UNIVERSITY OF BIRMINGHAM | BIFOR BIRMINGHAM INSTITUTE OF FOREST RESEARCH

BIFoR FACE
White Book

VERSION 7.0 (JAN 2021)

T I T L E P A G E

Version: Draft 7.0
Birmingham Institute of Forest Research (BIFoR) Free-Air Carbon Dioxide Enrichment (FACE) Facility

Contributing Authors:

Deanne Brettle, Giulio Curioni, Estrella Luna-Diez, Vincent Gauci, Kris Hart, Francis Pope, Rick Thomas, Rob MacKenzie, Jon Sadler, Scott Haywood, Stefan Krause, William (Bill) Bloss, William Allwood, Phil Blaen, Alex Poynter, Christopher Mayhew, Liz Hamilton

BIFoR would also like to extend our thanks to the Institute of Advanced Studies (IAS) for enabling the International Distinguished Visiting Fellows to join our team for significant periods of time since our inception. Nine international visitors have been hosted, including; Senior Professor Sharon Robinson, University of Wollongong (plant ecophysiologist); Professor David Ellsworth and Dr Kristine Crous, Western Sydney University (Forest ecophysiologists); Dr Debbie Hemming, UK Met Office (land surface climate modeller); Dr Theresa Blume, Helmholtz Centre Potsdam (Hydrology); Dr Tait Keller, Rhodes College in Memphis, Tennessee (Environmental History); Professor Rich Norby (Oak Ridge National Laboratory); Professor Mantha Phanikumar, Michigan State University (Hydrological modelling); Dr Xiaolong Liu and Dr Li Bai, Tianjin Key Laboratory (greenhouse gas measurements).

Contents

Executive Summary

By Rob MacKenzie, BIFoR Director FACE

This 'living' document is designed to give both internal and external stakeholders detailed information about the University of Birmingham's forest research woodland called Mill Haft and the rationale and science behind the Free-Air Carbon Dioxide Enrichment (FACE) experiment being undertaken.

The White Book is accessible to everyone to download by clicking on this link - this will download the latest version. To avoid a cumbersome document there are links in this document to download other important documents e.g. Project Forms, Risk Assessments. All documents are stored on the University of Birmingham Bear Data Share website.

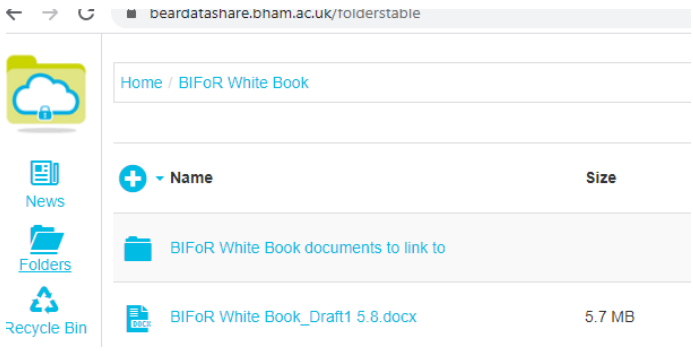
Field Code Changed

If you wish to be able to add to / edit the 'BIFoR White Book' please ask the BIFoR Project Administrator for access to the folder on Bear Data Share. The White Book and all the supporting documents are 'housed' in a folder called "BIFoR White Book" (image below) the Bear Data Share website allows 'live' edits to be made and saved (like google docs).

The BIFoR Administrator can be contacted if you have any problems accessing these files. BIFoR Project Administrator, 0121 414 6146, bifor@contacts.bham.ac.uk

To all internal / external collaborators considering research or already involved with research at the BIFoR FACE facility we hope this document will become your "bible" for your journey with us. The chance to be involved in a project like BIFoR FACE does not come around often, we want everyone's journey with us to be as smooth as possible. We have a willing team of people to answer questions if you cannot find the information you need included in this document.

Rob MacKenzie
Director of BIFoR and academic lead for BIFoR FACE



Introduction

About BIFoR

As a result of a visionary £15 million donation in November 2013, the University of Birmingham launched the Birmingham Institute of Forest Research (BIFoR).

BIFoR aims to provide fundamental science, social science and cultural research of direct relevance to forested landscapes anywhere in the world. We make the evidence-based case for forests as part of one-planet living.

BIFoR is focussed on addressing two major challenges: the impact of climate and environmental change on woodlands, and the resilience of trees to invasive pests and pathogens. Central to the £15 million donation was co-funding of the set up and running of a Free- Air Carbon Dioxide (FACE) facility, the only such facility in the northern hemisphere, and one of the three largest climate change experiments in the world. BIFoR FACE has placed scientists at the Universality of Birmingham alongside our external collaborators in a globally unique position to investigate the impact of climate change on trees.

Thanks to a further philanthropic donation in 2019 to BIFoR, we have been able to recruit a number of new positions, a Chair in Tree Pathology, Prof Rob Jackson and bio scientists (more information about the team online) working on pathology and physiology of trees. In addition, since 2014, more than 12 academics with expertise in environmental science have re-aligned a substantive element of their research to work on forest research.

There are four directors of BIFoR, **Prof Rob Jackson, Prof Rob MacKenzie, Prof Nicola Spence** and **Prof Jeremy Pritchard.** They report to a University internal Board and an external Advisory Group. BIFoR is a virtual institute of over 100 academics, primarily from the schools of Geography Earth and Environmental Sciences and Biosciences but also including members from Mathematics, Engineering, the Business School, International Development, Psychology, Humanities, and elsewhere. BIFoR is well connected across the University colleges, and are proud to be part of the Birmingham In Action campaign. We still very much seek engagement across the colleges. BIFoR has a team of over 33 PhD students which is rapidly expanding with thanks to the Leverhulme funded, Forest Edge Doctoral Scholarship Programme.

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BIFoR is at the heart of the University of Birmingham's response to the grand challenges facing the terrestrial environment. Understanding the coupling between forested landscapes and the atmosphere will be central to the research of the Institute. BIFoR adopts a systems-science approach from its field-scale experimental work, through its modelling, to its research on issues of governance and societal change.

More information about BIFoR is available on our website which includes links to our Annual Reports, Newsletters, our Annual meeting, information on our research into 'Forest Health' ,our 'Wider forested landscapes research', and our Education pages.

Our main social media platform is Twitter, our twitter handle is @BIFoRUoB

FACE Experiments
Context - extract from Hart et al (2019) paper

Extract from Hart et al (2019) **Hart, K.M.H, Curioni, G., Blaen, P., Harper, N., Miles,** P Lewin, K. Nagy, J. **Bannister, E., Cai, X.M., Thomas, R., Krause S.,** Tausz, M., **MacKenzie, A.R**., (2019) Characteristics of free air carbon enrichment of a northern temperate mature forest *Global Change Biology*, https://doi.org/10.1111/gcb.14786

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The 'greening' of the terrestrial surface across planet Earth has been driven by changes to the dynamics of vegetation and their interactions, to a large extent, with increasing levels of carbon dioxide (CO_2) in the atmosphere (Forzieri, Alkama, Miralles, & Cescatti, 2017; Zhu et al., 2016). The land carbon sink currently absorbs 20%–30% of CO_2 released by human activities (Le Quéré et al., 2018) and a large proportion of this absorption is by woody vegetation (Gaubert et al., 2019). This sink activity is largely ascribed to the fertilization effect of increasing atmospheric CO_2 concentrations (Schimel, Stephens, & Fisher, 2015), especially through the stimulation of growth and carbon sequestration in established, mature forest ecosystems (Luyssaert et al., 2008). However, the future magnitude of the land carbon sink, as atmospheric CO_2 continues to increase (at least until mid-21st century), is uncertain. Modelling of future C-uptake rates ranges from 0% to 30% of human CO_2 emissions, across the suite of Earth systems models used by the Intergovernmental Panel on Climate Change, Working Group 3 (Friedlingstein et al., 2014). The uncertainty in the sensitivity of the land C sink to increasing atmospheric CO_2 is due, in large part, to a lack of experimental data on mature forest ecosystems under future elevated [CO_2] (e[CO_2], Ellsworth et al., 2017; Norby et al., 2016). In the northern hemisphere, where about 40% of the net uptake occurs, highly seasonal mature forests dominate the land carbon sink (Luyssaert et al., 2008). Our experimental knowledge of how such forest ecosystems respond to further increases in [CO_2] is based on few 'first-generation' Free Air CO_2 Enrichment experiments (FACE), either on young, vigorously growing forest plantations (Hendrey, Ellsworth, Lewin, & Nagy, 1999; Norby et al., 2006) or on small seedlings or saplings (e.g. Dickson et al., 2000; Kubiske et al., 2015; Smith et al., 2013).

