG emission with **Andrea Rabbai** (pictured) & Prof. Stefan Krause - 80 vertical soil moisture probes have been installed across the different treatment zones. Roaming soil moisture surveys have been undertaken & quasi-3D soil moisture tomography of irrigated vs non-irrigated treatments have been created.

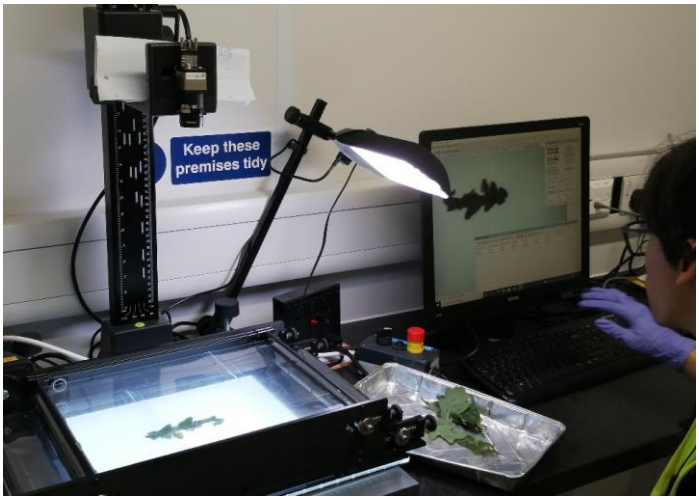
Aboveground measurements

Example core measurements and images of some project specific measurements

- Green chromatic coordinate (GCC) and red chromatic coordinate (RCC) – Phenocam
- Tree stem growt
- Tissue samples of leaves buds & catkins bio banked for future research
- Leaf Area measurements of green leaves
- Soil moisture (gravimetric and volumetric) & soil temperature
- Each tree is identified and given a number
- Leaf Area Index – both hemispherical and direct methods
- Phenology and biodiversity observations, including bryophyte, deadwood surveys
- Leaf litter traps – matter is separated into different categories including a 'woody material' archive and 'reproductive output' archive

Dr **Carolina Mayoral** working in the new woodland laboratory (right) - photosynthesis measurements.

New **JABBS Foundation**-funded, woodland laboratory with outdoor prep station and a first-floor office.



Volunteer **Drake Merrick** assists uses a new scanner to make measurements of leaf area.

Adam Kiani helped curate our leaf litter samples on campus. Adam was inspired to write a poem - '*Everyday I'm Rustling*'

Animals

- Camera traps are installed through the woodland

MIcrobial processes

- soil fungal metagenomics
- macrofungi surveys
- n-alkanes

New project - Katy Faulkner, CENTA PhD at Warwick University received a NERC Omics In-kind grant of £8,500 for the metagenomic characterization of soils exposed to flooding and elevated CO_2.

Research Collaborators at BIFoR FACE

BIFoR engages with more than 55 stakeholders. Throughout 2020/21 we have continued to work closely with national and international research collaborators, strengthening collaborations with:

- **Research institutions** - Amazon FACE, Centre for Ecology and Hydrology, CSIRO, Earthwatch Institute, EucFACE, Forest Research, Laboratoire des Sciences due Climate et de l'Environment (LSSCE), Met Office, Max Planck Institute for Biogeochemistry, National Centre for Atmospheric Research (NCAR), NIAB, and the Met Office.
- **Education stakeholders** – Universities of Bangor, Birmingham City, Bristol, California Davis, Exeter, Harper Adams, Helsinki, Imperial College London, Keele, Leicester Lancaster, Lund, Manchester, Munich, New South Wales (Australia) Plymouth, Reading, Southampton, Stafford, Swansea, Tennessee, Tianjin Normal University (China), Warwick, Western Sydney, Unicamp (Brazil) and the Open University.
- **Others** – the Ecological Continuity Trust, the Small Woods Association, the **STEAMHouse** art project **(**Clare Hewitt**),** the **British Bryological Society** and ArtDocs

Research Council funded collaborations:

QUINTUS (2018 -2024) - a £3.7m NERC funded large grant project, Quinquennial (half-decadal) carbon and nutrient dynamics in temperate forests: Implications for carbon sequestration in a high carbon dioxide world, led by Prof. **Rob MacKenzie** (University of Birmingham)

FACE Underground (2020 - 2023) - a standard NERC funded project. This project will use the FACE experiment to determine whether mature temperate forests will be able to access more soil nutrients under elevated carbon dioxide (eCO_2), led by Prof. **Sami Ullah** (University of Birmingham)

Disentangling mechanisms of co-adaption between trees and soil food webs in response to environmental perturbations (2019 - 2022) - a NERC funded project, led by Prof. **David Johnson** (University of Manchester)) in collaboration with Prof. **Rob MacKenzie** (University of Birmingham).

Above: Mathilde Chomel's (University of Manchester) harvest of leaf litterbags

Predicting the emergence of host-adapted bacterial phytopathogens (2020-2023) – a Bacterial Plant Diseases collaborative grant between Dr **Richard Harrison** (NIAB) and Prof.. **Rob Jackson** (University of Birmingham).

Distributed Real Time Soil (DiRTS) Monitoring (2020 - 2022) - a NSF-NERC funded project led by Prof. **Sami Ullah** (UoB) and involving the Universities of Keele and Tufts University.

NI: Network for Monitoring Canopy Temperature of Forests (netCTF) - a 2020 NERC funded project led by Dr **Sophie Fauset** (University of Plymouth). This project will increase the global network for infra-red monitoring of forest canopy temperatures (netCTF). *Image right: instrument ready to deploy at FACE*

UKRI Future of UK Treescapes call, MEMBRA – more details available on page 22.This project will have elements of research completed at the BIFoR FACE facility.

Health – The resilience of trees to invasive pests and diseases

We had several new staff commence in post in September 2020, they have quickly settled and adapted to the challenges of the COVID-19 restrictions including the world of online teaching (Prof. **Robert Jackson**, Dr **Florian Busch**, Dr **Megan McDonald**, Dr **Laura Graham**, Dr **Adriane Esquivel Muelbert**, and Dr **Mojgan Rabiey**). A Research Technician was appointed in 2021 (**Sophie Malkin**). Three new postdoctoral staff will start in September / October 2021 **Diana Vinchira** (metabolomics); **Sabrine Dhaouadi** (field pathology), **Olivia Mosley** (metagenomics and transcriptomics). In addition, five new doctoral researchers will also commence study next year; **Emily Grace**: oak bacteriophages, Biosciences - affiliated to **Action Oak**; **Katherine Hinton**: ash pathogens, Biosciences - affiliated to **Kew Gardens**; **Vanja Milenkovic**: soil and tree health, oak, Biosciences - affiliated to **Action Oak**; **Amy Webster**: cabbage tree disease on St Helena, Biosciences - affiliated to **St Helena Research Institute** & **CABI**; **Jiaqi Wei**: threat of *Xylella* on UK trees, Biosciences – affiliated to **Forest Research**).

Dr **Estrella Luna Diez** is Principal Investigator and Dr **Adriane Esquivel Muelbert** is CoInvestigator (Forest Ecology) for for a new £1.79m, Future of UK Treescapes, research project MEMBRA — exploring whether trees can remember past stress conditions such as drought or disease and transfer these memories to their descendants (see page 22). Recruitment of a new Research Associate and a postdoctoral researcher (Forest Ecology) will begin October 2022.

The new research project funded by Bacterial Plant Diseases call examining *Pseudomonas* bacterial pathogens of *Prunus* (Cherry Trees) with Dr **Mojgan Rabiey** and Prof. **Rob Jackson** is progressing. This collaboration with NIAB will examine how bacterial pathogens evolve on wild, ornamental and sweet cherry varieties and try to understand how we can improve management and control of these diseases.

The new Wolfson Advanced Glasshouses facility – kindly supported by the Wolfson Foundation – opened in May 2021. This facility will enable the plant pathologists and physiologists to carry out state-of-the-art experiments on trees, including provision of CO_2 fumigation.

Despite 2020's challenges due to the COVID-19 pandemic, colleagues in BIFoR have implemented robust health and safety procedures to ensure safe working practice, especially in the outdoor sites.

BIFoR continues to support the Action Oak (AO) initiative through a **JABBS Foundation** funded research project. As part of that project Dr **Thomas Welch** has developed a methodology for performing disease phenotype screening of oak seedling populations against AOD disease and Oak Powdery Mildew (OPM). Early results from these screens are similar to natural AOD infections in mature trees - the majority of oak seedlings are highly resistant to infection with AOD bacteria. Next, the team will investigate if oak seedlings collected from different UK tree provenances have varying susceptibility to AOD. Additionally, Dr **Rosa Sanchez-Lucas** has identified that a non-protein amino acid and a plant hormone result in enhanced protection against OPM. She has identified that the induced resistance observed is based on priming of two different defence responses, and has discovered an indication of a hormonal crosstalk of defence similar than those observed in other plant species.

Dr **Rosa Sanchez-Lucas** and Dr **Estrella Luna-Diez** have successfully run two day meetings with the members of the Priming in Trees consortium Dr Welch and Dr **Sanchez-Lucas** are currently preparing manuscripts based on data analysed during the COVID-19 pandemic. The team will be presenting work from the project at the **Our Plants Our Future Conference** to be held at UoB on 6-8 December 2021.

The virtual BIFoR annual meeting 2021 was well attended and had a focus on pest and disease. The proceedings for the meeting have also be been made available on our website.

A still image from a video with Prof. **Rob Jackson** and Dr **Mojgan Rabiey** *'Bacteriophages – a safe and natural alternative for treating cherry canker?'* Available on the Science Animated YouTube channel.

Dr **Rosa Sanchez Lucas, Mark Raw** and Dr **Estrella Luna Diez** sampling material from ash trees with different levels of ash dieback disease at the BIFoR FACE Facility.

Inside the new **Wolfson Advanced Glasshouses** facility. Offering state-of-the-art facilities for accelerating research into a wide range of areas including food security, sustainability and climate change. The Glasshouses connect colleagues working across biology, chemical sciences, ecology, water and atmospheric sciences.

Global – Big data approaches across space and deep time

BIFoR has been always doing research at global or continental scales and across different areas across the globe. Now these research areas are formalised into a separate theme: BIFoR Global.

This new theme includes research trying to understand the connection between trees and their environment at global and regional scales. The theme spans across several areas answering questions related to the life cycles of individual trees, large-scale biodiversity patterns, the effect of global change on forests, the links between the biosphere and atmosphere, the contribution of trees to the global carbon and methane cycles, and how forests fit within the broader land and climate systems. These areas of research allow us to put the experimental work led by BIFoR into a broader context.

January - September 2021 has seen 51 new publications related to this research theme (Appendix 4).

Nezha Acil, Dr **Tom Pugh** and Prof. **Jon Sadler** contributed to a response in *Nature* to a controversial paper on European forest harvest rates (**Palahai et a**l, 2021).

Prof. **Vincent Gauci** was co-author of a *Nature* paper which revealed that substantial cuts in global greenhouse gas emissions could be achieved by raising water levels in agricultural peatlands **(Evans et al**, 2021).

Dr **Jason Hilton** was co-author of a *PNAS* paper which had global media coverage under) the headline 'Pompeii of prehistoric plants' unlocks secret life of plants (Wang et al, 20210.

Dr **Adriane Esquivel Muelbert** was winner of the Forests 2020 Young Investigator Award and lead for the successful International Tree Mortality Webinar series. **Adriane** is also an author of the Science Panel for the Amazon.

