Institution: The Open University

Unit of Assessment: B7

1. Unit context and structure, research and impact strategy

1.1 Introduction

The Open University (OU) supports a vibrant Earth Systems and Environmental Sciences (B7 Unit of Assessment, UOA) community across two Schools in the Faculty of Science, Technology, Engineering and Mathematics (STEM). The Unit consists of 31 submitted researchers (28.9 FTE), including four early career researchers (ECRs). 13 research associates (RAs) and 27 postgraduate research students (PGRs) are also supported by the Unit.

Research is grouped into six thematic areas (Figure 1) that span the dynamics and evolution of the Earth system, determination of habitability on Earth and beyond, and anthropogenic environmental impact. Foci include evolution and management of biodiversity; carbon and nutrient cycling; the geological distribution of natural resources; and the interconnections between the natural environment, resources and human society. Five of these areas are hosted within the School of Environment Earth and Ecosystem Sciences; the sixth within the School of Engineering and Innovation.

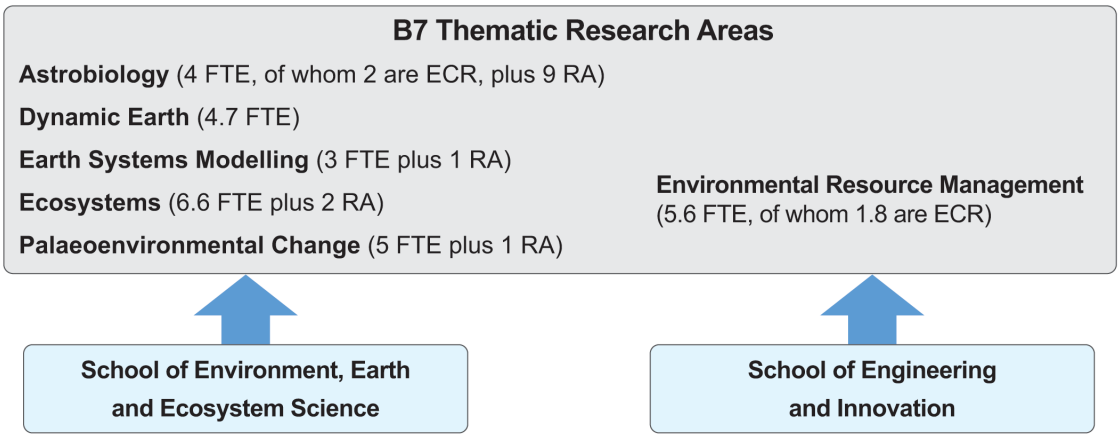

Figure 1 *Organisational chart showing how the thematic research areas are organised in OU UOA B7, including numbers of submitted full-time equivalent (FTE) staff. ECR= early career researcher; RA = research associate.*

Strategic leadership is provided by School-level Directors of Research (DoR), supported by School management teams and the research theme co-ordinators. The thematic areas are run as inclusive, collaborative and innovative groups that contribute to School and Faculty annual strategic research plans, share ideas, develop avenues for external funding and train/support ECRs and PGRs.

1.2 Achievement of Strategic Aims for Research and Impact

In REF2014, researchers submitted to UOA B7 were based in the cross-departmental Centre for Earth, Planetary, Space and Astronomical Research. A University reorganisation in 2015 allowed activity around areas of sufficient critical mass and vitality to be reconfigured in support of a more sustainable B7 research base. Since then, the overarching strategic objective of the Unit has been to reorientate focus towards grand-challenge environmental issues, notably the impacts of climate and environmental change, through increased participation in large-scale interdisciplinary research consortia and engaged research.

This objective has been realised through 13 permanent staff appointments, targeted to develop strength in Ecosystems research (now the largest research theme), support the development of Environmental Resource Management, and introduce a new interdisciplinary group (Astrobiology). Formal and informal peer-support mechanisms have increased contributions to interdisciplinary research, evidenced by participation in large collaborations (e.g. CENTA, FAMOS, IODP and LC3M; Sections 3.1 and 4.1).

Notable research findings deriving from these externally-funded internationally-collaborative efforts that have received international academic and media attention include:

- constraining the climate effects of carbon release events during thermal maxima in the geological past;
- linking changes in modern carbon dioxide levels to forest productivity;
- determining the role of ice-cliff instability in regulating Antarctic ice loss;
- the impact of global climate change on human evolution, and
- discovering the role of cycles of magmatism in delivering critical elements such as copper from the mantle to the Earth's surface.

Five REF2014 objectives have informed Unit planning:

Provision of a supportive and broad research environment:

The Unit provides an environment in which all researchers are enabled to excel through targeted investment (Section 3), workload allocations, formal and informal career support and mentoring (Section 2), and regular research meetings and seminars. This School-level support complements and supplements the Faculty-level Research, Enterprise and Scholarship team of 15 staff who support bid development and facilitate postgraduate student administration.

Since 2015, the Unit has run a dedicated Earth and Environment-specific "Proposal Support Process" (PSP), that supports pre-award planning from idea generation through to submission, incorporating upstream impact planning. The PSP has facilitated collaborative working, sharing of experiences and higher quality bidding. The experienced panel consists of seven academic and research support staff, selected for diversity in gender, research discipline and career stage. The process runs twice per year, in each case consisting of a series of meetings, moving from an open, exploratory discussion to generate ideas and connections, then successively refining the most novel and fundable options through to proposal submission in three further stages, with associated additional mentoring. The meetings also provide a forum to consider opportunities arising at short notice. Where quotas apply, proposals are ranked for institutional support at an appropriate point based on scientific excellence.

Through this support, Unit researchers were supported to win 97 grants encompassing £8.2m external research funding and £6.7m for developing research capacity and infrastructure within the REF2021 period (Section 3.1). Our open-access peer-reviewed outputs showcase the Unit's breadth in interdisciplinary science linking environmental and social change across modern and ancient environments.