Free Air Carbon Enrichment (FACE) experiments allow plants and trees to be exposed to elevated levels of carbon dioxide (e[CO_2]) under open-air, ambient conditions; CO_2 is supplied using a circular array of vertical tubes engineered to release jets of CO_2 enriched air on the windward side of the ring. Ambient wind is relied upon to diffuse the CO_2 into the ring. By contrast, although technically easier to engineer, chamber CO_2 enrichments can produce effects greater than that produced by elevated CO_2 alone, or amplify downregulation of CO_2 (Morgan et al 2001).

A somewhat different ('WebFACE') free-air methodology targeted canopy exposure of mature trees, but did not quantify the CO_2 field around the treated trees (Klein et al., 2016) and was not suitable for biogeochemical budget studies. Since the closure of important 'first-generation' forest FACE experiments—'Duke FACE' in an evergreen loblolly pine stand (Hendrey et al., 1999), the Oak Ridge National Laboratory FACE in a young deciduous sweetgum plantation (Norby et al., 2006), and the AspenFACE that followed aspen and poplar seedlings over a decade (Dickson et al., 2000; Kubiske et al., 2015)—the scientific community has advocated for large-scale, ecosystem-plot-sized FACE experiments in important forest ecosystems (Calfapietra et al., 2010; Norby et al., 2016).

The 'EucFACE' experiment in an open, Mediterranean-type sclerophyll forest in Australia (Drake et al., 2016) is the first such 'second-generation' forest FACE, which has been operating since September 2012;

Although numerous FACE experiment have been conducted on crops, there are significant challenges in installation, operation and time-scale when applying the technique to tree species. For this reason, there have been relatively few FACE experiments on trees, and even fewer on mature stands.

Summary of main forest/woodland FACE sites

Web FACE (Switzerland) – Mature forest (~100 year old some trees), Beech, Oak, other mixed deciduous. CO_2 530 ppm. Since 2000, still ongoing
Duke FACE (US) – (Duke Uni and Brookhaven National Lab) Loblolly pine plantation (~15 years old) in N Carolina 4 rings with CO_2 ambient+200ppm since 1996 – now ceased
Oak Ridge (US) – Tennessee. Sweetgum plantation (~15 years old). CO_2 550ppm
EucFACE (Australia) – Cumberland plain forest, dominantly Eucalyptus. Native woodland. 6 rings 3 control and 3 treatment, similar to BIFoR. Started 2012 ongoing. CO_2 550ppm.
Bangor FACE (UK) – Bangor Wales. Birch, Alder, Beech (< 20 years old), CO_2 ambient +200ppm. 2004-2009 in operation, now stopped CO_2 treatment

Figure 1 Other FACE experiments worldwide

A suggested further reading list is available. In particular the Norby et al paper.

Fundamental Research Questions

The BIFoR FACE facility will address the following fundamental questions regarding the ability of woodland to capture carbon dioxide:

- **Does elevated CO_2 increase the carbon storage within a mature woodland ecosystem?**
- **Do other macro- or micro-nutrients – i.e., nitrogen, phosphorus - limit the uptake of carbon in this ecosystem?**
- **What aspects of biodiversity and ecosystem structure-and-function alter when the ecosystem is exposed to elevated CO_2?**
- **How can lessons from the global network of second-generation Forest FACE experiments be generalised to other woodlands and forests?**

BIFoR FACE Description

A more in depth description of the site and the baseline measurements are currently being written up into an academic paper. You can contact the BIFoR Administrator to request a draft copy / to contribute to the paper.

Figure 2: Mill Haft woodland is set in arable woodland mosaic

To see a high resolution map of the site, click on the following link
Map of the site in High Resolution

Location

The private woodland of Mill Haft is set in the wider Norbury Estate and is located at Ordnance Survey Grid Reference SJ 799 223. It lies immediately to the south of Norbury Junction, 1.7 km to the south of the A519, 3 km north-west of Gnosall village, 5 km north-east of Newport and 12 km west of Stafford. Mill Haft is approximately 800 metres in its longest axis by 300m wide and covers an area of 21 ha. The research area (in the fence line) is 7.3 hectares. Directions to BIFoR FACE are available in this document.

Figure 3: Mill Haft location, ST20 0FJ, Staffordshire

The site comprises broadleaved woodland, principally formed by oak (*Quercus robur*) with a hazel (*Corylus avellana*) understorey, with areas of more recently planted coniferous plantation present in some locations. It is bound by agricultural land to the north, east and south and by Norbury Road to the west. The Wood Brook, a minor watercourse, runs through the site along the northern boundary. There are a number of existing woodland trackways throughout Mill Haft which are currently utilised for estate and woodland management purposes. The wider landscape comprises mixed farmland interspersed with small woodland parcels. The Shropshire Union Canal and Norbury Canal Junction is located to the west of the site. The topography of the site generally falls from east to west toward the Shropshire Union Canal with an overall change in ground level of approximately 10 m; additionally, the northern extremes of the site fall from the north-west towards Wood Brook.

Site History

The Mill Haft woodland is part of the Norbury Park Estate. The areas of woodland on the estate are typical of woodlands found within the wider landscape mostly comprising deciduous semi-natural or ancient woodland although with areas of more recently planted conifer species. There is evidence that the management of these woodland blocks has varied with time. For example some woodland blocks are dominated by oak standards with a hazel understorey which shows evidence of historical coppicing. Other areas have been cleared and replanted with fast growing conifers or a mix of native deciduous species. In addition, some of the previously arable fields have been planted with many thousands of native woodland tree species over recent years. Woodlands within the site have been used for rearing game birds in the recent past which has resulted in the understorey being allowed to develop to provide cover in some areas

A preliminary review of online historical mapping indicates that the site has been woodland since pre 1881 and appears to have been generally unchanged since that date. The historical map for 1881, indicates the presence of former quarry, gravel and marl pits surrounding the site. It is anticipated that the features were backfilled at a later date. Two of the features shown are currently used as ponds located adjacent and approximately 135m to the east of the site.

Close to the facility is the Shropshire and Liverpool Junction Canal. Famously Lord Anson would not allow Thomas Telford's preferred route for the canal so the only option was a massive embankment, which starts just below the site of the junction, and is punctured by two road tunnels. Shelmore embankment proved difficult to engineer, as the marl soil used to build it kept slipping. Its construction, opening in 1835, altered the watercourses in the area and, amongst other drivers, may have been the trigger for the change of land use to oak plantation at Mill Haft

Also close to the facility is the Aqualate Mere Nature reserve. This site is designated under RAMSAR as an internationally important wetland reserve for its habitats and overwintering wildfowl populations.

Furthermore north of the facility is Loynton Moss nature reserve, a unique landscape formed by retreating ice sheets at the end of the last age, 10,000 years ago. Doley

Common is also 1km east. This is 17Ha of agriculturally unimproved grassland containing a nationally rare and threatened marshy grassland community.