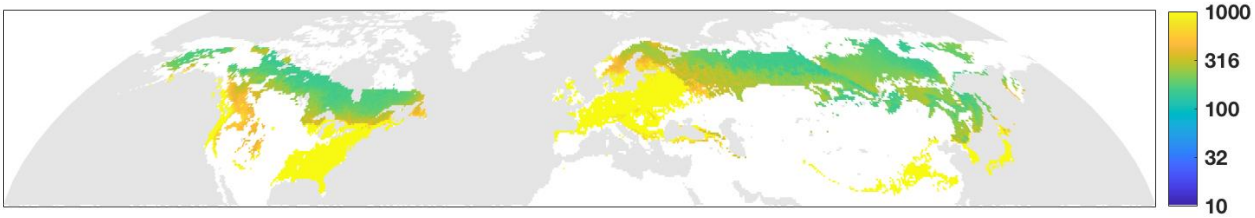
Researchers continue to communicate science results through seminars / conferences nationally and internationally and Dr **Adriane Esquivel Muelbert** and **Nezha Acil** presented at the BIFoR Annual meeting January 2021.

Tom Pugh gave a presentation on process uncertainty in global forest modelling and the implications for estimates of potential carbon sequestration at a workshop on 'Forest Dynamics in the Anthropocene', organised by the **Aspen Global Change Institute**.

Julen Astigarraga, a doctoral research student from Alcalá, visited BIFoR for 3 months to analyse how the performance of European and North American tree species varies across their ranges. He was hosted by Dr **Adriane Esquivel Muelbert** and Dr **Tom Pugh**.

Dr **Olanrewaju Olusoji Olujimi**, a FLAIR Research Fellow, African Academy of Sciences/ Royal Society UK, Federal University of Agriculture, Nigeria, completed a 3-month study visit in March, looking into air pollution from charcoal production.

The following page gives further details of some of our other global research but the best place for information is our updated website.



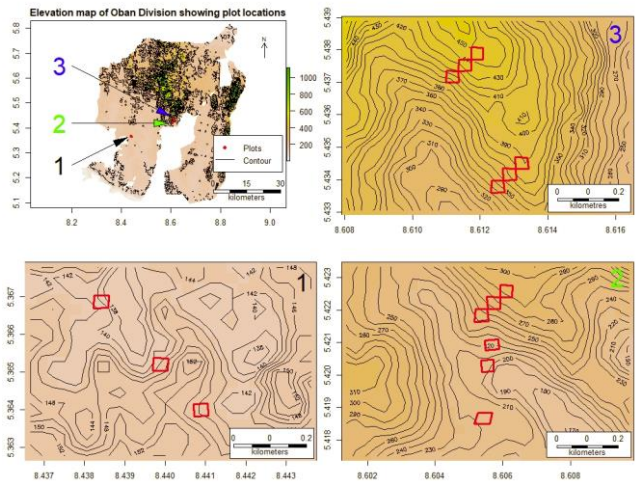
Estimated number of years between large forest disturbance events for natural forests in the absence of harvest, as simulated by the LPJ-GUESS model in a new study under preparation. Capability like this can help determine the climate mitigation potential of global forests.

Prof. **Vincent Gauci** out with a team of researchers monitoring emissions in a recently established beaver pond complex in the South Downs.

Dr **Josep Barber Ferrer** has been very busy with an intensive campaign of tree stem respiration measurements at the BIFoR FACE facility.

Dr **Adriane Esquivel-Muelbert** measuring trees in Central Amazon to understand the impacts of the 2015-16 El Niño drought

Dr **Marie Arnaud** in a Vietnamese mangrove forest (**Arnaud, M., 2021** - Capturing coastal wetland root dynamics with underground time-lapse)



Sijeh Asuk - 15 permanent 40m by 40m sample plots established at the Oban Division of Cross River National Park, Nigeria. In 2020, we began monitoring the phenology of trees in these plots.

Our team are part of ForestPlots which brings together over 2500 researchers working to transform scientific understanding of tropical forests- image above is a snapshot from ForestPlots new video

Interdisciplinary Research - Understand the wider importance of trees and forests to human and non-human actors

Interdisciplinary research resists neat compartmentalisation, but can be broadly separated into the following areas:

- Economics and Sustainable Development
- Forest Hydrology including Ecosystem Engineering
- Cultural Research including Environmental History & Literature and Ecocriticism
- Green Infrastructure and the Urban Forest
- Health and Wellbeing
- Human Geography
- Mathematics of the Forest

The BIFoR website has recently been updated, signposting visitors to the varied research underway and the academics involved.

The announcement of the successful **Future of UK Treescapes** awards (page 22) will greatly increase our interdisciplinary research; this £12.5M interdisciplinary programme is led by **UKRI-NERC** and jointly funded with the **Arts & Humanities Research Council** (UKRI-AHRC) and the **Economic & Social Research Council** (UKRI-ESRC).

Prof. **Frank Uekötte**r - working on environmental issues, both past and present, in a global context – recently received a prestigious Advanced Grant from the European Research Council of £1.74M (€2M) for his project, The Making of Monoculture: A Global History.

The research of Dr **James Levine** and Prof. **Rob MacKenzie** looks at how green infrastructure can provide effective barriers to pollution from vehicles, markedly reducing the public's exposure at the roadside. New software developed through the NERC funded Green Infrastructure for Roadside Air Quality (GI4RAQ) Platform project was launched in July 2021. The free software helps towns and cities use street-planting to reduce citizens' exposure to air pollution.

BIFoR's Dr **Emma Ferranti**, is Chair of the West Midlands Trees Design and Action Group (TDAG) and has led on the third of a successful "**First Steps**" series of publications: First steps in Air Quality for Built Environment Practitioners; First steps in Valuing Trees and Green Infrastructure'; and now 'First Steps in Urban Heat'.

Prof. **Dominique Moran** and Dr **Phil Jones** published results of their study which showed that increasing exposure to green space in prisons can reduce self-harm and violence.

Dr **Josh Larsen** was co-author on a comprehensive review of beaver impacts on the hydrology, geomorphology, biogeochemistry and ecosystems of river corridors systems.

Dr **John Holmes** & **Dion Dobrzynski** wrote an article about the role of the arts and humanities in tackling the climate crisis.

Our interdisciplinary research is strengthened greatly through the Leverhulme Trust Funded, Forest Edge Doctoral Scholarship Programme. We have recruited 16 postgraduate students in the first three years (pages 16 -18), students marked with the * symbol are part of the Forest Edge DSP) and September / October will see a further 2 students commence (**Gemma Baker**: animal-forest trophic interactions, GEES **Kieran Clarke**: Rapid Engineered Spectroscopic Technology (FoRESTech) for Identification of Filamentous Pathogens in Leaves, Chemical Engineering).

Education

Our thriving community networks through weekly science seminars and a fortnightly journal club run by a postdoctoral research fellows Dr **Josep Barba Ferrer** (GEES) and **Dr Carolina Mayoral** (Biosciences).

The new intake of PhD students due to start next academic year will take the total number of doctoral researchers to 47, with 6 graduated. The research topics cover a wide selection of forested landscape research.

Congratulations!

Very many congratulations to the BIFoR core funded students Dr **Liam Crowley,** Dr **Angeliki Kourmouli** and Dr **Clare Ziegler** who have all submitted and passed their PhDs! Also our congratulations go to **Alfred Bockarie** and **Anthony Hyacinth** who submitted their theses in 2021 and **Eszter Toth** set to submit in early October 2021.

Our Leverhulme-funded Forest Edge Doctoral Scholarship Programme has enabled the broad training of new postgraduate doctoral researchers in forestry and related areas over a broad set of disciplines. We aim to continue the legacy of this DSP via acquiring new funding that supports the training of new early career researchers.

We're proud of the 19 Undergraduate and Masters students, who despite the many disruptions, produced some very interesting dissertations and took part in summer placements in relation to BIFoR FACE data/samples.

The development of forest sciences teaching resources can be considered to have a three pronged approach

- Undergraduate teaching
- A level, GCSE and Key Stage 3
- Outreach

A new website which host these educational resources is available at https://canvas.bham.ac.uk/courses/52405 with thanks to the team at the Higher Education Futures Institute (HEFi).

Progress is being made on a joint project with the Forestry Commission and the Forestry Skills Forum, to map where in the curriculum it is possible to include teaching and learning about British trees and Forestry.

We have had two new undergraduate/master's degree programmes approved that will incorporate BIFoR colleagues research and teaching: MSci Human Sciences and MSci Global Environmental Change and Sustainability

A larger 'Education Working Group' has come together to help push forward with our ambition to weave teaching material with state of the art digital delivery to provide a live, research-rich, distance learning experience for pupils across the UK. Plans are afoot to develop full lesson plans for the 3 educational resources that have already been developed in collaboration with the University Birmingham [High] School:

i) transpiration using sap flow information taken from instruments installed in the BIFoR FACE woodland

ii) plant cell organisation / photosynthetic reaction / how plants use glucose using measurements of tree growth from dendrometers installed in the BIFoR FACE woodland

iii) infection and response in particular the fungal disease *Rose black spot* using images of sycamore leaves collected from the leaf litter traps at the BIFoR FACE woodland.

Volunteering with BIFoR in the early part of 2021, naturally became more difficult in relation to COVID-19. However, in the academic year 2020/21 we still recorded **613 hours of volunteering** bringing the total to just under 3,600 hours - the equivalent of employing a full time technician for almost 100 weeks!

The following pages show the breadth of doctoral research underway and the large number of supervisors both internal and external to the University.

New doctoral research

We welcomed 8 new PhD students in 2020 and in 2021 we are delighted to share a further 11 students will commence (details below). The * symbol denotes these students are part of the Forest Edge Doctoral Scholarship Programme. The ^ symbol denotes students will carry out their research at BIFoR FACE.