Support for, and delivery of, interdisciplinary research

Bids are supported by School and Faculty support teams; interdisciplinary funding opportunities above c. £1m are additionally supported by a University support team. The PSP panel includes researchers with extensive experience leading and convening large-scale interdisciplinary consortia. Interdisciplinary engagement is promoted through the University's centrally funded Strategic Research Areas (SRAs), which convene meetings and provide support for networking events. Individuals leading the development and delivery of large bids are offered project management training and are allocated dedicated time in their workload plans (Section 2).

As an example, the pathway to the success of the 2019 £6.7m Research England grant supporting the AstrobiologyOU Centre was paved by support from the OU Space SRA for an earlier £10m OU-led Leverhulme Centre bid demanding a c. £9m OU commitment to overheads. The AstrobiologyOU Centre now involves >50 researchers in microbiology, planetary science, law, international development and education working across three OU Faculties, three OU SRAs and with international organisations and developing countries. The Centre is submitting researchers to five REF2021 UOAs.

Support for, and delivery of, high-impact research

Impact is at the centre of all Unit research activities, which have been further developed through a targeted approach. Since REF2014, we have built on interventions developed through the OU's RCUK-funded Public Engagement with Research Catalyst, which defined "engaged research" and provided a framework for interaction with stakeholders throughout the research process, including through the PSP. Led by EEES' Head of School and Professor of Engaged Research, it forms a core element of our impact strategy and the interventions managed through the PSP. Specific recommendations have been embedded into the Unit's research culture:

- creation of a dedicated impact lead role, responsible for delivery of the Unit's knowledge exchange strategy, and the REF2021 Impact Case Studies (ICSs),
- specific staff workload allocation for impact activities, including the development of ICSs,
- targeted internal funding for realising and evidencing impact,
- provision of impact and engagement training for all Unit researchers,
- recognition of excellence in impact through career progression (Section 2).

Since 2014 the Faculty additionally employed a dedicated Impact Manager who helps develop pathways to impact in funding bids, and who supports the development, communication and implementation of impact of awarded projects.

Our commitment to engaged research as a methodology for generating and evidencing impact is demonstrated by two key examples. Firstly, two permanent posts were created for supporting knowledge-exchange within the Unit. Secondly, the upstream integration of engaged research played a key role in developing the AstrobiologyOU Centre: alongside excellent science, the Centre also explores the ethical, governance and international development challenges faced by astrobiology-related exploration missions.

Capitalising on expertise in communication and science engagement

Through workload and funding allocations, the Unit's expertise in communication and engaged research has been leveraged to generate impact. For example:

Workload was allocated to 12 Unit researchers to contribute scientific expertise to nine prime-time BBC TV (46 hours) and radio (84 hours) documentary series. These included Blue Planet II, Blue Planet Live, Earth from Space, Springwatch and Inside Science, which collectively reached 216.5m citizens. By shaping narratives and ensuring scientific accuracy, Unit researchers influence public understanding and debate. Posters and booklets prepared by Unit researchers were sent to over 830,000 enquirers following these broadcasts. Opportunities for related public presentations allowed Unit researchers to generate impact. These engagements have led to nearly 1.5m visits to B7-related content on OU open-access learning platform OpenLearn in the first few weeks after broadcast.

Continued financial and workload allocations for academic and PGR training in engaged research has ensured that the Unit's expertise is recognised nationally and internationally in doctoral training partnerships funded by NERC (CENTA) and the EU (FluidNET).

Building on expertise developed through a series of high-profile citizen-science projects, including climateprediction.net and iSpot, financial support was provided for a major citizen-

science initiative, Treezilla, that supports citizens, local authorities and businesses to co-produce a 'Monster Map of Trees'. The development of a stable OU-hosted web platform has facilitated new partnerships and knowledge exchange with forestry trusts and councils about the ecosystem service value of trees.

Finally, Unit research underpins 20% of the interactive activities hosted in the multi-award winning OpenScience labs, including the Virtual Microscope. Site usage on the latter increased by ~400% since March 2020 to ~1000 daily users due to the pandemic-related increase in online geoscience teaching.

Investment in areas of strategic promise

The Unit, supported at School, Faculty and University level, invests strategically in areas deemed to have potential for major future growth. Since 2014, the supported thematic areas, or specific projects within them, have included Astrobiology (Section 1.2), Dynamic Earth and Ecosystems.

Institutional funding to the elemental geochemists in the Dynamic Earth theme supported the purchase of a cutting-edge laser ablation ICP-MS instrument to develop capability in green and sustainable energy solutions. The ICP-MS has maximised our pre-existing world-leading expertise in measuring volatile elements in volcanic glasses and has facilitated the development of conceptual models for economic critical mental deposit formation. Three NERC consortium grant successes have resulted from this investment (Section 3.1).

Institutional recognition of the strategic importance of the Treezilla database for both research into forest sustainability and related impact led to targeted funding for the development of a stable web platform and support for developing new relationships with database-holders such as Forest Research, the National Trust, Treeconomics, and local authorities. Treezilla is now the UK's largest crowdsourced open tree map (>830,000 records, >300 active users engaging in citizen-led ecosystem services valuations of urban trees). Increased dialogue across the sector has already led to the development of a new standard for urban tree data collection and the implementation of state-of-the-art data analysis and display tools for end-users.

1.3 Supporting Open Access and Research Integrity

Since 2014, Unit researchers have deposited ~500 items in OU open access repositories ORO (~350 articles) and ORDO (~150 data items). Open access data and code are also integrated into OU teaching materials on OpenLearn and within the OpenScience Lab and deposited in international repositories including Pangea.de, GitHub, Dryad and the National Geoscience Data Centre. Unit researchers publish in open access, open review journals, deposit preprints in repositories such as EarthArXiv and bioRxiv, and contribute to the open access community as editors and on external scrutiny boards (Section 4.6).