Further information (heritage)

Ecological Description

The site mainly comprises broadleaved woodland with a stream and water-bodies also present. It is bounded to the north by arable fields, to the south by semi-natural broadleaved woodland and semi-improved grassland, to the west by Norbury Road and by semi-improved grassland to the east. The wider landscape comprises arable and pastoral farmland, woodland and the Shropshire Union Canal.

The woodland provides optimal habitat for badger and in 2014 three setts were noted within the woodland; one active main sett, one semi-active outlier sett and one active outlier sett.

Each tree that has a stem diameter greater than 10 cm has been given a unique number and is mapped on GIS. Basic information on trees across the site is available, more detailed information is available for trees within the arrays. Information can be requested via the BIFoR Data Manager."

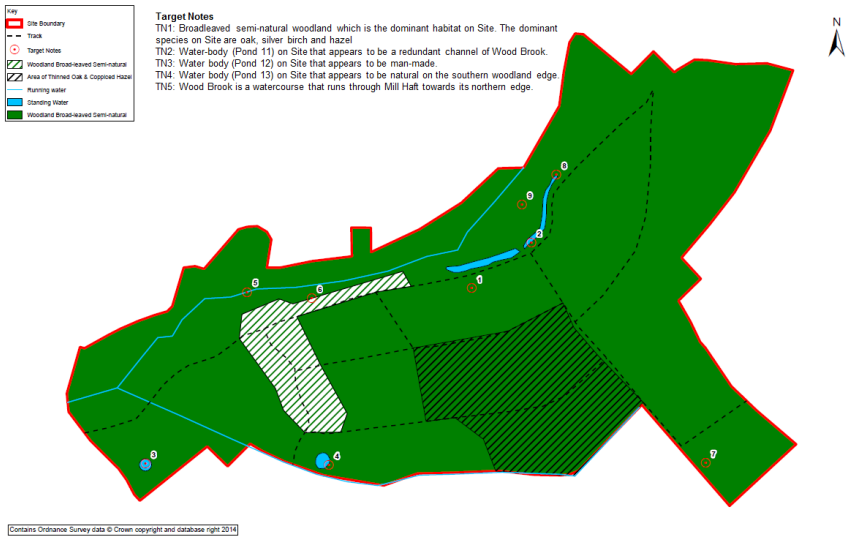

Figure 4: Habitat Map of Mill Haft – a site of Biological Importance. From WSP Phase 1 Habitat Survey Report 30/06/2014

The following documents related to the initial ecology of the site are available.

Great Crested Newts report
Botanical Survey Sept 2014
Extended Phase 1 Ecological Survey June 2014
Badgers
Flood Risk (including Geology information)
Initial Air Quality statement September 2014
Geotechnical Group Investigation report – Includes old maps & historic images 2014
Habitat Survey – June 2014

Tree Survey – August 2014 [From Tree survey]:

Tree species, number, age, management, etc

Understorey, type spread, existing Pests and diseases

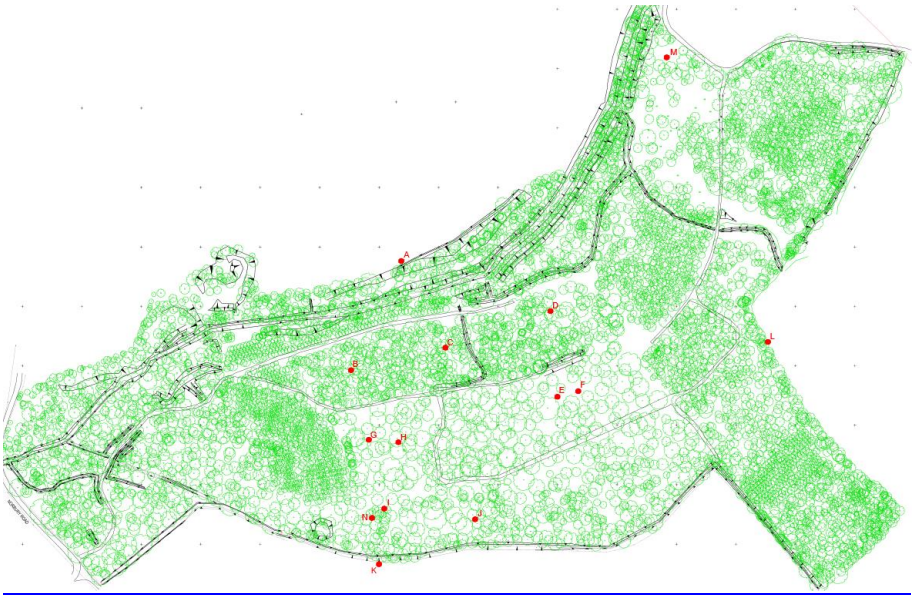

Figure 2~~5~~ Tree survey across the site

Geology and Hydrology

Extract from **Blaen, P. J.,** Khamis, K., Lloyd, C., **Comer-Warner, S.,** Ciocca, F., **Thomas, R. M., MacKenzie, A. R**., & **Krause, S**. (2017). High-frequency monitoring of catchment nutrient exports reveals highly variable storm event responses and dynamic source zone activation. *Journal of Geophysical Research: Biogeosciences, 122*, 2265-2281. doi:10.1002/2017JG003904

Wood Brook river (see image below) is a second-order stream which drains a 3.1 km^2 catchment ranging elevation from 90 to 150 m above mean sea level and is situated in a nitrate vulnerable zone (a conservation designation for land draining into nitrate-polluted waters; Directive 91/676/EEC). Land use was dominated by arable farming of potatoes and winter wheat and a mixture of young and mature deciduous woodland, primarily English oak (*Quercus robur*), hazel (*Corylus avellana*), hawthorn (*Crataegus* spp.), and sycamore (*Acer pseudoplatanus*). Young woodland areas were planted with saplings in 2014, prior to which the land was used for arable farming for more than 20 years. Tile drains are present in some arable and young woodland areas of the catchment. In spring 2016, arable farmland areas were dosed repeatedly with soil fertilizer (ammomium nitrate and ammonium sulfate) with application rates of 45–80 kg N/ha, which are typical for these crop types in the UK. Catchment geology is composed of red Permo-Triassic sandstone overlain by superficial deposits of glacial till up to 10 m thick, with organic-rich, sandy clay topsoils between 0.15 and 0.6 m thick.(Blaen, 2017)

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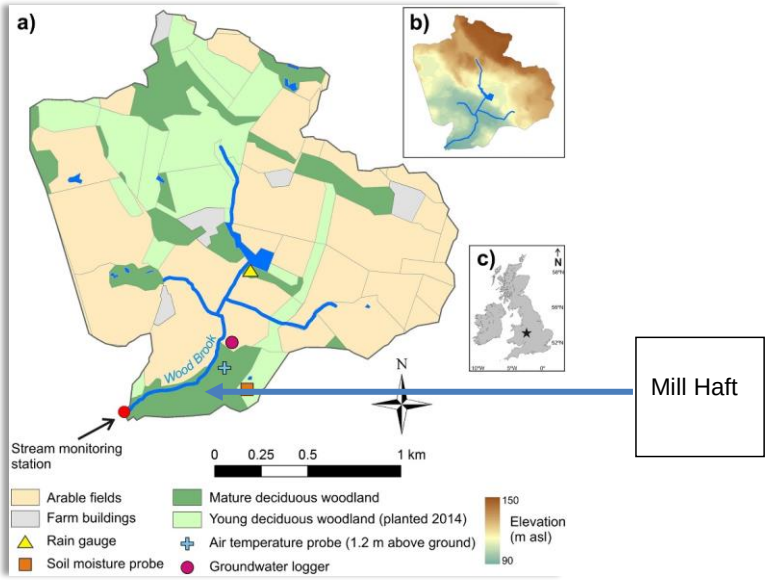

Figure 36 Blaen et al (2017) Map of catchment showing (a) location of stream monitoring station and dominant land cover distribution, (b) land surface elevation, and (c) location within the UK.