^Alex Armstrong - Effects of atmospheric Nitrogen pollution on Soil Carbon Storage and Greenhouse Gas Emission from Forests Soils. Reactive forms of aerially derived nitrogen deposition sourced from agriculture are often scavenged by tree's and deposited within woodland systems. Understanding how enhanced rates of nitrogen deposition impact woodland soil with regard to soil organic carbon decomposition, microbial activity and the release of nitrous oxide and carbon dioxide is required to understand how our woodlands and their soils can be conserved and their provisions preserved. Supervised by Prof**. Sami Ullah** (GEES) and Dr **Liz Hamilton** (GEES)
***Gemma Baker**– Life on the edge: New tools to track animal-forest trophic interaction across intact to degraded ecosystems. Madagascar is a haven of floral and faunal endemism, with lemurs at the centre of engineering and maintaining the diverse and varied forest habitats the island comprises. There is no such thing as a healthy Malagasy forest without the endemic lemur communities. Forest degradation and loss of lemur communities form a destructive positive feedback loop, causing the loss of large fruiting trees and a shift in forest composition to smaller faster-growing trees less efficient at carbon sequestration. Forest health and function can be monitored through the tracking of changes in the diets of inhabitant lemurs, especially in edge habitats where they are forced to adapt to ongoing changes in resources as a result of degradation. This project aims to use biomarkers, tools used primarily in organic geochemistry for palaeoclimate reconstruction, to investigate the diets of lemurs from faeces, with the aim of developing these techniques to be applied to wild lemurs in the future to monitor forestry changes and forest-lemur interactions. Supervised by Dr **Sarah Greene** (GEES), Dr **James Bendle** (GEES) and **Lydia Greene** (Duke Lemur Centre, Duke University
***Kieran Clark** - Study and Fabrication of Rapid Engineered Spectroscopic Technology (FoRESTech) for Identification of Filamentous Pathogens in Leaves. Ash dieback and oak powdery mildew are devastating pathogens, especially for young trees, and there are currently insufficient techniques to diagnose these infections in the early stages. My project aims to use the non-destructive, versatile analytical technique called Raman spectroscopy to probe the biomolecular changes that occur in the wax and cuticle layers of the leaves of Ash and Oak trees during the course of these infections. The primary goal of the project will be to provide insights into the disease mechanisms of both ash dieback and oak powdery mildew, and then design a handheld Raman spectrometer to allow in-field testing and monitoring of these diseases. Additionally, a study into the effect of elevated carbon dioxide on these disease models will take place such that the device can be used in the BIFoR FACE facility following development. Supervised by Prof. **Pola Goldberg Oppenheimer** (Chem Eng) and Dr **Estrella Luna Diez** (Bio)
Emily Grace: commences Sept/Oct 2021 (oak bacteriophages, Action Oak more details to follow)
^William Hagan Brown - Climate Change Impacts on Forest Canopy Temperatures: From Mechanisms to Implications. Using thermal imagery to capture leaf temperature, and a range of complementary measurements of leaf traits, William will study leaf energy balance for different species in different forests throughout the world, including looking at the effect of elevated CO_2 in BIFoR FACE. Supervised by Dr **Sophie Fauset** (Uni Plymouth), Prof **Ralph Fyfe** (Uni Plymouth), Prof **Emanuel Gloor** (Uni Leeds), and Prof **Rob MacKenzie** (BIFoR).
Katherine Hinton - Examining risk of new disease outbreaks in a diseased population using ash as a model. *Pseudomonas savastanoi pv. fraxinii* causes canker disease in ash trees, and although it is widespread in the UK, the severity of the disease is relatively low. Why this is the case is not understood and there could be potential for severity to increase in trees weakened by other diseases like ash dieback or pest attack like Emerald Ash Borer. This project therefore aims to develop new tools to study this pathosystem and examine whether there is any potential threat of bacterial disease outbreaks in ash. Supervised by Prof. **Robert Jackson** (Bio) Dr **Megan McDonald** (Bio), Prof. **Richard Buggs** (Kew Gardens)
***Fatima Khan** – Tree water istopes at the BIFoR FACE facility. Supervised by Joshual Larsen (GEES)
Yanzhi Lu - The potential of urban trees to remove air pollutants, carbon and heat: a large-scale analysis based on Google Street View. As an important urban green infrastructure, street trees can provide multiple ecosystem services and benefits. My research project aims to quantify the various environmental

benefits of street trees in Birmingham (including air pollutant removal, carbon sequestration urban heat island reduction, etc.), and to explore to what extent different factors of urban areas (especially social and economic factors) in urban areas can influence the spatial distribution of these benefits. As a measure for achieving the research aim, this project will also develop new methods for tree evaluation based on innovative technologies (especially Google Street View), and explore the potential of Google Street View in urban green infrastructure research and ecosystem service evaluation. Supervised by Dr **Christian Pfrang** (GEES), Dr **Emma Ferranti** (Chemical Engineering), Prof **Lee Chapman** (GEES)

Vanja Milenkovic - Examining the impact of soil on tree health and disease progression. Soil around plant roots (rhizosphere) is critical to plant health and biotic and abiotic stresses in the tree rhizosphere may cause tree health to drop and make them more prone to disease. Previous work in the PuRpOsE project on protecting oak ecosystems has indicated that trees with acute oak decline may be pre-disposed to disease due to water fluctuations in the root system. This project aims to examine soil properties around diseased and healthy trees with a view to alleviating the stress. This project will work in concert with a PDRF to develop an experimental design to look at what changes occur in trees living in different soil environments. This should involve a study of tree changes (traits and internal metabolome and biochemistry) as well as monitor pathogen population changes and performance. Together, these experiments will allow us to understand how soil influences tree health and enable us to develop policy advice for this. Supervised by Prof. **Robert Jackson** (Bio), Prof. **Vincent Gauci** (GEES)

Nigar Parvin: commenced March 2021 studing green infrastructure. Supervised by Dr **Emma Ferranti** (Chemical Engineering)

Amy Webster - A study of tree disease on the Island of St Helena. The invasion of non-native species to remote environments can lead to a chain of detrimental reactions. The island St Helena is subject to such problems, where an unknown pathogenic species is leading to a significant decline in the native cabbage trees on the island. Without these trees, the island's cloud forests will diminish, and no longer support a hotspot for biodiversity. By exploring the microbe community surrounding the trees, soil and neighboring plants, disease causing agents may be uncovered and with it, a management plan established for the conservation of this unique ecosystem. Supervised by Prof. **Rob Jackson.**

Jiaqi Wei - Evaluating the threat of Xylella on UK trees. *Xylella fastidiosa* is a bacterium that is endemic to central America. It is an established pathogen in the US and is a recently emerging pathogen causing devastating disease in southern Europe. Presently, they are limited to Italy, Portugal, Spain and France, but detection of infected plants has been found in other countries in Europe triggering control and eradication procedures. Tree species like ash and oak have also been observed with *Xylella* infections in Europe, highlighting the wide host range of the pathogen. There is considerable concern around the potential threat to the UK's horticulture and ecosystem, particularly to trees, should *Xylella* establish in the country and thus it is important that investment is made to fully understand the threat the pathogen poses. This will help with identifying the potential hosts for the pathogen and whether any resistance exists in the plant population. It will also help with identification and monitoring as well as considering the risk of widespread disease spread. Supervised by Prof. **Robert Jackson** (Bio) and Dr **Graeme Kettles** (Bio).

Forest Edge students **Nine Douwes Dekker**, **Ben Howard** and **Jenny Knight** stepped up to help organise the Treescapes 2021 conference. They joined a team of other doctoral researchers from the Doctoral Training Programmes CENTA and Envision.

The conference was praised for its organisation and ambition to bring the research and practitioner community together. Not only did they help organise the conference but they all presented too and Nine was a panel member!(pages 20 & 29)

- **Anna Gardner** and **Jenny Knight** both secured a placement with the Welsh Government to carry out short-term policy placements in support of the delivery of the Woodlands in Wales strategy. **Jenny** is now a member of the Advisory Panel - Trees and Timber Deep Dive.
- **Aileen Baird**, is now Lead Adviser on Tree Action Plan Delivery at **Natural England**. She plans to submit her thesis early 2022.
- **Liam Crowley** has gone on to work for the University of Oxford, Wytham Genome project, part of the Darwin Tree of Life Platform.
- **Eszter Toth** will be the first Forest Edge student to submit a thesis. Eszter has gained employment at Nottingham Trent University.

Continuing doctoral research

- **Nezha Acil -** global forest dynamics – storm related tree mortality and its influence on global forest cycling. Supervised by Dr **Tom Pugh** (GEES) and Prof. **Jon Sadler** (GEES)
- **Sijeh Asuk -** Population ecology and phenological responses of food-producing forest trees to climate change: implications for rural food security. Supervised by Dr **Tom Pugh** (GEES), Prof. **Nick Kettridge** (GEES) & Prof. **Jon Sadler** (GEES)
- **^Aileen Baird -** Fungal biodiversity. Supervised by Prof. **Francis Pope** (GEES) & Prof. **Robin May** (Bio) Poster 2021
- **^Ed Bannister -** environmental aerodynamics of the BIFoR FACE site. Supervised by Dr **Xiaoming Cai** (GEES) and Prof. **Rob MacKenzie** (GEES)
- **Hector Camargo Alvarez -** describe and model the deleterious effect of ozone pollution on cereal production and its economic consequences in China. Supervised by Dr **Tom Pugh** (GEES)
- ***Harriet Croome** - understanding how elephant behaviours have changed with wildlife conservation initiatives in Mukogodo Forest. Supervised by Dr **Brock Bersaglio** (International Development Department (IDD)), Prof. **Fiona Nunan** (IDD) Poster 2021
- **^Liam Crowley -** Insects as key drivers of change in woodland systems under climate change. supervised by Dr **Scott Hayward** (Bio), Prof. **Jeremy Pritchard** (Bio) and Prof. **Jon Sadler** (GEES) Poster 2021
- ***Bradly Deeley** – Mathematics of biological invasion of plant species poses a major threat both to the ecosystem and the economy. Supervised by Dr **Natalia Petrovskaya** (EPS) and Dr **Rosemary Dyson** Poster 2021
- ***Dion Dobrzynski**, Forest Ecology in Fantasy Fiction: Mobilising the Imaginative Resources of Fantasy Fiction for Living with Forests. Supervised by Prof. **John Holmes** (English), Prof. **Jon Sadler** (GEES) and Dr **Will Tattersdill** (English) Poster 2021
- ***^Nine Douwes Dekker** – Greenhouse gas emissions from soils under elevated CO_2. Supervised by Prof. **Sami Ullah** (GEES)**,** Prof. **Vincent Gauci** (GEES) & Prof. **Rob MacKenzie** (GEES) Poster 2021
- **^Katy Faulkner** - **l**ooking at the resistance and resilience of forest soil microbial communities and greenhouse gas emission to extreme weather events and a high CO_2 world. Supervised by Prof. **Gary Bending** (Warwick) and Prof. **Sami Ullah** (GEES) Poster 2021
- **^Anna Gardner -** Leaf physiology under elevated CO_2. Supervised by Prof. **Rob MacKenzie** (GEES), Prof. **David Ellsworth** (WSU) and Prof. **Jerry Pritchard** (Bio) Poster 2021
- **Lavinia Georgescu -** Machine learning to find patterns and relationships regarding droughts and forests at a biogeographical level. Supervised by Dr **Tom Pugh** (GEES)
- **^Richard Hill,** Cotutelle/Dual Award based initially at EucFACE, Western Sydney University. Supervised by Dr **Jonathan Plett** and Dr **Graeme Kettles** (Bio)
- ***^Ben Howard,** Coppice management to reduce nutrient loads in forest streams. Supervised by Prof. **Stefan Krause** (GEES), Prof. **Nick Kettridge** (GEES), Prof. **Sami Ullah** (GEES) and **Ian Baker** (Small Woods) Poster 2021
- **Dr Anthony Hyacinth -** Plant volatile compounds under elevated CO_2. Supervised by Prof. **Rob MacKenzie** (GEES) and Prof. **Francis Pope** (GEES)
- ***^Laura James** – 'Talking' trees; the impacts of ozone and elevated CO_2 on chemical communication networks. Supervised by Dr **Christian Pfrang** (GEES), Dr **Robbie Girling** (Reading) and Prof. **Rob MacKenzie** Poster 2021