Our technicians are supported to succeed in gaining Continuing Professional Development certifications including Science Council Registration and the NEBOSH Certificate in Occupational Health & Safety, in line with the OU's commitment to the Technician's Charter.

1.4 Future Strategic Aims and Goals for Research and Impact

Our vision for the next REF period is to evolve the Unit's unique approach to engaged research through large-scale, interdisciplinary projects addressing grand-challenge societal problems. Unit-level strategic research plans are reviewed annually in response to external drivers and to maintain coherence with Faculty and University strategies. The Unit's future objectives are to:

Broaden and diversify income through supporting large-scale interdisciplinary project activity:

We will align our thematic areas (Figure 1) more closely to areas of major interdisciplinary opportunity, and responses to the climate emergency, building on the established record of

strategic funding awarded to the Environmental Resource Management and Astrobiology teams from grant bodies and industry, specifically:

- Dynamic Earth towards industrial strategy and mineral resources through our current research in lithium and copper geo-systems.
- Ecosystems towards global-change impacts, ecosystem services, technology, and citizen science.
- Palaeoenvironmental Change and Earth System Modelling towards planning for a net zero-carbon emission future.

Formal and informal mentoring and our Proposal Support Process will be key enablers in realising this goal.

Develop engaged research communities:

The Unit has a strong record of contract research with industry and third-stream income particularly around Environmental Resources Management and Ecosystems, including providing evidence and policy-relevant understanding to government bodies, and developing practical solutions to real-world problems with businesses. Seven of our 37 PhD studentships in the REF2021 period were supported by external funding (Section 2.4).

Through responsive and responsible approaches to knowledge exchange we will facilitate the development of further enterprise activity through a programme of engaged research, including researcher training, mentoring, collaborative activity and support to engage with key external stakeholders and relevant external events. We will develop a broader range of formal or informal industry or policy partnerships and secondments for all academic staff, PDRAs and PGRs.

Areas already identified for targeted support include:

- using engaged research approaches to seek shared solutions to plastics in the oceans, soil and atmosphere;
- supporting emerging case studies, e.g. developing online distributed collaboration through citizen science initiatives, such as Treezilla and iSpot;
- policy and economic impact associated with climate-economic interactions modelling research;
- legal and governance impact of planetary protection research.

Broaden the representation of our research community, embracing equitable and inclusive practices:

The Unit is committed to implementation of the Schools' EDI and Athena SWAN action plans and was a co-author of, and has responsibility for, points targeting the research area.

Our part-time staff and those on agile working arrangements, along with staff returning to research activity after periods of parental or sickness leave, or career breaks have additional challenges to engage as productively with research. We will develop and target our mentoring programme to be more inclusive and to meet the needs of these diverse groups.

Through the PSP and mentoring schemes, we will encourage researchers to address EDI and we aspire to diverse representation across all internal and external research partnerships and through all stages of activity, including pre-award planning and post-award delivery.

2. People

2.1 Introduction

The Unit comprises two independent research fellows (both ECR, 1 Female (F), 1 Male (M)), seven lecturers (5F of which two are ECR, 2M), 16 senior lecturers (8F, 8M) and six professors (3F, 3M). Staff demographic and changes since 2014 are shown in Figure 2. The Unit has

recruited 11 lecturers (6F, 5M), two senior lecturers (1F, 1M) and six postdoctoral research fellows/associates (3F, 3M) since 2014. Within these, five were externally- and OU-funded research fellows (4F, 1M) who accepted open-ended contract positions at the end of their fellowships; two were Daphne Jackson return-to-career fellows. Within the assessment period, we have had a maximum of two Category-A eligible staff employed on fixed-term contracts at any one time. Three members of staff initially on short-term teaching-related appointments have been converted to permanent standard academic contracts.

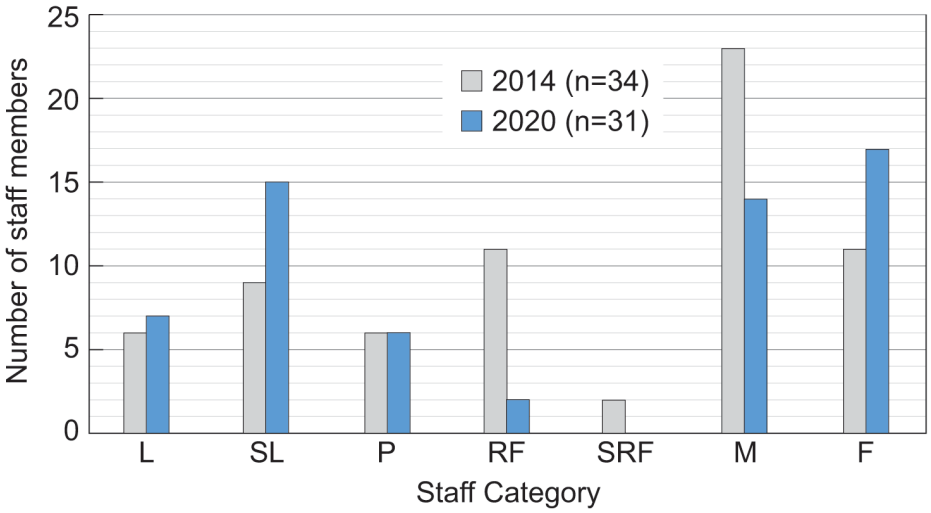

Figure 2 *Histogram showing changes in staff demographic in OU UOA B7 since 2014. (S)L = (Senior) Lecturer (including Reader), P= Professor, (S)RF = (Senior) Research Fellow; M=male, F=female.*

2.2 Staffing strategy

Staffing strategy has focused on developing and strengthening the sustainability of the research themes described in Section 1 whilst also working towards a more diverse and balanced staff demographic. The proportion of submitted female academics is now 55%F (compared to 23%F in REF2014, Figure 2) and we have increased the proportion of women in leadership positions. A key Unit focus is to implement and monitor specific actions for improving equality, diversity and inclusion practices in research (Section 2.5).