General Site Meteorology

The nearest Met Office surface weather station is situated 10 miles to the west at Shawbury. Based on proximity and a comparison between the available Mill Haft meteorological data collected so far, Shawbury serves as a good proxy for conditions at Mill Haft (Figure 7) and historical Shawbury wind speed data has been used to predict experimental CO_2 usage. Figure 7 displays Shawbury surface climatology over the period (1981 - 2010).

Mean annual temperature at the site is 9°C, and mean annual precipitation is 690 mm [*Norby et al.*, 2016]. Less than the mean UK average of 660 mm/yr.

Period	Max. Temp (°C)	Min. temp (°C)	Days of air frost (days)	Sunshine (hours)	Rainfall (mm)	Days of rainfall >= 1 mm (days)	Monthly mean wind speed at 10m (knots)
Dec - Feb	7.3	0.8	36	171	158	33	8.7
Mar - May	12.9	4.1	14	442	149	32	8.3
Jun - Aug	20.1	10.6	0	549	167	29	7.3
Sep - Nov	13.9	6.2	9	292	187	33	7.5
Annual	**13.6**	**5.4**	**60**	**1454**	**660**	**126**	**7.9**

Figure ~~4~~7 Wind rose data indicates a south westerly trend

The climate at Mill Haft (and the UK in general) fits with the general UK Köppen–Geiger Cfb class, where the warmest month is less than 22 °C on average with four months above 10°C on average. The domination of the polar front leads to changeable, usually overcast weather, with ocean currents reducing the annual temperature variability resulting in cool summers and mild winters. Anecdotally (from local forester) there is some variability in phenological indicators, such as first leaf flushing, due to temperature gradients across the site associated with orientation relative to the southerly sun position.

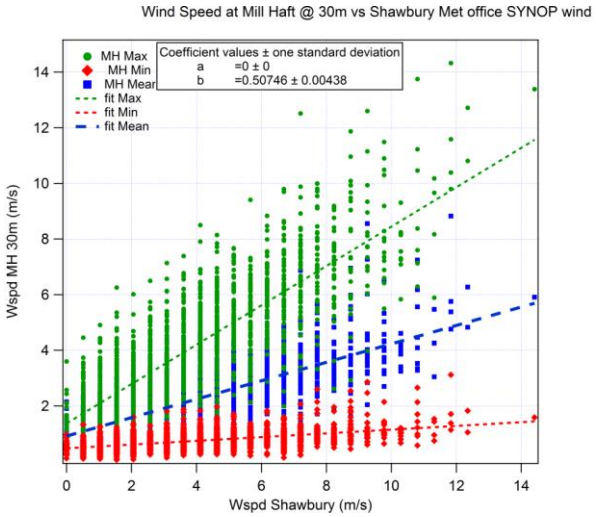

Figure 58 Mill Haft data at 26m (3m above canopy) is approximately 50% of Shawbury measurements. Shawbury data are taken at 10m in an open field setting.

Extract from Hart et al (2019) **Hart, K.M.H, Curioni, G., Blaen, P., Harper, N., Miles,** P. Lewin Nagy, J. **Bannister, E., Cai, X.M., Thomas, R., Krause S.,** Tausz, M., **MacKenzie, A.R**., (2019) Characteristics of free air carbon enrichment of a northern temperate mature forest *Global Change Biology*, https://doi.org/10.1111/gcb.14786

FACE facilities have a simple scientific aim—that is, to subject ecosystem patches to consistent elevated [eCO_2]—but are complicated to engineer. In order to meet the science aim without altering other environmental parameters, the CO_2 fumigation must be accomplished using infrastructure that minimally influences canopy structure, environmental aerodynamics and microclimate. BIFoR FACE consists of nine experimental patches of forest, three infrastructure arrays dosing air +CO_2, three infrastructure arrays dosing with ambient air only and three noninfrastructure patches Fumigation of 30 m diameter patches is accomplished using approximately circular arrays of 16 free-standing la towers, supporting perforated pipes from which premixed air/CO_2 is released from the upv quadrant.

The operating target is an enhancement of [CO_2] of +150 µmol/mol (150 parts per million by volume) above am tment array. Daily fumigation times, on in the r r elevation.

The first y 4) and lasted until 27 October (300) 201 rmined using current and previ years' phe nt is due to run until 2027.

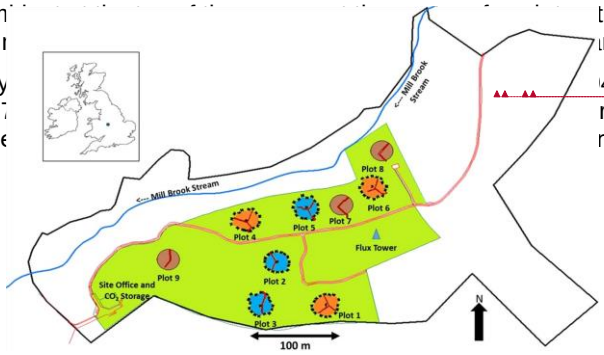

Figure 9 Schematic map of the BIFoR FACE facility within Mill Haft wood

Schematic map of the BIFoR FACE facility within Mill Haft wood. Main access road highlighted in red. Mill Brook stream (blue line) passes through the northern periphery of the wood flowing NNE to WSW. Fumigated (e[CO2]) arrays highlighted in orange, infrastructure controls (delivering ambient air) are highlighted in blue, and noninfrastructure control arrays are highlighted in brown. All nine arrays contain elevated walkways, highlighted in red, to minimize footfall on the forest floor. Blue triangle denotes the position of a 40 m lattice tower ('Flux Tower') and location of an atmospheric sampling laboratory. Site office, CO2 storage and evaporation facility at bottom left next to the main entrance from the public highway. The green area represents the total experimental area controlled by the University of Birmingham covering 7.3 ha. The thick black line shows the border of the greater forest covering 19.1 ha. Inset map shows location in the UK

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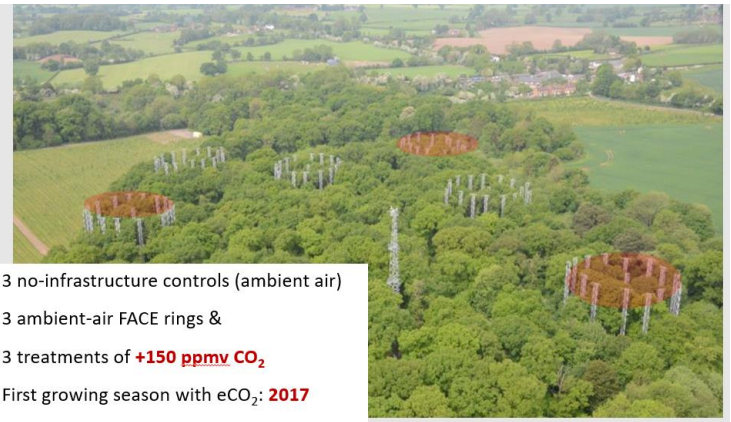


3 no-infrastructure controls (ambient air)

3 ambient-air FACE rings &

3 treatments of **+150 ppmv CO_2**

First growing season with eCO_2: **2017**

2015/16 baseline; eCO_2 **2017-2026**

Carbon Dioxide Supply

The suppliers of the CO_2 to BIFoR FACE are - have always been - Air Liquide. The CO_2 is delivered in a liquid form. It arrives by tanker almost every day and is stored in the 3 large storage tanks (image right). The CO_2 comes from an ammonia fertilizer plant in Cheshire and is at food grade quality, BIFoR FACE has storage for 120 tonnes overall. On average 24.5 tonnes is used per day so the storage tankers hold enough to last 4-5 days in case of emergencies such as motorway closure. The CO_2 added to the woodland has an isotopic signature different to the one occurring naturally in this region, so there is a potential to detect where in the ecosystem the carbon being added is going once it has been fixed by the plants during photosynthesis.