- ***Polly Jarman -** Young people's experiences of and learning in urban woodlands. Supervised by Prof. **Peter Kraftl** (GEES) and Dr **Sophie Hadfield-Hill** (GEES)
- ***Jordan Johnston** - Understanding how forest ecosystems react and recover in the wake of a destructive event. Supervisors: Dr **Seb Watt** (GEES), Dr **Tom Pugh** (GEES), Dr **Tom Matthews** (GEES) and Susanna Ebmeier (Leeds) Poster 2021
- ***Thomas Kaye** - 'The Forestry of Writing.' Supervised by Prof. **Alexandra Harris** (English), **Dr Matthew Ward** (English) Poster 2021
- ***Jennifer Knight,** Exploring the desirability of forest landscapes in a natural flood management context. Supervised by Dr **Steve Emery** (GEES) and Dr **Simon Dixon** (GEES)
- **^Thomas King,** based at Lancaster University: Ecophysiology of plant volatiles under elevated carbon dioxide. Supervised by Dr **Kirsti Ashworth** (Lancaster) and Prof. **Rob MacKenzie** (GEES)
- **^Angeliki Kourmouli** - Soil respiration & biogeochemistry at BIFoR FACE – supervised by Dr **Rebecca Bartlett** (GEES), Dr **Liz Hamilton**(GEES), Prof. **Iain Hartley** (Exeter University) & Dr **Zongbo Shi**
- **Aleksandra Kulawska -** On thin ice: predicting the effects of future permafrost thaw on boreal forest ecosystems. Supervised by Dr **Thomas Pugh** (GEES), Dr **Nick Kettridge** (GEES)**,** Prof. **Rob MacKenzie** (GEES) & Prof. **Sami Ullah** (GEES)
- **^Sophie Mills** – The effect of elevated CO_2 on primary biological aerosol (bioaerosol) production, in particular pollen and fungal spores, in woodlands. Supervised by Prof. **Francis Pope** (GEES) and Prof. **Rob MacKenzie** (GEES) Poster 2021
- **^Sue Quick -** Tree-soil-water relations under elevated CO_2. Supervised by Prof. **Stefan Krause** (GEES) and Prof. Rob **MacKenzie** (GEES) Poster 2021
- *^**Mark Raw** - Priming of defence in an elevated CO_2 world. Supervised by Dr **Estrella Luna Diez** (Bio) and Dr **Scott Hayward** (Bio) Poster 21
- **Andrea Rabbai** - Trends in soil moisture and temperature dynamics in juvenile forests align to those of mature forest from the time of canopy closure. Supervised by Prof. **Stefan Krause** (GEES), Prof. **Nicholas Kettridge** (GEES) and Prof. **Sami Ullah** (GEES) Poster 2021
- **^Manon Rumeau -** Exploring the effects of elevated CO_2 on free living N fixation as well as on other N cycle processes. Supervised by Prof. **Sami Ullah** (GEES) & Prof. **Rob MacKenzie** (GEES) Poster 2021
- ***Bruno Santos** - Wastewater treatment trees: can forests filter helps solve our wastewater crisis? Supervised by Prof. **Philip Davies** (School of Engineering) and Dr **Joshua Larsen** (GEES) Poster 2021
- ***Maria Teresa Gonzalez Valencia -** Using satellite and house price data our research will identify the size and persistence of the impact of pure information effect on the perception of forest fire risk. Supervised by Prof. **David Maddison** and Dr **Alan Beltran Hernandez** Poster 2021
- ***Eszter Toth -** Focus on Cognition: Can forests balance the brain? Supervised by Dr **Ali Mazaheri** (Psychology) and Prof. **Jane Raymond** (Psychology)
- *^**Klaske van Wijngaarden** - Woody carbon dynamics of the trees at the BIFoR FACE and eucFACE experiments. Supervised by Dr **Tom Pugh** (GEES), Dr **Josh Larsen** (GEES), Prof. **Ben Smith** (Western Sydney University (WSU) Prof. **Belinda Medlyn** (WSU) Poster 2021
- ***^Bridget Warren -** Development and application of novel ecological and environmental proxies based leaf wax lipids. Supervised by Dr **James Bendle** (GEES) and Dr **Florian Busch** (Bio) Poster 2021
- **Joe Wayman -** Biodiversity-climate interactions, looking at a variety of sites across the tropics. Supervised by Dr **Thomas Pugh** (GEES) and **Thomas Matthews** (GEES)
- **^Clare Ziegler -** Quantitative modelling of root growth and carbon allocation bridging theory and experiment. Supervised by Dr **Iain Johnston** and Dr **Rosemary** Dyson (Maths)

Strategic Stakeholder Engagement

In January, we announced the appointment of **Jonathan Drori** as Honorary Professor of science communication. This appointment reflects our ambition to shape and communicate our world-leading research to a wide range of audiences.

The University of Birmingham is committed to engagement across civil society and BIFoR participates enthusiastically in this. BIFoR Director and Defra Chief Plant Health Officer, Prof. **Nicola Spence**, advises the BIFoR team on effective engagement with policy-making.

Accompanying publication of the England Trees Action Plan in May 2021, Prof. **Rob MacKenzie** was invited to Chair the Trees and Woodlands Science Advisory Working Group (TaW-SaG). Prof. **Rob Jackson** is a member of the group updating the UK Forestry Standard. Dr **Emma Ferranti** has joined the West Midlands Forests and Woodlands Advisory Committee (WM FWAC) and the FWAC Urban Forest Network and Prof. **Sami Ullah** continues on the Nutrient Management Expert Group at Defra. Dr **Josh Larsen** has been appointed to the independent scientific advisory panel of the UK Beaver Trust. Prof. **Christine Foyer** and colleagues submitted evidence to parliament's Environment, Food and Rural Affairs (EFRA) Committee and were called by the National Audit Office to provide evidence for the NAO assessment of the Nature for Climate Fund. Doctoral student **Jenny Knight** is a member of the Advisory Panel for the Welsh Government Trees and Timber Deep Dive.

COP26 is a major event in the world's calendar. The institute contributed to; no fewer than 10 of the essays published by the university to put its knowledge in front of decision-makers (page 31); a new film of BIFoR FACE is being produced with thanks to PR company Spoke; art by **Ben Wrigley** will feature in a Green Zone exhibition on the Nature presidency theme day; BIFoR FACE and Amazon FACE will be presented by colleagues from the Met Office; two BIFoR research related images will form part of the exhibition 'Images of Research' by the Universities 21 network i) BIFoR FACE and a ii) forest ecology and fantasy fiction research project with Dr **John Holmes** and **Dion Dobrzynski.**

BIFoR FACE research is included in the following public spaces:

- The inaugural exhibition -'The Air We Breathe' - at the University of Birmingham's newly refurbished city-centre building — The Exchange until September 2022.
- The British Science Museum - Our Future Planet
- The Thinktank - Our Changing Planet exhibition

We continue to refresh the BIFoR webpages and January – August we received over 20,914 views. The BIFoR newsletter circulation outside of the University of Birmingham consistently exceeds 1,000 people. The newsletter is produced twice a year – spring and autumn. Previous versions of the newsletter are available.

The number of followers on Twitter has increased by 474 in the past 6 months and there were an average of 54,625 Twitter impressions per month.

BIFoR's reputation in forest sciences is growing. Conferences in 2021 have been mainly online.

Our own online BIFoR Annual Meeting took place on 27 and 28 January 2021. We had 335 registrations with many more international delegates thanks to the accessibility of online conferences. The posters and (most) presentations are available online.

Our next annual meeting - ***Transforming our understanding of global forests*** (6th annual BIFoR Community Meeting) will be a major meeting of the world's leading researchers in this area.

BIFoR are co-organisers of a large hybrid conference, coinciding with COP26 in early November 2021 – Trees for the Future.

Other 2021 highlights include the summer Treescapes 2021 conference. This conference was led by doctoral students from Forest Edge, CENTA and Envision with support from BIFoR and the Royal Forestry Society. Below is an example of one of the outputs by science communications artist Holly McKelvey.

+40,000 views of the Virtual BIFoR tour

20,914 views on the website

54,625 average monthly twitter impressions

7,967 views of the BIFoR introductory video

2,676 followers on twitter

+1,800 estimated total number of visitors to the BIFoR FACE facility

BIFoR FACE research in the vault of **The Exchange**, Birmingham City centre

One of 5 items on display at the Our Future Planet exhibition at the **British Science Museum** – soil respiration kit damaged during a storm

BIFoR Volunteer **Halimah Begum** represents BIFoR at campus based event

BIFoR FACE research featured at the Thinktank Birmingham

Outputs

The 8 months of January 2021 to August 2021 saw 11 journal articles published in the first-rank of general science journals (i.e., the *Nature* family, *Science*, PNAS). A full list of papers (n=78) can be found in Appendix 4 Two research highlights are summarised below:

Old Oaks New Tricks
by **Anna Gardner**

The first substantive science results from the BIFoR FACE facility have been published in *Tree Physiology*. The research shows mature oak trees will increase their rate of photosynthesis by up to a third in response to the raised CO_2 levels expected to be the world average by about 2050. Our research team are measuring leaves, wood, roots, and soil to find out where the extra carbon captured ends up and for how long it stays locked up in the forest.

Gardner A., Ellsworth D.S., Crous K.Y., **Pritchard J**. and **MacKenzie A.R.** (2021). Is photosynthetic enhancement sustained through three years of elevated CO_2 exposure in 175-year old Quercus robur? *Tree Physiology,* **https://doi.org/10.1093/treephys/tpab090**
Details of more FACE publications can be found in Appendix 4) including:
Baird, A.B., et al (2021) Bioaerosols **https://doi.org/10.5194/bg-2021-162**
Crowley, L.M. et al (2021) Entomology **https://doi.org/10.3390/insects12060512**
Bannister, E. et al (2021) Wind flow through a forest – **https://doi.org/10.5194/bg-2021-162** (preprint)

VIROPLANT (Virome NGS analysis of pests and pathogens for plant protection)
by **Mojgan Rabiey** and **Rob Jackson**

As part of the EU-funded VIROPLANT project, Dr **Mojgan Rabiey** and Prof. **Rob Jackson** isolated and characterised bacteriophages (virus that kills bacteria) to examine their use as a potential biological control of bacterial canker of cherry. The bacteriophages had a specific host range, able to lyse strains of *Pseudomonas syringae* pv. *syringae* and *P. syringae* pv. *morsprunorum*, causative agents of cherry canker. Application of the phage could effectively reduce bacterial disease progression and infectivity in vitro and in different plant systems, with no effect on beneficial bacteria. Genome sequencing revealed some of these bacteriophage were new discoveries and did not carry toxins, indicating their use as an environmentally friendly biocontrol agent in cherry industry and in agriculture.

Rabiey, M., Roy, S. R., Holtappels, D., Franceschetti, L., Quilty, B. J., Creeth, R., . . . **Jackson, R.** W. (2020). Phage biocontrol to combat Pseudomonas syringae pathogens causing disease in cherry. Microbial Biotechnology, 13(5), 1428-1445. doi:https://doi.org/10.1111/1751-7915.13585

Funding

The first two-thirds of 2021 has seen considerable grant award success. Further details of all funding received in 2021 to date can be found in Appendix 5. The pipeline of funding proposals in development reflects the vigour of the research within the Institute.

European Research Council, Advanced Grant, Prof. **Frank Uekötter**, The Making of Monoculture: A Global History Value to University of Birmingham £1.74m

Using a global histories approach to examine the persistence and growth of crop monocultures, the project aims to make history relevant in a 21st-century world where organic production will face unprecedented challenges and where food security is an increasingly prescient issue.

Over five years, the project will harness historical research in exploring a field which has traditionally been dominated by agriculture and activism. Examining global history will demonstrate the similarities between otherwise different monocultures (the practice of growing a single type of crop, plant, or livestock at a time), identifying common patterns in the trajectories of monocultures from across the world, and offering a new interpretation of why monocultures are so resilient and pervasive despite plenty of evidence for their socioeconomic, political and ecological problems.

UKRI Future of UK Treescapes call, MEMBRA PI Dr **Estrella Luna Diez** Co-Is: Adriane Esquivel Muelbert; Marco Catoni; Scott Hayward; Rob Mackenzie from UoB. Total value £1,790,122 value to UoB £1,373,199

Institutions: UoB (lead), University of Exeter, University of Leeds, University of Leicester and Bangor University.