2.3 Staff development

The Unit's success is predicated on identifying, supporting and nurturing excellence appropriate to career stage across all aspects of the academic portfolio. All new staff are allocated dedicated mentors and 'start-up' funding for research.

2.3.1 Career Development, Staff Appraisal, Mentoring and Training

All staff, at whichever career stage, have full access to School, Faculty and University-wide support systems including the well-resourced, central Research Career Development hub. The Unit also provides dedicated proposal support, conference attendance funding, networking opportunities and seed-funding for research, enterprise and knowledge exchange projects.

All staff participate in a University-wide annual appraisal with interim 6-monthly review to consolidate progress, develop future objectives, identify training/development needs and managed academic workload. Workloads are managed to encourage and foster a balance between engaged research, high- quality distance education and service to the wider community. Dedicated research/impact workload allocations (44-79 days depending on School norms) may be taken as blocks or dispersed time.

ECRs are additionally offered tailored support within the Unit from experienced, independent mentors, including assistance with internal and external funding applications, independent fellowship applications, designing effective PhD projects and offering effective PGR supervision.

The Unit supports and delivers Earth and Environment-specific and engaged research training for all staff. Training in broader career aspects such as career progression, search, supporting others and EDI aspects are offered by qualified experts at an institutional level.

2.3.2 Promotion, Recognition and Reward:

The Unit supports staff working towards academic promotion along pathways that include knowledge exchange as well as research. Since REF2014 nine submitted academics were promoted to senior lecturer and four to professor.

Formal recognition for excellence in research and related activities also comes through annual School-level Merit Award (16 awarded to female, 18 awarded to male staff since 2014) and Salary Increment allocations (20F, 9M), and through University-level Research and Impact Awards (Astrobiology was awarded runner up in 2019). We successfully nominate our staff for national and international recognition: in 2019 one of our technical support staff won the Times Higher Education Outstanding Technician of the Year award.

2.4 Postgraduate Researchers (PGRs)

The Unit hosts a vibrant research student environment, graduating 4-6 PGRs per year. Since 2014, 37 PGRs have completed their PhDs, three of whom studied part-time. Non-academic partnerships co-fund PhD studentships across our portfolio. Over the REF2021 period the Unit has trained seven externally co-funded PGRs, through Earthwatch, Operation Wallacea and the Floodplain Meadows Partnership. 21 additional studentships were funded through NERC/EU, eight through University-funded studentships and one through industry support. The Unit is a key (and founding) partner in the central England NERC-funded CENTA doctoral training partnership (DTP).

2.4.1 Recruitment:

The Unit recruits PGRs in accordance with University fair selection and recruitment policies with emphasis on recruitment panel independence and diversity considering gender, ethnicity, research field, and experience.

In 2019/20 Unit academics changed recruitment practices to address a national lack of ethnic and socio-economic background diversity in Earth and Environmental Science PGR cohorts. These changes have been adopted across the CENTA DTP and encompass broader evidence of research aptitude, diversity in academic journeys, wider evidence for problem-solving skills and adjustment for individual circumstances.

Declared disabilities can lead to adjustments for interviews following best practice and treated in confidence. Diversity data is collected, anonymised and tested for potential bias to improve future recruitment.

2.4.2 Supervision, Monitoring and Training:

All PhD projects are designed and supervised by at least two OU-based supervisors, with attention paid to supervision team diversity. Supervision teams commonly also include external (academic or industry) supervisors to ensure that the PGR is exposed to a diverse range of expertise. PGRs are assigned an independent Third-Party Monitor to provide additional pastoral care and an independent/confidential route for raising concerns. School-based Postgraduate Research Tutors (PGRT) provide additional pastoral care and guidance as required. Formal supervision meetings take place weekly to fortnightly, and their progress is monitored by University-level reports twice yearly.

PGRs are offered project-specific training by their supervision team, centralised training through the OU Graduate School and CENTA, and specific Earth and Environmental Science training, including in engaged research, through the Unit.

2.4.4 Integration into research culture:

All Unit PGRs, whether full or part-time, are provided with dedicated on-campus office space (3-5 per room), a networked computer and IT resources, and full access to the library and laboratory facilities. PGR integration into the Unit's research culture is supported through regular thematic area meetings, paper discussions and weekly research seminars. Collaboration on research papers outside their PhD projects and input into grant proposals is also supported and encouraged.

PGRs are encouraged and financially supported to present their research at national and international conferences and to disseminate their work to a wide audience through, for example, live events, social media, blog posts or other platforms. School funding is available for presentation for at least one international conference. Since 2014, five Unit PGRs have won (inter)national prizes and recognition for their poster and oral presentations, research publications and public engagement work. Examples include an invitation to become Artist in Residence at EGU 2020/21 and a shortlisting at the Bristol Science Film Festival for "The Great Geo Bake Off!" in 2018.

2.4.5 Career support:

The Unit has an excellent record of helping its PGRs to identify their strengths and support them to develop outstanding research and transferrable skills for their chosen academic or non-academic career paths.

Industry: PGRs are encouraged to apply to the Santander Scheme, which provides funding for 3-to-9-month industry placements; two PGRs have used this opportunity to gain critical career-related experience for instance in national science policy. All CENTA-funded PGRs undertake a funded two-week work placement to explore future options and build networks outside academia.