Rick Thomas
04/04/2017 & 15/05/2017

CEH Lancaster LSMSF node NERC Services and Facilities
United Kingdom Accreditation Services ISO17025 accredited

	Date sampled		$\delta^{13}CO_2$	Duplicate analysis	Average
T1	30/06/2016	BIFOR CO2 Storage Tank	-6.43 ‰	-6.45 ‰	-6.44 ‰
T2	11/07/2016	BIFOR CO2 Storage Tank S2	-10.44 ‰	-10.35 ‰	-10.40 ‰
T3	11/07/2016	BIFOR CO2 Storage Tank S3	-13.28 ‰	- 13.27 ‰	-13.28 ‰
T4	01/02/2017	Bleed off from Evap 1 CO2 from NH3 plant	-22.32 ‰	-22.62 ‰	-22.47 ‰
T5	28/02/2017	BIFOR CO2 storage tank S3	-26.61 ‰	-26.53 ‰	-26.57 ‰
T6	04/04/2017	Ambient Air Mill Haft Blank	-11.39 ‰	-11.54 ‰	-11.46 ‰
T7	04/04/2017	Millhaft CO2 store tank	-27.36 ‰	-27.16 ‰	- 27.26 ‰
T8	06/04/2017	Mill Haft CO2 gas sample	- 27.95 ‰	-27.93 ‰	-27.94 ‰
T9	06/04/2017	Mill Haft tanker sample 12:10	-27.80 ‰	-27.72 ‰	-27.76 ‰
T10	10/04/2017	Mill Haft bulk 11:30 superheater	-29.51 ‰	-29.48 ‰	-29.49 ‰
T11	12/04/2017	Mill Haft 9:00am Tanker DJ0128069	-27.17 ‰	-27.04 ‰	-27.10 ‰
T12	21/04/2017	Mill Haft tanker 12:15	-28.34 ‰	-28.21 ‰	-28.27 ‰
T13	24/04/2017	Mill Haft tanker	-26.88 ‰	-26.84 ‰	-26.86 ‰
T14	03/05/2017	Mill Haft storage 14:00 hrs	-28.54 ‰	-28.61 ‰	-28.57 ‰

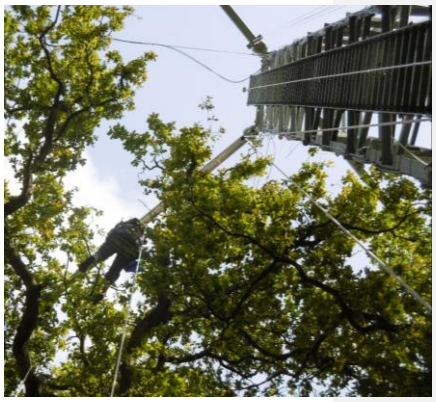
Figure 10 CO_2 supply information

Flux Tower and Flux Tower Laboratory

A permanent laboratory is situated at the foot of the 40 meter flux tower (installed Nov 2017). It provides housing for mass spectrometers and other equipment as well as some bench space. The lab has internal and external power and data capacity. A driveable pathway leads to the tower which allows mobile labs access. The flux tower was installed at the same time as the main infrastructure in early 2016.

Flux Tower Equipment				
Description	**Height (m)**	**Make**	**Model**	**Comments**
CO_2/H_2O Enclosed Path	40	LiCor	LI7200RS	Eddy Flux
CH_4 Probe open Path	40	LiCor	LI7700	
Smart Flux System	40	LiCor	LI7550	Eddy Flux
Wind Master Pro 3D	40	Gill	R3-50	Eddy Flux
Net Radiometer	40	K&Z	CNR4	Temp. probe not functioning
Tipping Bucket Rain Gauge	40	Texas Electronics	TR-525M	
Quantum PAR Sensor	40	LiCor	LI190	
Relative Humidity	40	Vaisala	HMP155	
Phenocam	40	StarDot	NetCam SC	
Quantum PAR Sensor	20	LiCor	LI190	
Relative Humidity	20	Vaisala	HMP155	

Canopy Access System (CAS)



BIFoR enlists the help of local tree surgeons monthly from March to October to collect leaf and twig tissue from 3 heights in the canopy in each of the 9 arrays. For further information refer to section 4 of the Physical Samples & storage document and the Green Leaf Protocol.

A canopy access system (CAS) for researchers is in place in Arrays 1 to 6. This system was installed Spring 2018. At the top of each 25 meter high central tower, a cross bar extends from the tower, to a maximum of 4 metres. The length of each cross bar differs between arrays dependant on the proximity of the trees. A winch system can be moved between arrays and connected to a researcher's choice of cross bar and also at their specified distance away from the central tower. The electric ascender system is operated by the BIFoR Operations team who have all had considerable training and deemed competent persons, however the researcher does not need prior training in order to be a user of the CAS.

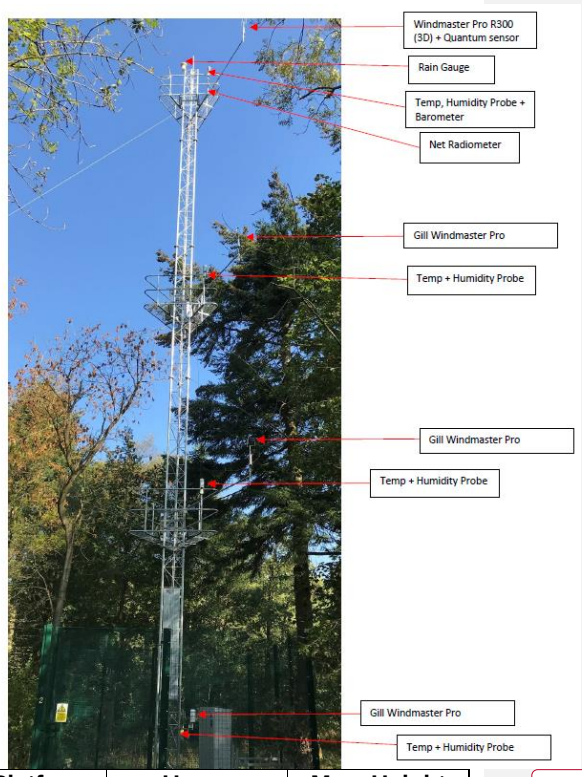
Ground-level walkways

Aboveground walkways are in place in arrays 1 – 9. These were installed autumn 2017. They are Glass Reinforced Plastic (GRP) style walkways situated approx. 15cm above the forest floor have been installed to transect each plot from North to South to minimise foot traffic. These reduce ground compaction within the research plots. GRP walkways are gridded panels that provide anti-slip surfaces that allow light and water to pass through freely. Each plot has a bespoke design that works around existing tree stocks, woody debris, science equipment and local gradients. Users are able to exit the walkways at any point within the plot by removing a chain link, this allows access to the entire plot while reducing footfall.