MEMBRA will study the concept of memories of stress in trees. The project will also integrate science and humanities to inform our approaches to enhancing resilience of UK Treescapes. We will provide experimental verification of how trees are capable of adapting to stress and transferring these memories to progeny through epigenetics-based imprinting of memory. Moreover, we will surface narratives of collective treescape experience and human-tree environmental ethics — 'understories' — to explore how the understanding of tree memory impacts on our decision-making capabilities and our moral relationship with trees.

UKRI Future of UK Treescapes call, Creative Adaptive Solutions for Treescapes of Rivers (CASTOR) PI Dr Matthew Dennis, University of Manchester. Total value £2,000,000 value to UoB £265,000 UoB CoI Dr Joshua Larsen

Institutions:
Universities of Manchester (lead), Cumbria, Leeds, Nottingham, Birmingham and Salford.

CASTOR identifies that the 150,000 miles of rivers and streams in England with potential for restoring woodland on their banks present a substantial opportunity for meeting the Government's goal of 17% tree cover by 2050. The project will explore and provide solutions for the challenges that restoration of riverside woodland may present. CASTOR will also identify unique opportunities through which restoring woodland located alongside rivers and waterways can promote natural and cultural heritage, and deliver nature recovery through providing wilder, better connected landscapes which build climate resilience.

UKRI Future of UK Treescapes, Voices for the Future —Collaborating with children and young people to re-imagine Treescapes. PI Manchester Metropolitan University Total value £1,600,000 value to UoB £100,000 UoB CoI Prof. Peter Kraftl

Institutions:
Universities of Manchester Metropolitan University (lead) Cumbria, Sheffield, Cambridge, Middlesex and Aberdeen

This project will explore how Treescapes how Treescapes could be expanded to meet the UK's net zero targets, and examine how trees and society can benefit each other.

It will involve children and young people in conducting innovative scientific research evaluating how trees adapt to and mitigate climate change, with the aim of developing a future curriculum in schools that will improve environmental literacy.

Going Forward

Our main priorities we reported in 2020 for 2021/22 are below with a short response:

- Develop and implement a research resilience strategy to successfully achieve our research objectives during the pandemic - **achieved, as evidenced by the current report**
- Strengthen our contribution to UK and international policy debates - **progressing strongly, see page 20**
- Map our research onto national schools curricula and provide tailored educational material - **in progress through Education Working Group in collaboration with Forestry Skills Forum page 14**
- Develop effective communications that bring our research to life for stakeholders, students, and wider publics - **increasing reach of conferences and social media, see page 20**
- Change cultures and climates, to increase diversity and to nurture greater scientific coherence - **more to do, but firm commitments and first steps made.**
- Engage with other organisations to raise visibility and bring BIFoR science to society - **partnerships with Association of Applied Biologists (AAB) and Royal Forestry Society (RFS) for conferences with strong practitioner involvement; very good links to media.**
- Advocate the extrapolation of FACE experiments to underrepresented forest types of global significance, particularly in the low and middle income countries – **Amazon FACE initiative see page 3**

Our [draft] main priorities through academic year 2021/22 are:

- Agree, embed, and deliver our 5-year plan
- Manage and mitigate external risks (e.g., supply chain issues; energy prices; CO_2)
- Respond with agility to COP26 outcomes to shape research and engagement for policy outcomes
- Evidence equality, inclusivity and culture change for greater scientific coherence
- Focus engagement through high-quality science outputs
- Develop and trial innovative teaching materials for new undergraduate programmes

Key dates in 2021 /2022

3rd to 4th November 2021

Trees for the Future – Diversity and complexity for resilience and carbon storage

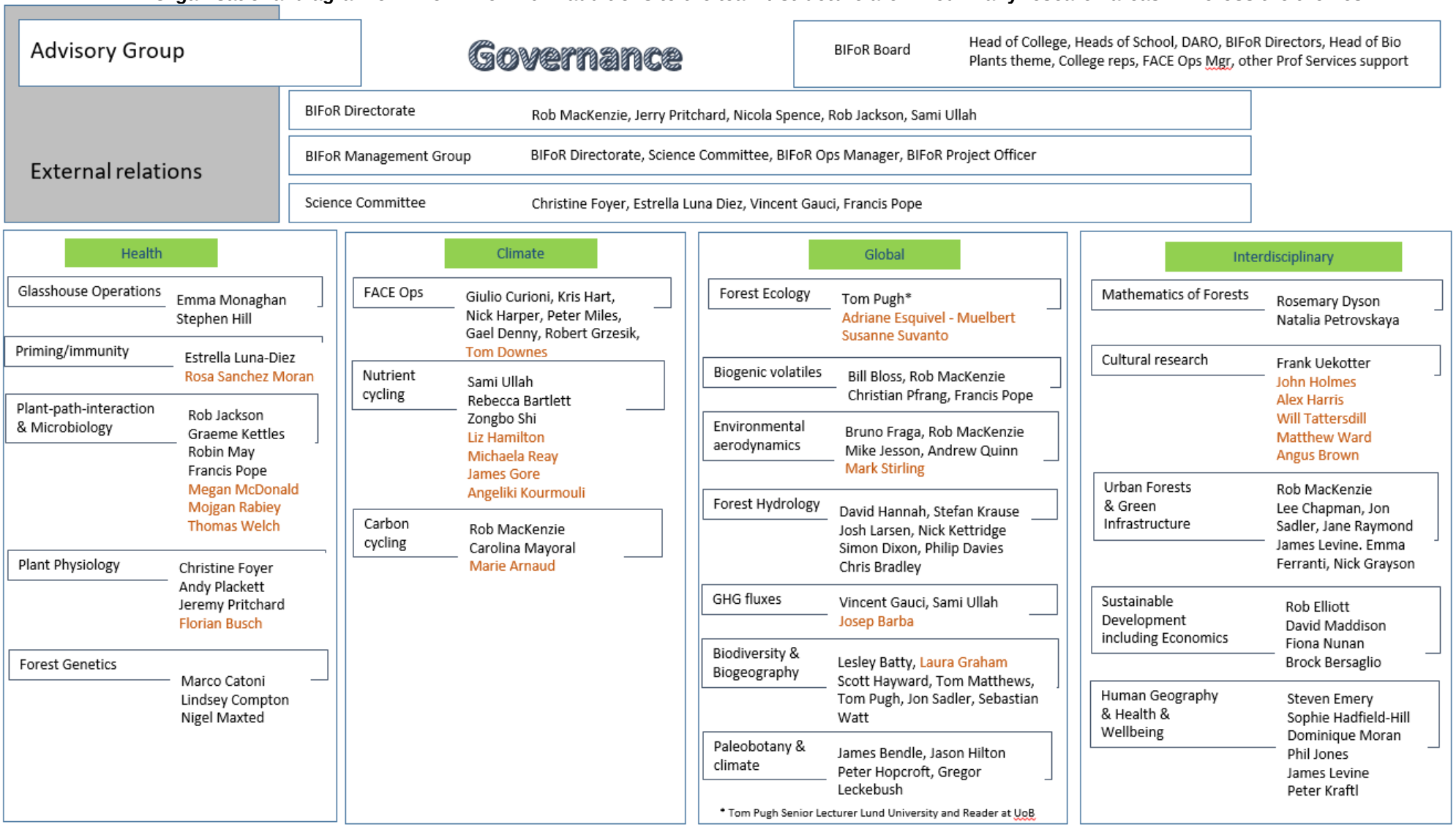
A main objective of this conference is to explore state-of-the-art scientific evidence showing that higher tree species diversity enables higher productivity and stability, with a lower susceptibility to biotic and abiotic stress, together with a portfolio of ecosystem services, as well as economic and management benefits.

26 and 27 January 2022

Transforming our understanding of global forests - 2022 BIFoR sixth annual Community Meeting

Appendix 1: People

Organisational diagram of BIFoR - new 2021 additions to the team / structure are in red. Many research areas will cross the themes.



BIFoR Advisory Group Members

Chaired by Prof. Laura Green, Head of College of Life & Environmental Sciences
Caroline Ayre, National Manager for England, CONFOR
Prof. Bradwell, Honorary Professor Immunology University of Birmingham
Dr Alice Broome, Project Leader for Protected Species, Forest Research
Dr Anna Brown, Head of Tree Health and Contingency, Forestry Commission England
Dr Matt Elliott, Policy Advocate, Tree Health & Invasives, Woodland Trust
Dr Clive Elphick, independent Director with the National Grid Gas Place and National Grid Electricity Transmission Plc, on the Board of the Environment Agency.
Dr Jeanette Hall, Woodland Advisor, Scottish Natural Heritage
Prof. David Johnson, Chair in Microbial Ecology, University of Manchester
Prof. Richard Norby, University of Tennessee, USA
Prof. Sir Ghillean Prance, formerly Director of Royal Botanical Gardens KEW
Prof. Malcolm Press, Vice Chancellor, University of Manchester
Prof. Nicola Spence, Chief Plant Health Officer, Defra and University of Birmingham

BIFoR Directors

The Directors of BIFoR are Professors Rob Jackson, Rob MacKenzie, Jeremy Pritchard, Nicola Spence and Sami Ullah.

BIFoR Board

Chair of the BIFoR Board is Prof. Laura Green, Pro-Vice-Chancellor and Head of College of Life & Environmental Sciences
Charlotte Allen (Development and Alumni Relations Office (DARO)
Lorna Booth (College Finance)
Lesley Ann Ford (College of Life and Environmental Sciences)
Prof. Christine Foyer (College of Life and Environmental Sciences)
Prof. Vincent Gauci (College of Life and Environmental Sciences - GEES)
Prof. David Hannah (College of Life and Environmental Sciences)
Dr Kris Hart (College of Life and Environmental Sciences)
Prof. Neil Hotchin (College of Life and Environmental Sciences - Biosciences)
Prof. Rob Jackson (College of Life and Environmental Sciences - Biosciences)
Dr Estrella Luna-Diez (College of Life and Environmental Sciences - Biosciences)
Bronwen Lord (Director of Operations - College of Life and Environmental Sciences)
Prof. Rob MacKenzie (College of Life and Environmental Sciences - GEES
Prof. David Maddison (College of Social Sciences)
Prof. Robin May (College of Life and Environmental Sciences)
Dr Jon Oldfield (College of Life and Environmental Sciences - Head of School GEES)
Prof. Francis Pope (College of Life and Environmental Sciences - GEES)
Prof. Jeremy Pritchard (College of Life and Environmental Sciences - Biosciences)
Dr Andrew Quinn (College of Engineering and Physical Sciences)
Dr Frank Uekötter (College of Art and Law)
Prof. Sami Ullah (College of Life and Environmental Sciences - GEES)

BIFoR Management Group

Dr Adriane Esquivel Muelbert, (College of Life and Environmental Sciences - GEES)
Prof. Christine Foyer (College of Life and Environmental Sciences)
Prof. Vincent Gauci (College of Life and Environmental Sciences - GEES)
Dr Kris Hart (College of Life and Environmental Sciences – GEES)
Prof. Rob Jackson (College of Life and Environmental Sciences - Biosciences)
Dr Estrella Luna Diez (College of Life and Environmental Sciences - Biosciences)
Prof. Rob MacKenzie (College of Life and Environmental Sciences – GEES)
Prof. Jeremy Pritchard (College of Life and Environmental Sciences - Biosciences)
Prof. Nicola Spence (Defra and Honorary Professor at the University of Birmingham)
Prof. Dr Sami Ullah (College of Life and Environmental Sciences - GEES)
Deanne Brettle – Secretary (College of Life and Environmental Sciences - GEES)

BIFoR Science Committee

Prof. Vincent Gauci (College of Life and Environmental Sciences - GEES)
Prof. Christine Foyer (College of Life and Environmental Sciences)
Dr Kris Hart (College of Life and Environmental Sciences – GEES)
Dr Estrella Luna-Diez (College of Life and Environmental Sciences - Biosciences)
Prof. Sami Ullah (College of Life and Environmental Sciences – GEES

BIFoR Professional Service Staff

Deanne Brettle - Project Administrator
Dr Giulio Curioni - Data Manager & Analyst
Gael Denny - Field Technician BIFoR FACE facility
Thomas Downes - Apprentice Engineer
Iwan Evans - Research Technician, FACE Underground project (maternity cover)
James Gore – Research Technician, QUINTUS
Robert Grzesik - Research Technician, QUINTUS
Nicholas Harper - Senior Engineer FACE facility
Dr Kris Hart - Operations Manager
Angeliki Kourmouli - Senior Research Technician, QUINTUS project
Hannah Martin - Research Technician, FACE Underground project
Peter Miles - Field Technician BIFoR FACE facility

International visiting scientists in 2021

Dr **Olanrewaju Olusoji Olujimi**, a FLAIR Research Fellow, African Academy of Sciences/ Royal Society UK, Federal University of Agriculture, Nigeria, completed a 3-month study visit in March, looking into air pollution from charcoal production.