Teaching: PGRs are encouraged to engage with online teaching experience including designing assessments and multi-media activities and supporting students on Massive Open Online Courses (MOOCs). Conventional face-to-face teaching opportunities are provided through residential schools and supporting school-level and undergraduate work-experience students through the Nuffield and NERC Research Experience Placement schemes (Section 4.4). Since 2014, six of our students have also gained school-level teaching experience through the Brilliant Club.

Application and CV mentoring: The OU Graduate School and Unit provide general and tailored training respectively for identifying and showcasing research and transferrable skills in CVs, cover letters and interviews.

All 37 PGRs we have trained since 2014 have found meaningful employment in both academic and non-academic fields. Eight have continued with careers in academic research through postdoctoral, technical and lectureship positions since 2014. Four have qualified as secondary school science teachers. The others have all achieved success in other professional careers such as in the science media (e.g. Wild Space Productions), marketing (e.g. Savills) and industry (e.g. Fugro).

2.5 Equality, diversity, inclusivity and accessibility (EDIA)

Both Unit Schools have dedicated EDIA leads who proactively ensure that the principles of equality, diversity and inclusion inform and support the School's overall business and practice, including allocation of workload for research, access to facilities (Section 3) and diversity of all panels and committees. One of our Schools has recently gained their Athena SWAN Silver

accreditation, the other has gained Bronze and is working towards Silver. Annual institutional staff satisfaction surveys and, more informally, discussions at quarterly School meetings allow issues to be identified and resolved, and to share best practice.

2.5.1 Recruitment and selection:

The Unit has successfully addressed an historical gender imbalance at all career stages (Figure 2). Participation in the competitive Advance HE Aurora programme (supported by central funds and School-level time allocation for career development opportunities) has specifically contributed to career success of three female academic and research support staff including promotions to professor and senior lab manager, and appointment as REF UOA co-chair. Current focus is on measures to improve the imbalance in minority (especially ethnic) group representation amongst our researchers.

2.5.2 Flexible and remote working:

Even before the Covid-19 pandemic, the Unit supported flexible working arrangements to allow for caring duties, religious beliefs and/or other requirements. Official meetings are arranged to take place within core working hours (10-4). Remote working has long been facilitated, with all Unit meeting rooms containing video-conferencing capability through large screens and conference-facility microphones (see also Section 2.6).

2.5.3 Career pathways for part-time and fixed-term staff:

Part-time staff in the Unit are afforded identical rights and privileges as full-time staff, including pro-rata study/research leave and holiday allocations. They have the same opportunities to be considered for promotion and other formal recognition. Individual circumstances are considered in promotion cases. Unit Schools have an excellent track record of converting fixed-term positions into permanent appointments. Bridging contracts to support staff between externally-funded fixed-term contracts are available.

2.5.4 Research support:

The Unit has a dedicated research budget to support staff. Requests for travel funding to research conferences or workshops may include extra costs incurred due to e.g. disability or caring responsibilities. To ensure fair allocation, the awarding panels are regularly trained in unconscious bias and fair selection. The diversity of staff being put forward for promotion, recognition, and new senior roles is regularly monitored.

Weekly research seminars run by the Unit were made remotely accessible in 2018 to improve access to the research community by our (teaching-focussed) regional staff, which put us in a strong position to adapt fully to remote seminars as a result of the pandemic.

2.5.5 Specific Support for Returning/Disabled Staff:

All Unit Schools are committed to fully supporting disabled staff and those returning to research activity following substantial leave, with arrangements agreed on an individual basis and following the University's agile working policy. This includes support for equipment and software, types of office space and workload considerations.

2.5.6 Wellbeing:

All staff and PGRs have access to the University online well-being resources, recreational facilities, and a free, independent, and confidential counselling service (OU Employee Assistance Programme). Four Unit members are trained as mental health first aiders and provide confidential advice and mental health sessions.

A central social hub and meeting place is provided by a large, dedicated and inviting space with adjoining kitchen facilities, and the Unit has undertaken specific actions to create an inclusive and supportive working culture. All Schools have regular informal refreshment break times at least once a day. There are annual away days and other social and recreational events including

various Unit-focussed sports teams. Following our EDI commitments all organised social activities are inclusive to all staff and PGRs considering access, focus and provisions.

2.5.7 Equality and Diversity in the REF submission:

The six-member OU B7 REF panel was chosen by the Chair to encompass diversity in gender, career experience and research discipline. REF-related workloads were included in annual workload plans, and tasks were allocated within the panel based on expertise and other immediate workload considerations. Workloads were reassessed on a monthly basis. The REF panel has worked within the best-practice guidance outlined in the University REF Code of Practice (CoP) including undertaking mandatory EDI training.

The Unit staff who were identified as having significant responsibility for research and research independence through the CoP reflect the staff demographic across the two Schools. They were each asked to submit up to seven outputs that they thought demonstrated their best research. Each output was assessed by at least two panel members using the REF scoring criteria. Each researcher was assigned their highest scoring output and the draft output list was populated with remaining outputs on the basis of their scores. The draft list was compared and adjusted against gender balance, research discipline and career stage of our researchers to ensure that our outputs list reflects our best research as well as the gender, career-stage and discipline diversity of our submitted researchers.

2.6 Covid-19 effects and mitigations

At the start of the first UK lockdown in March, all Unit staff and PGRs were allowed to transport home any IT and office equipment they required to continue their work. Appropriate portable equipment was arranged for delivery where required. Researchers were also allowed to collect materials such as samples, microscopes and other equipment from campus to facilitate research progress from home.

A particular challenge for the Unit's researchers was safely and efficiently supporting continuation of lab- and field-based research within the Government rules and guidelines. Business critical and time-sensitive field and lab work was supported by, and managed through, the Faculty Pandemic Recovery Group.

Since early July, when a phased return to campus was allowed, technical support staff have mitigated impact of the slow-down in data collection and training by revising risk assessments, upgrading instruments to allow remote access, using cameras to train and support researchers working in the laboratories and running more analyses themselves.