Met Masts

There are four met masts around the around perimeter of Mill Haft (image right). These are with the same meteorological equipment (see link below), they are connected to the BIFoR grid. The met masts were installed in November 2017 and the instrumentation was installed autumn 2018,

[BIFoR Measurements and Equipment List]



The following is a brief update of where we are with the installation of equipment on the 4 met masts located on the edge of the wooded areas of Mill Haft.
Each tower varies in height with rest platforms installed where equipment is installed. The heights above ground level are as follows:

Tower	Lower Platform	Mid Platform	Upper Platform	Max. Height
1	5.5	12.5	24.0	26.0
2	5.5	12.5	22.0	24.0
3	5.5	12.5	25.5	27.0
4	5.5	12.5	20.0	22.0

Equipment list:
The following equipment was ordered and installed, list per tower. On the rest platforms, height equals tower platform height in meters + 1.115 m as boom arms are extended off platform hand rails:

	Equipment	Qty	Height Location
1	Gill Instruments R3-100 Sonic Anemometer	1	Upper Platform
2	Gill Instruments Windmaster Pro Sonic Anemometer	3	Mid Platform; 10 m; Lower Platform
3	LI-190R Quantum Sensor	1	Upper Platform

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4	Kipp and Zonen NR Lite 2 Net Radiometer	1	Upper Platform
5	Texas Electronics TR-525m tipping bucket rain gauge	2	Maximum height; Ground Lvl (0 m agl)
6	Vaisala PTB 210 Barometer and pressure port	1	Upper Platform
7	Vaisala HMP155 humidity and temperature probe + shield	4	Upper Platform; Mid Platform; Lower Platform; Ground Lvl (1.4 m agl)

All equipment will be wired into the logger cabinet which is located at the middle platform height. Each cabinet has two 12v power supplies (1 per logger), backed up by a 12v recreation grade battery on charge to provide a continuous power supply in the event of a power outage. Each logger also has its own data connection to the infrastructure cabinet at the base of the tower. Inside the cabinet will be two data loggers, a CR1000x and a CR6.

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BIFoR DATA

Intellectual Property and Data Protocol

Everyone completing research at BIFoR FACE needs to read the BIFoR FACE Intellectual Property and Data Protocol in advance of starting research - this includes undergraduate / masters students. In summary the maximum scientific exploitation of BIFoR FACE depends on the **collaborative utilisation of all data** collected at BIFoR FACE for research. The BIFoR FACE science community believe and advocate transparency in science assured through **open data** after an agreed period of **privileged use**. All data acquired through BIFoR FACE projects will be deposited in a **shared database** in good time and with appropriate accompanying metadata after consultation with the BIFoR Data Manager. A scientist **sharing data does not relinquish ownership** of that data but recognises that all BIFoR FACE data will become open data, with due care taken to record data **provenance**, in a timely manner in order to ensure transparency, to be compatible with the requirements of funding agencies, and to accelerate scientific advance.

Data Management

The Data Manager for BIFoR is Dr Giulio Curioni g.curioni@bham.ac.uk. He was recruited autumn 2019.

BIFoR Research Data Store (RDS) Access

There are 4 BIFoR Research Data Stores.

1 - a store of processed and unprocessed data used interactively by researchers. Data may not be properly organised.
2 - a store for large files such as photos and videos (see photo gallery)
3 - a store for processed / clean data. This store should be used to download data but no data should be removed or modified without first contacting the BIFoR Data Manager.
4 - a store for raw data (particularly raw core data such as weather data, CO_2 delivery data). Access is restricted to the BIFoR Data Manager and a few other key BIFoR members.

A request to access the RDS can be made to the Data Manager. Currently access to the RDS is available only to those with a @bham.ac.uk email address. Historically, all data should have been saved on the BIFoR Research Data Store by researchers directly themselves. A naming convention was created for folders by Dr Rick Thomas, this can be found on the RDS to help explain how data prior to Giulio Curioni's appointment was stored. However, as stated above new researchers are encouraged to talk to the Data Manager to work together to discuss meta data and discuss use of agreed common data formats and metadata fields to ensure compatibility.

RDS - how to access the RDS (once permission has been granted - UoB only)

Live Data

Live images and data are publicly available from a phenoCam mounted at the top of the 40 meter high flux tower at the BIFoR FACE Facility
https://phenocam.sr.unh.edu/webcam/browse/millhaft/

Live stream data from the Wood Brook stream that runs alongside the BIFoR FACE Facility is also publicly available (NOTE Sept 2020 - this site is not live) .

Live Data for University of Birmingham staff on campus only

To follow are some links to live data available to staff and students based at the University of Birmingham, we are looking into how we can share this more widely with those off campus.

81.149.196.87:666/Bifor_Web_V1/index.html (Air Temp, Soil Moisture, Rainfall, all plots)
81.149.196.87:666/Bifor_LAI/index.html (Nick Harper's test page testing some ideas)
81.149.196.87:666/Nick_Test_P/index.html (Nick Harper's interpretation of an Overview, PAR, Air Temp, Soil Temp, all plots)
81.149.196.87:666/Bifor_SAP/index.html (SAP, Transient Heat Transfer with Air Temp and PAR, all plots)
81.149.196.87:666/BiforSAP_NJH/index.html (SAP, Transient Heat Transfer inverted for my display, with Air Temp and PAR, all plots)

Practicalities of completing research at the BIFoR FACE Facility

Process for starting research at BIFoR FACE

BIFoR-FACE runs as an international field facility for environmental research and prospective users of the Facility and/or its data MUST complete an initial enquiry form online. This form MUST be completed by internal and external colleagues that wish to commence a formal grant application, PhD studentship, request data or even a short pilot project, no matter how speculative. The form is short and should only take 5 minutes to complete. Once submitted it goes to Dr Kris Hart (Secretary for the Science Access Committee), Rob MacKenzie (Director), Deanne Brettle (Administrator) and Giulio Curioni (Data Manager). This way everything can be logged and the 'Science Access Committee' can be made aware of the larger proposals to ensure the larger aims are being met etc. Once the form is received the Secretary for the Science Access Committee (Dr Kris Hart) opens a line of communication to ensure the FACE facility is a) being costed into proposals correctly, b) the current resource is able to accommodate requests, c) the proposal joins a log of proposals to demonstrate facility use and users. For resubmissions of proposals to funding bodies after a form was submitted or withdrawn projects, simply maintaining communication with Kris Hart should be sufficient to keep things under control. It is extremely important that we maintain a central point to keep track of all the research activity that is taking place at FACE, and especially what is planned for in the future.

Undergraduate students and masters students must also complete a form, this is a shortened version, we need a signed copy of this, so we a) be sure they will submit their data and b) have the written consent (if they agree) to hold their dissertation in our shared library.

Project Form – initial enquiry
Project Form - detailed
Student Enquiry Form - Undergraduate / Masters student project

Process for including FACE access costs into research proposals

When FACE costs are to be built into research grant proposals it is important to first complete an initial enquiry form, so the Science Access Committee, are aware of your intentions and can work with you and the Research Support Office to make sure BIFoR FACE access costs are properly costed into the proposal. It is the BIFoR Operations Manager that estimates these costs upon completion of the enquiry form and possibly some follow up questions. The BIFoR Operations Manager welcomes the opportunity to talk about site access costs even before the Project Form is completed should potential users have any concerns regarding costings.

In order to function as an environmental modification facility, BIFoR FACE requires full-time operation throughout every growing season from now until 2027. However, scientific engagement with BIFoR FACE can take many forms. Use of BIFoR FACE varies from the requirement for **small numbers of tissue samples** from treatment and control plots, to **long-term instrumental monitoring** of physical, chemical or biological parameters away from the FACE facility but making use of the broader infrastructure and research support the facility provides. When considering BIFoR

FACE as a facility, it cannot, therefore, be treated analogously to a 'white box' that is switched on when required by a user and moth-balled in between. A **charging model** has been developed based on full economic costing and the full capacity use of the facility. The charging model balances scientific exploitation of the facility with the principle of equitable cost-sharing.

The charging model places prospective users in one of 9 bands based on the maturity of the research (i.e., proof-of-concept works vs mature grant-funded research) and the duration of the measurements (i.e., one-off samples vs long-term measurements).

Please note if applying to the Natural Environment Research Council (NERC) standard grants scheme, they have agreed that BIFoR FACE is one of just a few research facilities that when submitting a proposal there is an exception that funds greater than the £0.8million can be requested (see extract below).

Extract from the NERC Research Grants and Fellowships Handbook, Feb 2020. Section 14 and 15 which references BIFoR FACE.