Prof. **Richard Norby**, University of Tennessee, USA

Honoary members of the Institute

Prof Jonathan Drori, Honorary Professor of science communication.
Dr Debbie Hemming – Scientific Manager, Vegetation-Climate Interactions group,Met Office

he number of academic members of staff affiliated to BIFoR has continued to grow. The Institute is open to University of Birmingham staff and students whose research interest is related to the natural science, social science or cultural relevance of forested landscapes.

College of Life and Environmental Sciences

School of Biosciences

Academic Staff	*Postdoctoral Researcher*	*Doctoral Researchers*
Dr Florian Busch	Dr Sabrine Dhaouadi	Liam Crowley
Dr Marco Catoni	Dr Carolina Mayoral	Anna Gardner
Dr Lindsey Compton	Dr Olivia Mosley	Emily Grace
Prof. Christine Foyer	Dr Mojgan Rabiey	Richard Hill
Dr Scott Hayward	Dr Jade Taylor-Phillips	Katherine Hinton
Prof. Rob Jackson	Dr Rosa Sanchez Lucas	Vanja Milenkovic
Dr Graeme Kettles	Dr Thomas Welch	Mark Raw
Dr Estrella Luna-Diez	Dr Diana Vinchira	Amy Webster
Dr Megan McDonald		Jiaqi Wei
Prof. Lynne Macaskie		Clare Ziegler
Prof. Nigel Maxted		
Prof. Robin May		
Dr Andrew Plackett		
Prof. Jeremy Pritchard		

School of Geography, Earth and Environmental Sciences

Academic Staff	*Academic Staff*	*Postdoctoral Researcher*	*Doctoral Researchers*
A – L	**L - Z**		
Dr Rebecca Bartlett	Dr Joshua Larsen	Dr Marie Arnaud	Nezha Acil
Dr Lesley Batty	Dr Gregor Leckebush	Dr Josep Barba Ferrer	Alex Armstrong
Dr James Bendle	Dr James Levine	Dr Michaela Reay	Sijeh Asuk
Prof. William Bloss	Prof. Rob MacKenzie	Dr Susanne Suvanto	Gemma Baker
Dr Chris Bradley	Dr Thomas Matthews		Aileen Baird
Dr Xiaoming Cai	Dr Dominique Moran		Edward Bannister
Dr Lee Chapman	Dr Christian Pfrang		Alfred Bockarie
Dr Julian Clark	Prof. Francis Pope		Nicolai Brekenfield
Dr Simon Dixon	Dr Tom Pugh*		Hector Carmago
Dr Steven Emery	Prof. Jon Sadler		Nine Douwes Dekker
Dr Adriane Esquivel Muelbert	Dr Zongbo Shi		Lavinia Georgescu
	Prof. Sami Ullah		Ben Howard
Dr Emma Ferranti	Dr Sebastian Watt		Tony Hyacinth
Prof. Vincent Gauci			Laura James
Dr Laura Graham			Polly Jarman
Dr Nick Grayson			Jordan Johnston
Dr Sophie Hadfield-Hill			Fatima Khan
Dr Liz Hamilton			Thomas King
Dr Jason Hilton			Jennifer Knight
Dr Peter Hopcroft			Angeliki Kourmouli
Dr Phil Jones			Alex Kulawska
Prof. Prof. Peter Kraftl			Kerryn Little
Prof. Stefan Krause			Sophie Mills
	*Tom Pugh Senior Lecturer Lund University and Reader at UoB		Sue Quick
			Andrea Rabbai
			Jordan Rowling
			Manon Rumeau
			Klaske van Wijngaarden
			Bridget Warren
			Joseph Wayman

School of Psychology

Academic Staff

Dr Ali Mazaheri
Prof. Jane Raymond

Doctoral Researcher

Eszter Toth

College of Engineering and Physical Sciences

Academic Staff

Dr Andrew Quinn (College Rep. for BIFoR)
Prof. Phillip Davies
Dr Rosemary Dyson
Dr Bruno Fraga
Dr Mike Jesson
Dr Chris Mayhew
Dr Natalia Petrovskaya

Postdoctoral Researcher

Dr Galene Luo

Doctoral Researchers

Kieran Clark
Bradly Deeley
Bruno Santos

College of Arts and Law

Academic Staff

Dr Frank Uekötter (College Rep. for BIFoR)
Dr Angus Brown
Dr Louise Hardwick
Prof. Alexandra Harris
Prof. John Holmes
Prof. Corey Ross
Dr Will Tattershill
Dr Matthew Ward

Doctoral Researchers

Dion Dobrzynski
Thomas Kaye

College of Social Sciences

Academic Staff

Prof. David Maddison (College Rep for BIFoR)
Dr Allan Beltran
Dr Brock Bersaglio
Prof. Robert Elliott
Prof. Fiona Nunan

Postgraduate Researchers

Maria Teresa Gonzalez Valencia
Harriet Croome

Appendix 2: BIFoR Presence at Sectoral Conferences and Workshops

Date	Information
19 -21/01/2021	BES Protected Areas and Climate Change, poster and lightening talk by Susan Quick
27 and 28 January 2021	BIFoR Annual meeting. 2 key note speakers (Christine Foyer / Scott Hayward) and 8 talks from PhD students and early career researchers.
21/03/20211	Keynote Speaker Dr Emma Ferranti. Royal Town Planning Institute, UK: Green Infrastructure in the West Midlands; invited presentation to welcome new RTPI Chair.
25/03/2021	iLEAPS Lite Conference, **"**Urban Forests provide Ecosystem Services in times of COVID-19**"** by Rob MacKenzie
April 2021	European Geosciences Union (EGU) 2021 Nezha Acil Remotely sensed quantification of non-fire-related disturbances and their contribution to global forest dynamics Sijeh Asuk Does foraging impact tropical forest composition? Josep Barba Methane Stem Fluxes under eCO_2 Sophie Comer Warner The role of land-use change and restoration on nitrogen processing in tropical coastal wetlands of Vietnam Anna Gardner The effects of elevated CO2 and canopy position on chlorophyll concentration in mature *Quercus robur.* Francis Pope Air of the Anthropocene Sue Quick Tree-soil-water relations in a mature temperate forest under eCO_2
05/05/2021	The European Forum on Urban Forestry annual meeting, The Air Trees 'Breathe': Results from A Mature Temperate Broadleaf Forest Under Elevated CO_2 by Rob MacKenzie
21/05/2021	Invited panelist Dr Emma Ferranti, ClimateExp0 International Conference: Nature-based solutions for heat risk management.
06/07/2021 – 8 /7/2021	Treescapes 2021 Invited talk "**At the interface of soil and air; What happens under future climates?**" Nine Douwes Dekker, University of Birmingham, BIFoR Invited talk **"Integrating lived experience and expertise into tree planting for Natural Flood Management" by** Jenny Knight, University of Birmingham, BIFoR Invited talk **"The contribution of instream wood to ecosystem (dis)services"** Ben Howard, University of Birmingham, BIFoR Poster presentations from **Sue Quick** (GEES), **Manon Rumeau** (GEES), **Klaske van Wijngaarden** (GEES), **Jordan Johnston** (GEES), **Bradley Deeley** (EPS) **Mark Raw** (Bio) **and Bruno Santos** (EPS) Conference proceedings available at Treescapes 2021

Appendix 3: BIFoR Stakeholder engagement

The following programme of engagement gives a flavour of our stakeholder engagement in 2021. Without stakeholders, our research will lie unused. The following programme of engagement gives a flavour of our stakeholder engagement in 2021.

External Stakeholder Engagement - Academic			
Date		BIFoR contact	Location
03/02/2021	School of Geography, Earth and Environmental Sciences seminar programme at the University of Plymouth, invited speaker **"A temperate deciduous forest Free-Air Carbon Enrichment (FACE) facility – results from seasons 0, 1, 2 (& 3) of 10" by** Rob MacKenzie	Rob MacKenzie	Virtual

External Stakeholder Engagement - Education			
02/04/2021	University of Birmingham MSc Carbon Management virtual tour of BIFoR FACE	Rob MacKenzie	Online
May 2021	Invited speaker "Tutkija tavattavissa" Part of a national science communication programme in Finland – A Finnish version of the Skype a Scientist programme.	Susanne Suvanto	Virtual
16/06/2021	Invited speaker, Geography online seminar, **"Rethinking nature in cities"** by Phil Jones	Phil Jones	Virtual
Summer 2021	Contributor to the British Ecological Society Undergraduate Summer School	Aileen Baird	Hybrid

External Stakeholder Engagement – Private, Public & Third Sector			
Date	Details	BIFoR contact	Location
21/04/2021	Staffordshire Business and Environment Network (Sben) Virtual tour of the BIFoR FACE facility	Rob MacKenzie	Virtual
16/06/2021	Invited speaker, Arboricultural Association seminar series "Urban trees and clean air" by James Levine	James Levine	Virtual
30/06/2021	World Congress of Soil Science members tour of BIFoR FACE	Sami Ullah	BIFoR FACE

External Stakeholder engagement – Public Engagement with Research			
Date	Details	BIFoR contact	Location
29/04/2021	Defra Forest and Land Use Team	Rob MacKenzie	Virtual
29/07/2021	Presentation by Claire Hewitt on her art project at BIFoR FACE	Claire Hewitt	Virtual

Social media and grey literature

- GI4RAQ press release 05/07/2021
- Technician make it happen website, BIFoR FACE technicians included in blog piece for World Environment Day - part 1 | Technicians
- Prof. **Jon Drori** took part in a book launch event with Prof. **Suzanne Simard,** the session was very well attended and Jon mentioned the BIFoR FACE facility. See the recording online
- Podcast for the Ecological Continuity Trust with Dr Kris Hart
- "Take a mental break, connect with nature" forest bathing blog piece by Dr **Fiona Clarke** (Sportex)
- The Amazon is now a net carbon producer, but there's still time to reverse the damage by Ane Alencar and Adriane Esquivel Muelbert in the Guardian
- Improved management of farmed peatlands could cut 500m tonnes of CO_2 by Prof Vincent Gauci University of Birmingham News
- David S Jenkinson Fellowship Grant Report by Dr **Marie Arnaud**, British Society of Soil Science website