The collegiate research community that the Unit had previously benefitted from has been maintained as much as possible through weekly research meetings, School seminars and dedicated online "coffee times".

3. Income, infrastructure and facilities

3.1 Research funding and income generation strategy

Since 2014, Unit researchers have raised £8.3m of external research funding; the main sources being UKRI research councils (£3.5m) and UK industry (£3.2m). Figure 3a shows totals for each research theme. The overall average is £289k per FTE, Figure 3b shows the average per FTE within each research theme.

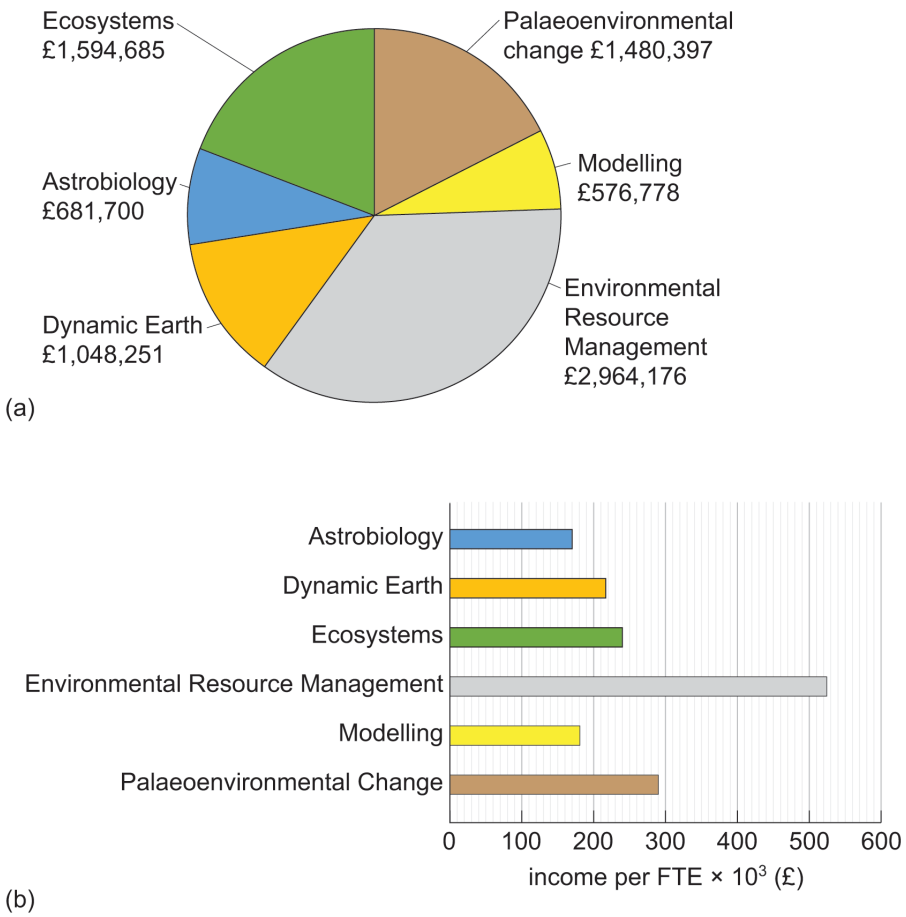

Figure 3 *Unit overall research funding by* (**a)** *research theme and* **(b)** *FTE per theme.*

The Unit's strategy for external income generation focuses on individual capabilities and internal and external collaborations, aiming to support researchers in progressing up the funding pathway from small internal pump priming projects to large consortia. Mechanisms include the Proposal Support Process (PSP, Section 1.2), targeted time, finance and workload resource allocation, horizon-scanning, networking and training, and pursuing synergy with major funding opportunities through the University Strategic Research Areas (SRAs). Examples of how the Unit's strategy has led to success include:

- Institutional investment in world-leading geochemical (laser ablation ICP-MS) analytical capability and support staff underpinned three successful NERC-funded international consortia: **Mantle Volatiles** (NE/M000427/, 2014-21), **TeaSe** (NE/M010848/1, 2015-2019) and **FAMOS** (NE/P017045/1; 2017-2022). These combined more than 15 academic and industry partners and supporting ten Unit researchers and PGRs. Major results, detailed in seven recent outputs, include constraining the role of cycles of magmatism in delivering critical elements such as copper from the mantle to the Earth's surface.
- Support for emerging fields related to University SRAs in Space, Governance, and International Development led to the creation of Astrobiology as a thematic area (Section 1.2). New collaborations underpinned by a further £620k in initial project funding from STFC, UKSA and the Royal Astronomical Society, led to the successful infrastructure grant of £6.7m from Research England that supports the AstrobiologyOU centre.
- A national technical guidance note was underpinned by trials in OU labs, bolstered by QR and HEIF funding to develop and refine pathogen testing contracts from the waste industry to develop and test compliance protocols per year, and to the development of the impacts outlined in the Waste ICS.

- Pump priming funding for drone-based ecosystem monitoring work and links to the Space and International Development SRAs has led to a series of successful grants from NERC, Research England, UKSA, STFC and the British Antarctic Survey totalling >£1.2m in funding and in-kind support for work on British, tropical and polar ecosystems in the UK, Africa, South America, Alaska and Antarctica.
- Staff time support for the Floodplain Meadows team led to multiple awards including £770,881 for impact- and policy-related work from the Esmée Fairbairn Foundation. This fed directly into the Floodplain Meadows ICS and related outputs.

3.2 Infrastructure and facilities

To facilitate the Unit's research strategy (Section 1.2), the OU has invested in extensive, dedicated and world-class specialist laboratories. Long-term sustainability is maintained through a diverse portfolio of external and internally funded "blue skies", applied research and in some research themes buoyant consultancy work.