14. If in exceptional cases the research proposed requires resources above the £0.8 million limit, but is unable to meet the scale and complexity of research required in the Large Grant scheme, applicants may contact NERC prior to submission to request permission to submit a standard grant proposal that exceeds the maximum funding limit. Please note that as shiptime and/or marine equipment costs are not calculated prior to submission for standard grant proposals it is not necessary to request exceptional permission to exceed the standard grant maximum based on these anticipated costs.

15. Where the proposal includes costs for the GEF Ocean Bottom Instrument(s), GEF seismometer(s), FAAM/ARSF/BAS Twin Otter aircraft (the facility will be able to advise on eligible instrument or aircraft costs), EISCAT Radar facility, BIFoR FACE facility or other ship-time or marine facility related costs and as a result of these costs alone, the requested budget is greater than the £0.8million limit, please e-mail researchgrants@nerc.ukri.org at least 2 months before the call closing date and confirm:

- Principal Investigator (lead PI if joint proposal)
- Research Organisation
- Intended Standard Grant call closing date for submission
- Project title
- Estimated total cost at 100% fEC (for the whole project if a joint proposal) and the cost and details of the exceptional elements (the GEF Ocean Bottom Facility, GEF seismometer, FAAM, ARSF, BAS Twin Otter, EISCAT Radar facility, BIFoR FACE facility or other ship-time or marine facility related costs)

The requested budget minus these facility costs must not exceed the £0.8million limit.

Process for requesting site access

There are two important things to consider:

1) Giving due notice to the site team
   It is imperative that the BIFoR FACE facility, Technical Team have at least one work days' notice of for any intended visit to the FACE facility. This will allow them to organise the daily/weekly schedules and better facilitate research needs. The Technical team must also have the opportunity to ask people not to attend on certain days. Refusal to enter the site will occur only under extreme circumstances or when the resources are stretched beyond capacity to cope.

   There is a shared calendar in outlook where all University of Birmingham professional services staff, research staff and students can look to see what is happening at BIFoR FACE. Your planned visit to BIFoR FACE needs to appear in this calendar and that of the Technical team too. Please note undergraduate

or masters level students cannot access the calendar, due to IT constraints. Instructions on how to access / add to the calendar are in document link below
Calendar - How to access /add an appointment to the BIFoR FACE calendar

2) Ensuring all paperwork including risk assessment and method statements are complete
Before any new research activity is to be completed at BIFoR FACE the team there must be provided with a Risk Assessment and Method Statement (RAMS). The correct form is available by clicking on the link below

RAMS template form

Risk Assessments and Method Statements Examples (For Deanne memory Z:\BIFOR_FACE_DISK_to_SORT\BIFOR_Backup\BIFOR_SHARE_OFFICE\A_Risk_Ass_Method_Stat)

BIFoR FACE Induction

Before being allowed into the BIFoR FACE facility, all researchers, sub-contractors, visitors and volunteers must have an induction. For day visitors arriving just for a tour of the site, a verbal induction is given, for all others they must read and sign the relevant Induction Sheet. The induction sheets contain the "Intellectual Protocol" document too.

Induction Sheet Researcher
Induction Sheet Sub Contractors
Induction Sheet Volunteer

Process for requesting canopy access

Researchers requiring access to the Canopy Access System, must give the technical team a minimum of 2 weeks' notice. The CAS coordinator is Peter miles and any specific questions should be sent to him. The intention to complete research in the canopy should be communicated in a Risk Assessment & Method Statement (RAMS) and at the start of each year so the team can forward plan the significant human resource needed to operate the system.

Requesting Field Research Technician support

Researchers requiring support from the two field research technicians based at the FACE facility should put their request in writing to the BIFoR Operations Manager. Workloads need to be carefully managed, due respect will be given to the fact that weather related changes of plan do sometimes happen.

Travel to the BIFoR FACE facility

It is very difficult to reach the BIFoR FACE facility using public transport. The nearest main train station is Stafford, a one-way taxi trip is circa £20.00. Return journeys by taxi from BIFoR FACE to Stafford need to be booked in advance as most taxi firms will need to send a driver from Stafford, the return journey would also be circa £20.00. Car hire can be arranged through the UoB Transport dept. Car hire costs should be referred to the appropriate grant or school fund. In some rare cases the

costs can be attributed to the BIFoR FACE account but only with prior arrangement with the project administrator and/or the BIFoR Operations Manager.

Directions to the BIFoR FACE Facility
Car hire / other transport hire eg minibus / large transit van
Driving at Work Risk Assessment

Accommodation nearby

The nearest local accommodation is the Quirky Bird B and B, this is within walking distance of the BIFoR FACE facility. Please call Helen Keyzor on 07790356678 to book a room. The Quirky Bird is set up as a supplier on New Core, but cannot be booked through Key Travel.
The following hotels are a 10+ minute drive away
The Swan at Forton
The Premier Inn (Newport) 4.7 miles
Travel Lodge (M6 Stafford) 8.1 miles
Travel Lodge (Stafford city centre) 8.3 miles
Travel Lodge (Newport) 10.7 miles)
Travel Lodge (Newport Shawbirch 10.9 miles)

Lab space available at BIFoR FACE

There is currently very limited lab space at the BIFoR FACE facility. However, there are plans for a new lab to be installed in the forest in the coming year. It is vital that when using the space, you do not leave items out, you must tidy away after yourself. A complete audit of equipment is available (see link below). However, to follow is a reduced list that might provide the was frequently asked questions around what equipment is available in the lab:

- Cameras
- Incubator oven
- Drying oven
- Larder fridge
- Larder freezer
- -20 chest freezer
- Scale 6000g x 1g
- bench balance
- bench stereo microscope
- LED magnifying lamp
- label printer
- centrifuge
- Laser distance finder

Equipment_BIFoR FACE Facility

Transporting samples for -80 degree storage

BIFoR has a dry shipper available for transporting samples from the facility to the campus. A COSHH form has been completed for this activity. Training on how to use the dry shipper MUST be taken before using the dry shipper and only those with the training may handle the dry shipper during it's time away from campus. Contact Celia Smith to arrange the required training C.Smith.12@bham.ac.uk

Dry Shipper COSHH form
Dry Shipper Operation instructions

Physical Samples and storage

The Science Access Committee member who is assigned responsibility for sample storage and future storage is Professor Vincent Gauci.

In early 2020, Pro-Curo 'sample tracking' software was purchased which will be rolled out for the summer 2020 season. Pro Curo will be used throughout the University of Birmingham College of Life and Environmental Sciences. The Data Manager is the best point of contact regarding Pro- Curo software.

A recording of how to use Pro-Curo is available the passcode to access the talk is ~~is~~ " l.5=W9eu "
Link to Pro-Curo Talk

In the meantime until the software is rolled out, when physical samples are removed from the BIFoR FACE facility it is necessary to complete a "chain of custody form"

Chain of custody form

There are nine types of baseline sample routinely collected that require storage facilities at the University of Birmingham:

1. Leaf litter
2. Rain water
3. Leaf wax
4. Canopy
5. Entomological samples
6. Seeds
7. Microbial cultures
8. Fungal biopsies
9. Soil

Further information can be found in the following document NB this was created Nov 2019

Physical Samples from BIFoR FACE

BIFoR FACE People

Academic leads

Rob Mackenzie (Director), Rob Jackson (Director) and Carolina Mayoral (Post-doctoral researcher) have the overview of all research being completed at the BIFoR FACE facility.