University of Birmingham, Addressing the Climate Challenge – a collections of essays

- Not just standing there: the carbon utility of established forest by **Rob MacKenzie**
- Tree susceptibility and resilience to pests and disease by **Rob Jackson, Estrella Luna-Diez, Graeme Kettles** and **Megan McDonald**
- Improving the climate resilience of infrastructure networks by Lee Chapman, David Jaroszweski and **Emma Ferranti**
- The implications of net zero ambitions for infrastructure resilience to climate change, by Sarah Greenham, **Emma Ferranti,** David Jaroszweski, **Lee Chapman, Andrew Quinn** and Ruth Wood
- Clean Air: bringing local synergies to the global climate challenge by **William Bloss**, Joe Acton and Jian Zhong
- Embedding climate change adaptation as business as usual within the railway sector by **Emma Ferranti, Andrew Quinn**, John Dora, Sarah Greenham, Rachel Fisher, Nick Pyatt and Tim Reeder
- Building better, safer, healthier cities for children and young people by **Peter Kraftl, Sophie Hadfield-Hill** and Susanne Börner
- The amenity value of the climate by **David Maddison**
- The air we breathe and clean air day by **William Bloss,** Suzanne Bartington and John Bryson
- 'No wealth but life': the role of the arts and humanities in tackling the climate crisis by **John Holmes** and **Dion Dobrzynski**

Appendix 4: BIFoR Papers

Papers from previous years can be found online

Climate – BIFoR FACE

1. **Baird, A. B., Bannister, E. J., MacKenzie, A. R.,** & **Pope, F. D. (2021)**. Mass concentrations of autumn bioaerosol in a mature temperate woodland Free Air Carbon Dioxide Enrichment (FACE) experiment: investigating the role of meteorology and carbon dioxide levels. *Biogeosciences Discuss.* 1-25. https//doi:10.5194/bg-2021-162 **Preprint**
2. **Crowley, L. M., Sadler, J. P., Pritchard, J., & Hayward, S. A. L.** (2021). Elevated CO_2 Impacts on Plant–Pollinator Interactions: A Systematic Review and Free Air Carbon Enrichment Field Study. *Insects,* 12(6), 512. Retrieved from https://doi.org/10.3390/insects12060512
3. **Gardner, A.,** Ellsworth, D. S., Crous, K. Y., **Pritchard, J.,** & **MacKenzie, A. R**. (2021). Is photosynthetic enhancement sustained through three years of elevated CO_2 exposure in 175-year-old Quercus robur? *Tree Physiology*. doi:10.1093/treephys/tpab090
4. **Khamis, K., Blaen, P. J., Comer-Warner, S., Hannah, D. M., MacKenzie, A. R., & Krause, S**. (2021). High-Frequency Monitoring Reveals Multiple Frequencies of Nitrogen and Carbon Mass Balance Dynamics in a Headwater Stream. Frontiers in Water, 3(43). doi:10.3389/frwa.2021.668924
5. **MacKenzie, A. R., Krause, S., Hart, K. M.,** Thomas, R. M., Blaen, P. J., **Hamilton, R. L., Curioni, G., Quick, S. E., Kourmouli, A., Hannah, D. M., Comer-Warner, S. A., Brekenfeld, N., Ullah, S., &** Press, M. C. (2021). BIFoR FACE: Water–soil–vegetation–atmosphere data from a temperate deciduous forest catchment, including under elevated CO_2. *Hydrological Processes,* 35(3), e14096. https://doi.org/https://doi.org/10.1002/hyp.14096
6. **Ziegler, C., Kulawska, A., Kourmouli, A., Hamilton, L., Shi, Z., MacKenzie, A. R.,** . . . Johnston, I. G. (2021). Quantification and uncertainty of root growth stimulation by elevated CO_2 in mature temperate deciduous forest. *bioRxiv*, 2021.2004.2015.440027. https://doi:10.1101/2021.04.15.440027 Preprint

Health

1. Crozier, L., Marshall, J., Holmes, A., Wright, K. M., Rossez, Y., Merget, B. **Jackson R.W.** , . . . Holden, N. J. (2021). The role of l-arabinose metabolism for Escherichia coli O157:H7 in edible plants. *Microbiology, 167*(7). doi:https://doi.org/10.1099/mic.0.001070
2. **Grace, E. R., Rabiey, M.,** Friman, V.-P., & **Jackson, R. W.** (2021) Seeing the forest for the trees: Use of phages to treat bacterial tree diseases. *Plant Pathology,* https://doi.org/10.1111/ppa.13465
3. Horton, J. S., Flanagan, L. M., **Jackson, R. W.,** Priest, N. K., & Taylor, T. B. (2021). A mutational hotspot that determines highly repeatable evolution can be built and broken by silent genetic changes. *bioRxiv*, doi:10.1101/2021.01.04.425178
4. Hotto, A. M., Salesse-Smith, C., Lin, M., Busch, F. A., Simpson, I., & Stern, D. B. (2021). Rubisco production in maize mesophyll cells through ectopic expression of subunits and chaperones. *Journal of Experimental Botany*. https://doi:10.1093/jxb/erab189
4. Hulin, M. H., Vadillo Dieguez, A., Cossu, A., Lynn, S., Russell, K., Neale, H., **Jackson, R. W.**, Arnold, D. L., Mansfield, J. W. and Harrison, R. J. Horton, J. S., Flanagan, L. M., Jackson, R. W., Priest, N. K., & Taylor, T. B. (2021). A mutational hotspot that determines highly repeatable evolution can be built and broken by silent genetic changes. *bioRxiv*, doi:10.1101/2021.01.04.425178
6. Neale, H. C., Hulin, M. T., Harrison, R. J., **Jackson, R. W.,** & Arnold, D. L. (2021). Transposon Mutagenesis of Pseudomonas syringae Pathovars syringae and morsprunorum to Identify Genes Involved in Bacterial Canker Disease of Cherry. *Microorganisms*, 9(6), 1328. Retrieved from https://doi.org/10.3390/microorganisms9061328
8. Paliwal, D., Hamilton, A. J., Barrett, G. A., Alberti, F., van Emden, H., Monteil, C. L., . . . **Jackson, R. W.** (2021). Identification of novel aphid-killing bacteria to protect plants. *Microb Biotechnol*. doi:10.1111/1751-7915.13902
9. **Plackett, A. R.** G., Emms, D. M., Kelly, S., Hetherington, A. M., & Langdale, J. A. (2021). Conditional stomatal closure in a fern shares molecular features with flowering plant active stomatal responses. *Current Biology*. doi:https://doi.org/10.1016/j.cub.2021.08.008
10. Storey, N., **Rabiey, M**., Neuman, B. W., **Jackson, R. W**., & Mulley, G. (2020). Genomic Characterisation of Mushroom Pathogenic Pseudomonads and Their Interaction with Bacteriophages. *Viruses,* 12(11), 1286. https//doi:10.3390/v12111286
11. Wood, S. V., Maczey, N., Currie, A. F., Lowry, A. J., **Rabiey, M.,** Ellison, C. A., . . . Gange, A. C. (2021). Rapid impact of Impatiens glandulifera control on above- and belowground invertebrate communities. *Weed Research*, 61(1), 35-44. doi:https://doi.org/10.1111/wre.12454

Global

1. **Arnaud*, M.*** *(2021). Capturing coastal wetland root dynamics with underground time-lapse. Nature Reviews Earth & Environment, 2(10), 663-663.* doi:10.1038/s43017-021-00217-0
2. **Arnaud M.,** Morris P.J., Baird A.J. Dang H. & Nguyen T.T. (2021) Fine root production in a chronosequence of mature reforested mangroves. *New Phytologist* https://doi.org/10.1111/nph.17480
3. **Bannister, E., MacKenzie, A. R., & Cai, X.** (2021). Realistic forests and the modeling of forest-atmosphere exchange. In. Washington: American Geophysical Union. https://www.proquest.com/docview/2515920515?pq-origsite=gscholar&fromopenview=true# **Preprint**
4. **Barba, J.,** Poyatos, R., Capooci, M., & Vargas, R. (2021). Spatiotemporal variability and origin of CO2 and CH4 tree stem fluxes in an upland forest. *Global Change Biology*, 27(19), 4879-4893. https://doi.org/10.1111/gcb.15783
5. Bordin, K.M, Esquivel-Muelbert, A. […] Müller, S. C. (2021) Climate and forest structure drive above-ground biomass in subtropical forests. *Forest Ecology and Management,* https://doi.org/10.1016/j.foreco.2021.119126
6. **Comer Warner, S.A.,** Anh, T. Q. N., Minh, N. N., Manlin, W., Antony, T., Hue, L., . . . **Sami, U.** (2022). Restoration impacts on rates of denitrification and greenhouse gas fluxes from tropical coastal wetlands. *Science of The Total Environment, 803*, 149577. doi:https://doi.org/10.1016/j.scitotenv.2021.149577
7. Dalagnol, R., Wagner, F. H., Galvão, L. S., Streher, A. S., Phillips, O. L., Gloor, E., **Pugh, T.A.M, . .** . Aragão, L. E. O. C. (2021). Large-scale variations in the dynamics of Amazon forest canopy gaps from airborne lidar data and opportunities for tree mortality estimates. *Scientific Reports, 11*(1), 1388. doi:10.1038/s41598-020-80809-w
8. Dembicz, I., Dengler, J., Steinbauer, M. J., **Matthews, T. J.,** Bartha, S., Burrascano, S., . . . Biurrun, I. (2021). Fine-grain beta diversity of Palaearctic grassland vegetation. *Journal of Vegetation Science, 32*(3), e13045. https://doi.org/10.1111/jvs.13045
9. Deshmukh, C. S., Julius, D., Desai, A. R., Asyhari, A., Page, S. E., Nardi, N. **Gauci V.,,** . . . Evans, C. D. (2021). Conservation slows down emission increase from a tropical peatland in Indonesia. *Nature Geoscience, 14*(7), 484-490. doi:10.1038/s41561-021-00785-2
10. Draper, F.C., Costa, F.R.C., Arellano, G. […] **Esquivel-Muelbert, A.,** et al. (2021) Amazon tree dominance across forest strata. *Nature Ecol Evol* https://doi.org/10.1038/s41559-021-01418-y
11. Evans, C. D., Peacock, M., Baird, A. J., Artz, R. R. E., Burden, A., Callaghan, N., . . .Morrison, R. (2021). Overriding water table control on managed peatland greenhouse gas emissions. *Nature 593*(7860), 548-552 doi:10.1038/s41586-021-03523-1
12. ForestPlots.net, Blundo, C., Carilla, J., Grau, R., Malizia, A., Malizia, L. **Pugh. T.A.M,** . . . Tran, H. D. (2021). Taking the pulse of Earth's tropical forests using networks of highly distributed plots. *Biological Conservation,* 260, 108849. doi:https://doi.org/10.1016/j.biocon.2020.108849
13. Fotis, S., Christopher, A. Y., Charlotte, E. M. L., Ernesto, S., Daniel, N. S., Sam, T., . . . **Sami, U.** (2021). Chronic atmospheric reactive N deposition has breached the N sink capacity of a northern ombrotrophic peatbog increasing the gaseous and fluvial N losses. *Science of The Total Environment*, 787, 147552. doi:https://doi.org/10.1016/j.scitotenv.2021.147552
14. Gora, E. M., & **Esquivel-Muelbert, A.** (2021). Implications of size-dependent tree mortality for tropical forest carbon dynamics. *Nature Plants*, 7(4), 384-391. https://doi:10.1038/s41477-021-00879-0
15. Harper, A. B., Williams, K. E., McGuire, P. C., Duran Rojas, M. C., **Hemming, D.,** Verhoef, A., . . . Wohlfahrt, G. (2021). Improvement of modeling plant responses to low soil moisture in JULESvn4.9 and evaluation against flux tower measurements. *Geosci. Model Dev., 14*(6), 3269-3294. doi:10.5194/gmd-14-3269-2021
16. He, X. **Hilton J.,** Wang S., & Cheng X. (2021). Exploring the stem to crown group transition in Marattiales: A new species of frond from the late Permian of China with features of the Psaroniaceae and Marattiaceae. Review of Palaeobotany and Palynology, 295, 104506. doi:https://doi.org/10.1016/j.revpalbo.2021.104506
17. **Hemming, D.L**., J. Garforth, T. Park, A. D. Richardson, T. Rutishäuser, T. H. Sparks, S. J. Thackeray, and R. Myneni 2020: Phenology of Primary Producers. [in "State of the Climate in 2019"]. Bull. Amer. Meteor., 101 (8), S95–S98.
18. Jackson, F. L., **Hannah, D. M., Ouellet, V.,** & Malcolm, I. A. (2021). A deterministic river temperature model to prioritize management of riparian woodlands to reduce summer maximum river temperatures. *Hydrological Processes*, 35(8), e14314. doi:https://doi.org/10.1002/hyp.14314
19. **Kettridge, N.,** Lukenbach, M. C., Hokanson, K. J., Devito, K. J., Petrone, R. M., Mendoza, C. A., & Waddington, J. M. (2021). Regulation of peatland evaporation following wildfire; the complex control of soil tension under dynamic evaporation demand. *Hydrological Processes*, 35(4), 14132. doi:https://doi.org/10.1002/hyp.14132
20. **Khamis, K.,** Blaen, P. J., **Comer-Warner, S., Hannah, D. M., MacKenzie, A. R.,** & **Krause, S**. (2021). High-Frequency Monitoring Reveals Multiple Frequencies of Nitrogen and Carbon Mass Balance Dynamics in a Headwater Stream. *Frontiers in Water, 3*(43). doi:10.3389/frwa.2021.668924
21. Kusumoto, B., Kubota, Y., Baselga, A., Gómez-Rodríguez, C., **Matthews, T. J.**, Murphy, D. J., & Shiono, T. (2021). Community dissimilarity of angiosperm trees reveals deep-time diversification across tropical and temperate forests. *Journal of Vegetation Science*, 32(2), e13017. https://doi.org/10.1111/jvs.13017