3.2.1 Current and planned investments in infrastructure and facilities:

Since 2014 >£1.3m has been invested by the OU in upgrading Unit laboratory facilities, including improvements to sample preparation laboratories, expansion of the microbiology laboratories and consolidation/optimisation of instrument laboratories to accommodate and facilitate a rapid expansion of microbiology and waste resource research.

During 2013/14 a specialist waste 'field site' facility was constructed on campus. This site has facilitated research into food waste microbiology and how waste produces and releases bioaerosols; providing an important consultancy income stream and research data that has underpinned the Waste Management ICS.

3.2.2 Specialist infrastructure and facilities:

Specialist facilities across the B7 remit attract regular use from national and overseas researchers, as well as service-based consultancy which specifically underpins our waste management impact.

Mass spectrometry facilities include two Agilent quadrupole inductively-coupled-plasma mass spectrometers (ICP-MS) for solution or laser ablation analyses in conjunction with a Photon Machines Analyte G2 193 nm excimer laser system; Gas Chromatography (GC) gas analyses; MAP 215-50 and Nu Instruments Noblesse mass spectrometers coupled with laser ablation extraction for $^{40}Ar/^{39}Ar$ and noble gas analyses; a Thermo Delta and a MAT253 IR-MS for isotopic C, O, N, H analyses of organic and carbonate samples.

Elemental analysis facilities include an inductively coupled plasma atomic/optical emission spectrometer (ICP-AES / ICP-OES) for elemental analysis of aqueous samples; Absorption Spectrometry (AAS) for trace metal analyses; an elemental analyser for measuring organic and inorganic carbon and nitrogen; a Cameca SX100 electron microprobe elemental analyses of polished solid samples.

Microscopy facilities include a Zeiss Supra 55VP FEG-SEM, an FEI Quanta 3D FIB-SEM with CL capability, a remote-access desktop SEM Phenom XL Desktop SEM and a state-of-the-art microfossil microscope suite.

Microbiology facilities provide specialist equipment and techniques for characterising microorganisms from both aerobic and anaerobic environments. The state-of-the-art low biomass facility, including new GC-FID and NIR instruments enables characterisation from low biomass environments, whilst gas mixers, bioreactor, anaerobic chambers and dedicated anaerobic growth curve facility facilitate the isolation, growth and characterisation of microorganisms from extreme environments.

- methods and protocols for waste industry compliance. These have led to between four and six consultancy *Environmental simulation facilities* include four bespoke environment

chambers for simulating different atmospheric conditions on Earth and elsewhere in the Solar System; from -20 to 365°C and from 0 to 34.5 MPa. The biodegradability laboratories contain bespoke respirometers and biodegradability test equipment.

Computing facilities include a high-performance 512-core Linux cluster supported by a cloud storage system and inter-node communication for fast parallel computing.

3.2.3 Centralised laboratory support:

Since the 2015 restructure, the Faculty has supported laboratories through an effective system of centralised support. Apart from positions explicitly funded through research grants, all laboratory staff are centrally managed. This arrangement promotes interdisciplinary and multi-disciplinary collaboration, increases efficiency and enables technical support staff to diversify their expertise. The Faculty employs a dedicated Head of Laboratory Facilities; and within the Unit, four laboratory managers have responsibility for 17 permanent technical staff and two fixed-term apprentice technicians. The centralised support ensures equality of access to facilities and training for all staff and PGRs, and facilitates laboratory booking and delivery of consultancy work. The effectiveness of our centralised system was proven during the rapid changes required to keep laboratories running during the COVID-19 pandemic.

3.2.4 Use of Infrastructure, facilities and expertise for Impact

Various Unit facilities, especially those related to more applied research, support the Unit's impact activities. In particular, the Waste ICS is underpinned by data collected in the microbiology and environmental field facilities, partially funded by external contracts from, for example, the Environment Agency and Defra. These contracts have included testing whether bioaerosols meet national standards, monitoring environmental compliance and testing waste breakdown for residual waste collection policy development. These facilities also support a 2018 Innovate-UK-funded knowledge transfer partnership between the OU and Albion Environmental on bioaerosol monitoring.

The underpinning research data for the Floodplain Meadows ICS comes from the soil physics and chemical analysis facilities, and for the Blue Planet II ICS comes from the geochemistry and microscopy facilities. The generation of impact is additionally underpinned by the science communication and knowledge-exchange expertise of researchers within the Schools.

3.3 Collaborative use of research infrastructure and benefits in kind

All Unit research facilities are available for collaborative use by external researchers (examples are detailed in Section 4.1). Our researchers also share and collaboratively use other UK and international research facilities. For example, RainDrop, a new field-based climate change experiment, was developed collaboratively by Ecosystems researchers, the University of Oxford and The Ecological Continuity Trust in 2016. This national asset allows the impacts of changing rainfall patterns on calcareous grassland to be investigated, and has seen engagement from three additional institutes, hosted 2 PhD projects and >10 undergraduate projects since its instigation.

Since 2014 Unit researchers have also been funded to use major collaborative facilities in the UK and overseas, including the NERC Environmental Isotope Facility for Palaeoenvironmental Change and Dynamic Earth research (seven grants in kind totalling c. 160k, supporting six PhD students), the STFC Diamond Facility (£60.2k), ship time for Paleoenvironmental Change research (three expeditions funded by NERC (NE/M021181/1, 2016, £32k), IODP (expedition 353, 2015, c. £400k) and the EU (ICY-LAB, DY081, 2017), in total supporting three PhD students) and Antarctic fieldwork support equating to £65k from the British Antarctic Survey.