BIFoR Science Committee

Prof Christine Foyer - leading on a large conference for 2021
Prof Vincent Gauci - leads on campus space
Dr Estrella Luna-Diez - leads on the grant pipeline
Dr Sami Ullah - leads on paper pipeline

BIFoR Professional Service Staff

- denotes they are part of the Technical Team / Site staff

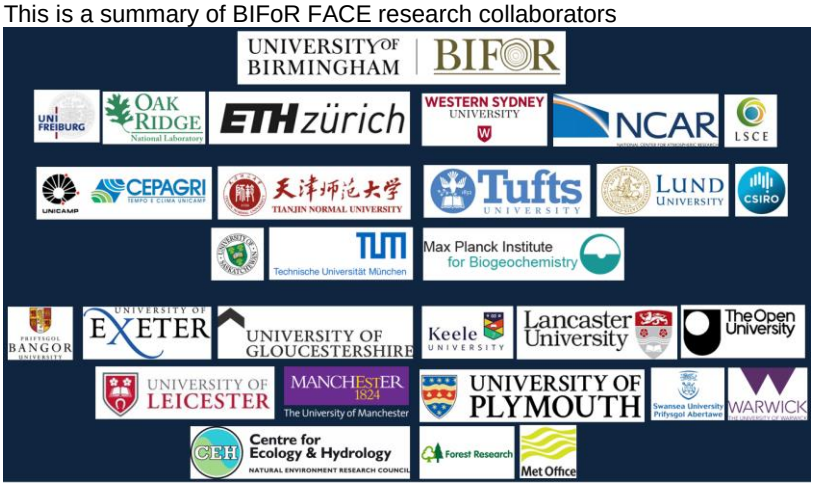
Deanne	Brettle	Project Administrator	d.brettle@bham.ac.uk
Giulio	Curioni	Data Manager	g.curioni@bham.ac.uk
*Gael	Denny	Field Technician	dennyg@adf.bham.ac.uk
*Tom	Downes	Apprentice Engineer	T.M.Downes@bham.ac.uk
*Robert	Grzesik	Research Technician, QUINTUS	R.T.Grzesik@bham.ac.uk
James	Gore	Research Technician, QUINTUS	J.Gore@bham.ac.uk
*Nick	Harper	Senior Engineer	N.J.Harper@bham.ac.uk
*Kris	Hart	Operations Manager	K.M.Hart@bham.ac.uk
Angeliki	Kourmouli	Research Technician, QUINTUS	A.Kourmouli@bham.ac.uk
Hannah	Martin	Research Technician, FACE Underground	H.M.Martin@bham.ac.uk
*Peter	Miles	Field Technician	P.Miles@bham.ac.uk

BIFoR Researchers

The BIFoR website lists the research team and is updated at least every 6 months
https://www.birmingham.ac.uk/research/bifor/research/research-team.aspx

BIFoR Collaborators

This is a summary of BIFoR FACE research collaborators



Volunteers

The volunteer coordinator for BIFoR is Deanne Brettle. Volunteering with BIFoR has gone from strength to strength, more information about BIFoR volunteering is available on our blog site https://biforuob.wordpress.com/info/ In summary since 2016 we have recorded 2,800 hours of volunteering time with BIFoR - these hours have been completed mainly by UoB undergraduate students, and include a mix of both volunteering on campus and field based volunteering at the BIFoR FACE facility. It is our duty to keep them safe and so a guidance document has been pulled together. If you are considering taking or meeting a volunteer at the BIFoR FACE facility you MUST follow the guidance. You should consider it like you are running a field trip and in summary:

- you must make sure they are registered on our insurance
- you must go through the risk assessment for the activity
- you must have an 'In Case of Emergency' contact detail for each volunteer
- you must ensure they complete a medical details form beforehand.

Any personal data collected must be treated in line with the University of Birmingham GDPR rules

Volunteering with BIFoR for volunteers
Guidance for having a volunteer
Volunteer Medical Form

~~BIFoR Community~~

University of BIFoR lead on two NERC funded projects which have BIFoR FACE research at their core. The £3.7m NERC large grant QUINTUS and the NERC standard grant FACE Underground. There is also a University of Manchester led NERC project "Disentangling mechanisms of co-adaptation between trees and soil food webs in response to environmental perturbations"

There are many more projects and measurements of course and a list of these and the equipment we have in-situ / available can be found in the following document

Ongoing measurements and projects

All science equipment is also plotted onto GIS maps which are available on request through the BIFoR Technical Team

BIFoR Outputs

A list of BIFoR papers is on the website, those marked with an * are related to BIFoR FACE

Future projects / student projects

We would like to keep track of future projects that could be undertaken at BIFoR FACE. Most of this information is captured in the Funding Pipeline document held by Estrella Luna-Diez. However, as we don't wish to miss "blue sky BIG ideas" or

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smaller “student dissertation” sized projects information is captured in the following document

Student / future potential projects/ student projects

Other Useful Information

Further Reading

A list of further reading is available
Reading - further reading

Adding BIFoR affiliation on PURE (UoB Staff / Students)

‘Pure’ is a Current Research Information System (CRIS) used by the University of Birmingham, collecting information about Research, researchers, publications and much more. It brings together information from several university systems collecting, storing and integrating information in a structured and standardised way, reducing duplication of work and supporting both internal and external processes.

Academic staff and post-doctoral students should automatically be given a ‘Pure’ user account. To login go to https://pure.bham.ac.uk and enter your normal university username and password. If you have not been given a user account and would like to have one, this can be requested from the IT help desk - select ‘Make a request’ and choosing ‘Set up access to Pure’.

Your researcher profile defaults to your school, however BIFoR can and should be added as a second/third address or changed to a primary address, just go to “add affiliation” and search Birmingham Institute of Forest Research (BIFoR).

Acknowledging BIFoR philanthropic donors in papers

The BIFoR FACE facility is a research infrastructure project supported by the JABBS Foundation and the University of Birmingham.
The facility has received support for scientific studies from the JABBS Foundation and The John Horseman Trust.

Presentations

The BIFoR Logo is available in various formats on the Bear Data Share site It is best practice to use the “Lockup” version of the BIFoR Logo. This is the University of Birmingham preferred branding. The BIFoR green colour is Pantone 450 (C = 60, M=50 Y=100 K=22)

There is now (Jan 2021) a common BIFoR colour palette, for presentations. Details are available
Colour Palette

A template PowerPoint presentation (link below) and examples of previous BIFoR presentations are available on the Research Data Store / upon request to the BIFoR Administrator.

Template PowerPoint presentation

Photo Gallery

A gallery of frequently used images of the BIFoR FACE facility is available on the website and also on Bear Data Share
One of the RDS stores stores (see BIFoR Data) is reserved for large files such as videos and photos. The photos 2015-2017 have been tagged and so you can search for an image using tags. A list of the tags is available below
Gallery of BIFoR FACE Images - clicking on this will download whole Gallery (very large download)
Photo tags - a list of the tags used for the BIFoR shared photo and video store

Letter Head

BIFoR Lead Headed paper

Memberships

IUFRO

The International Union of Forest Research (IUFRO). We have a membership that allows 20 academics to register to be part of their various divisions. All 20 spaces have been assigned, the divisions covered are

1. Silviculture
5. Forest Products
6. Social Aspects of Forests and Forestry
7. Forest Health
8. Forest Environment - Ecosystem functions
9. Forest Policy and Economics

List of academics registered with divisions in brackets

Francis Pope (1,7,8)	Stefan Krause (8)	Zongbo Shi (7,8)	David Maddison (9)	Frank Uekotter (9)
Rob MacKenzie (6,7)	Tom Pugh (2,4,7, and 8)	Emily Prestwood (8 and 5)	Nicola Spence (7)	Rebecca Bartlett (7)
Estrella Luna-Diez (7)	Graeme Kettles (2,7)	Rob Jackson (7)	Vincent Gauci (1,7,8)	Liz Hamilton (7,8)
Rosa Sanchez Lucas (7)	Adriane Esquivel-Muelbert (1,4)	Josep Barba Ferrer (1,7)	Michaela Reay (2,7,8)	TBC Florian Busch

Arboricultural Association
Ecological Continuity Trust
Royal Forestry Society

Contact the BIFoR Project administrator for further information

Journal subscriptions

We will be organising a subscription to the 'Forestry Journal'. We will consider taking out subscriptions to journals upon request. Contact the BIFoR Project administrator if you have a suggestion.