22. **Liu, D.,** Zhang, C., Ogaya, R., Fernández-Martínez, M., **Pugh, T. A. M.,** & Peñuelas, J. (2021). Increasing climatic sensitivity of global grassland vegetation biomass and species diversity correlates with water availability. *New Phytologist, 230*(5), 1761-1771. doi:https://doi.org/10.1111/nph.17269
23. Meade, L. E., Plackett, A. R. G., & Hilton, J. (2021). Reconstructing development of the earliest seed integuments raises a new hypothesis for the evolution of ancestral seed-bearing structures. *New Phytologist,* 229(3), 1782-1794. doi:https://doi.org/10.1111/nph.16792
24. Mao F., **Ullah S.,** Gorelick S., **Hannah D.M.** & **Krause S**. (2021). Increasing nutrient inputs risk a surge of nitrous oxide emissions from global mangrove ecosystems. *One Earth, 4*(5), 742-748. doi:https://doi.org/10.1016/j.oneear.2021.04.007
25. Márquez D.A., Stuart-Williams H., Farquhar G., Farquhar D. and **Busch F.A**. (2021). Cuticular conductance of adaxial and abaxial leaf surfaces and its relation to minimum leaf surface conductance *New Phytologist* https://doi.org/10.1111/nph.17588
26. **Matthews T.J.** (2021). On The Biogeography of Habitat Islands: The Importance of Matrix Effects, Noncore Species, and Source-Sink Dynamics. *The Quarterly Review of Biology,*96(2) https://doi.org/10.1086/714482
27. **Matthews T.J.**, Triantis K.A. and Whittaker R.J (2021). The Species–Area Relationship Theory and Application ISBN: 9781108752039 *Cambridge University Press*, Cambridge.
28. **Matthews T.J.** and Rigal F. (2021). Thresholds and the species–area relationship: a set of functions for fitting, evaluating and plotting a range of commonly used piecewise models in R. *Frontiers of Biogeography,* 13(1), e49404. https://doi.org/10.21425/F5FBG49404
29. Mittermeir J.C., Roll U., **Matthews T.J.**, Correia R., and Grenver R. (2021). Birds that are more commonly encountered in the wild attract higher public interest online. *Conservation in Science Practice,* e340 https://doi.org/10.1111/csp2.340
30. Müller C., Franke J., Jagermeyr J., ….**Pugh T.A.M**.(2021). Exploring uncertainties in global crop yield projections in a large ensemble of crop models and CMIP5 and CMIP6 climate scenarios *Environ. Res. Lett.* **16** 034040 https://doi.org/10.1088/1748-9326/abd8fc
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Appendix 5: Funding

Title	Lead HEI	PI	Funder	Total Value	Value to UoB
The making of monoculture: a global history	University of Birmingham	Frank Uekotter	ERC Advance grant	£1,740,000	£1,740,000
MEMBRA: Understanding Memory of UK Treescapes for Better Resilience and Adaptation	University of Birmingham	Estrella Luna Diez	UK Treescapes Programme	£1,790,122	£1,373,199
Creative Adaptive Solutions for Treescapes Of Rivers (CASTOR)	University of Manchester	Dr Matthew Dennis UoB CoI Joshua Larsen	UK Treescapes Programme	£2,000,000	£265,000
Voices of the future: Collaborating with children and young people to re-imagine Treescapes	Manchester Metropolitan University	Professor Kate Pahl UoB Co I Peter Kraftl	UK Treescapes Programme	£1,600,000	£100,000 circa
Constraining the Isotopic Response of Leaf Material Grown Under Elevated CO_2	University of Birmingham	Bridget Warren	NERC Life Sciences Mass Spectrometry Facility Grant	£25,410	£25,410
Root dynamics and turnover at BIFoR FACE	University of Birmingham	Marie Arnaud	Woodland Trust	£20,000	£20,000
Metagenomic characterization of soils exposed to flooding and eCO_2	University of Warwick	Katy Faulkner	NERC Omics	£8,500	£8,500
Effect of elevated CO_2 in DNA methylation in mature oaks	University of Birmingham	Estrella Luna Diez	Internal UoB Call	£5,000	£5,000
Methane Traits	University of Birmingham	Josep Barba Ferrer	British Ecological Society Small Grant	£4,772	£4,772
Long term sample curation	University of Birmingham	Kris Hart	Ecological Continuity Trust Small Grants	£2,000	£2,000
CO_2 and CH_4 fluxes from tree stems under elevated CO_2	University of Birmingham	Josep Barba	Ecological Continuity Trust	£1,914	£1,914
Long term sample curation	University of Birmingham	Kris Hart	Philanthropic donation	£1,300	£1,300
Impact of elevated CO_2 on isotopic composition of forest leaves”	University of Birmingham	Bridget Warren	Collaboration with Hokkaido University	£1,000	£1,000
CPD training for technical team members	University of Birmingham	Kris Hart	TALENT Technical Conference and Skills Fund	£2,288	£708

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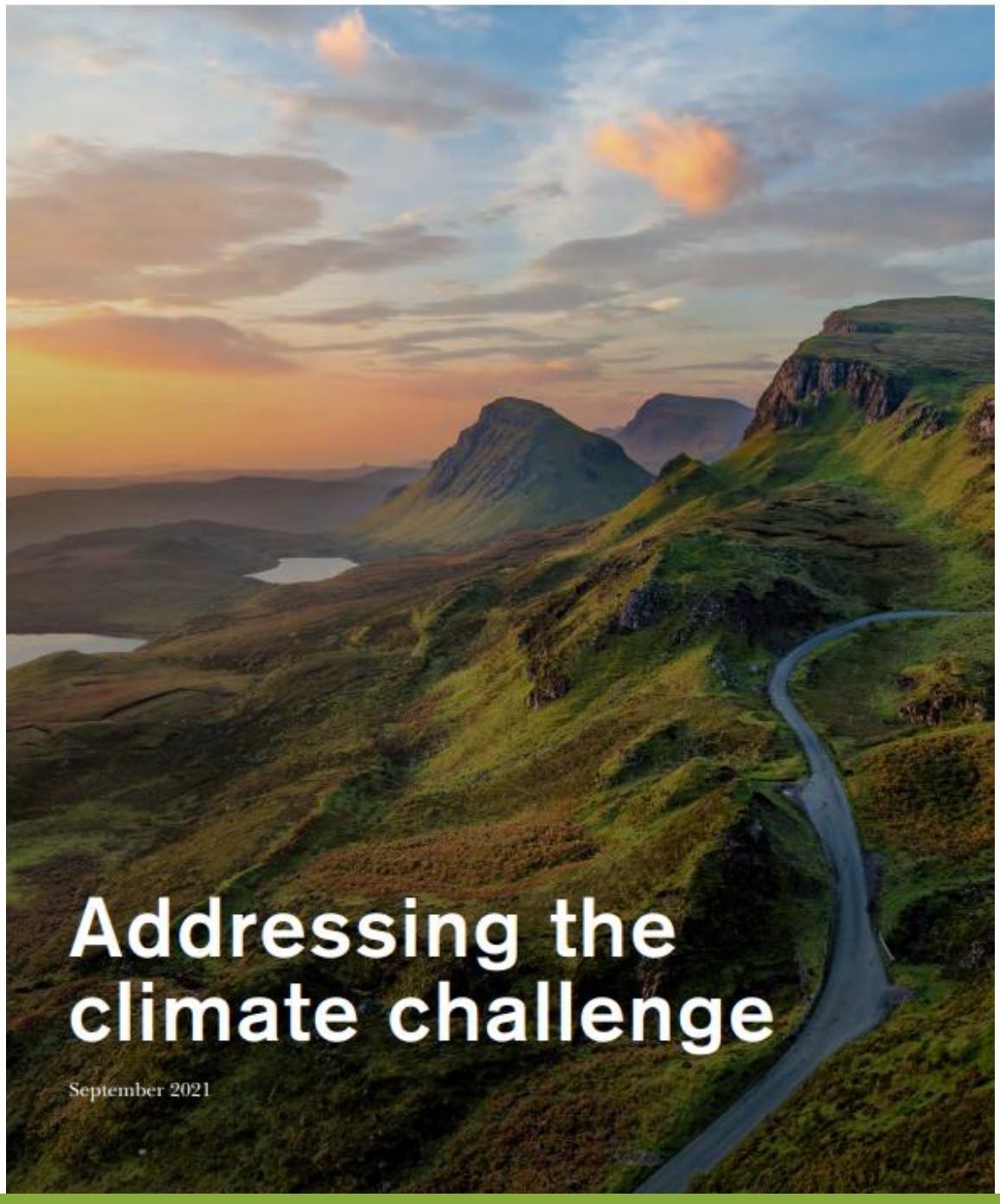

In 2021, colleagues from across the University of Birmingham community were invited to write articles about topics relevant to the COP26 climate change summit.

In this series of articles, including 10 by members of BIFoR, experts from across many different disciplines provide new insight and evidence on how we might all understand and tackle climate change.

https://www.birmingham.ac.uk/research/cop26/climate-publications/publications.aspx