4. Collaboration and contribution to the research base, economy and society

4.1 Effective research collaborations and partnerships.

Unit researchers are supported through workload allocation, pump priming funding and well-supported laboratories to play leading roles in international research collaborations (further details in Sections 1.2 and 3.2). Highlights showcasing the effectiveness of these collaborations and partnerships include:

Internal support for an international meeting of Earth system scientists, economists, technologists, financiers and lawyers in 2014 led to four consortium grants on policy modelling including a share of the £9.8M eight-partner **Leverhulme Centre for Climate Change Mitigation.** Results from this collaboration include a major study on the potential for large-scale CO_2 removal via enhanced weathering. Other results that fed directly into the 2018 International Panel for Climate Change (IPCC) Special Report on 1.5°C warming include a warning that retirement of fossil-fuel assets, driven by technological progress and climate policy, may cause global economic losses of $1-4trn and trigger another financial crisis.

Involvement in **International Ocean Discovery Program Expedition 342** (2012), which drilled Cretaceous to Paleogene successions, facilitated the collaboration with researchers in >10 partner institutes to tackle cross-disciplinary research into past episodes of rapid global warming. A notable result of this expedition was the quantification of the climate effects of carbon release events during thermal maxima in the geological past, reported in eight high-profile publications on climate evolution. The results have facilitated bids for further IODP support (Expedition #874 has recently been promoted to the IODP 'scheduling pool'), and underpin the Blue Planet II ICS.

The Unit's expertise in engaged research and science communication training, online learning platforms and diversity initiatives have led to the establishment of two doctoral training networks funded in the REF2021 period. The **NERC CENTA2** doctoral training partnership, a £7.8M consortium involving six partner universities and providing 18 studentships per year between 2018-2023, was built on the success of the 2013-18 CENTA consortium in which we were a partner. The success of the CENTA training programme underpinned the design of **FluidNet** (2020-2024), a £3.19M EU funded Innovative Training Network involving six European institutes to provide training for 13 PGRs.

4.2 Development of research end-user relationships for impact

The principle of Engaged Research underpins the Unit's approach to research (see Section 1.2), and both financial and workload support are provided by the Schools for citizen and stakeholder engagement to develop impact from our research. The AstrobiologyOU Centre and Treezilla project (Section 1.2), showcase examples of engagement pathways that are leading towards future impact. Two other examples showcase our impact development:

The Floodplain Meadows Partnership (FMP) was set up in 2006 to facilitate annual engagement between Ecology and Ecosystems researchers at the OU and end-users with a significant interest or stake in the conservation of floodplain-meadows. The Steering Group meets annually to decide research objectives and priorities, and review outputs. Since 2014 the Partnership has grown from an England-focussed group of seven end-users to a UK-wide group of ten, and has steered research focus from water management through nutrients and habitat restoration towards policy development. Since 2018 the partnership has trained an additional group of 40 ambassadors who hold professional posts in the environment sector across England, Wales and Ireland, and who advise end-users on the scientific implications of floodplain-meadows research. Within the OU the floodplain-meadows team consist of three researchers, a policy director and a partnership manager, all of whom contribute ideas on stakeholder engagement, citizen science and linking research to policy to the Unit as a whole.

The Waste Industry Safety and Health (WISH) forum was set up in 2003 as a new strategic partnership between industry, the public sector, non-governmental organisations and the governmental Health and Safety Executive regulator. The main focus of the forum was, and still is, to provide the waste industry with practical guidance, information sheets and webinars; Environmental Resource Management expertise has been pivotal in its development. Since 2012, external funding has underpinned the development of an OU-hosted independent website to host HSE-approved guidance, and has broadened the remit of the forum to directly inform policy. Engagement with the forum has allowed Environmental Resource Management research to move from a more academic-focussed approach on bioaerosols towards contract research on occupational and public health issues – including health surveillance of industry workers. Their results have increasingly underpinned both industrial and governmental policy on waste management issues.

These collaborations have enriched our research environment in three main ways: external researchers in these wider networks have presented Unit-wide research seminars that have increased exposure to a wider variety of scientific methods, ideas and areas of impact. Partners in non-academic environments have hosted work placements for the PGRs, thus widening their view on successful doctoral-level career paths. The appointment of a policy director to the Floodplain Meadows team has brought new expertise into the Unit which broadens our approach to developing impact.

4.3 Wider contributions to the economy and society

Researchers within the Unit have impacted upon the economy and society over and above the highlighted impact case studies across our research portfolio.

For example, research from the Earth Systems Modelling team has revealed that climate mitigation represents an economic opportunity and that rapid action to decarbonise brings substantial financial benefit. This work is influencing the Climate Emergency debate at global government and corporate policy levels through e.g. the UK Department for Business, Energy and Industrial Strategy, the Bank of England, the International Monetary Fund and a well-established network of corporate stakeholders. Climate simulations from this group have furthermore been included in the 5th and 6th IPCC Assessment reports.

Contributions from the Environmental Resource Management team to a national task group coordinated by the Department for Environment, Food and Rural Affairs led to a 2018 review of standards for plastic biodegradability. Work carried out at the OU also led to an evaluation of the carrier bag tax.

Bringing lessons and experience from their research careers, two of our senior female academics have been official role models on either the AdvanceHE Aurora programme, or the Women in Science Education (WISE) programme run by the Women's Health Research Institute. Both these programmes provide leadership development, mentoring and networking experiences for women in science and the HE sector.

4.4 Engagement with Diverse Communities

Researchers within the Unit engage a diverse array of end-member communities with their research.

For example, we have led the development of the Milton Keynes Soapbox Science community, an international grassroots public outreach platform that promotes female scientists, since 2016. The group involves four local institutes, and 11 Unit researchers. Each year between four and eight female scientists promote their science on a "soapbox" on a busy Saturday morning in the Milton Keynes shopping centre. The engagements typically reach >1000 people each year.

Ecosystems researchers work with UK-based charity Neno Macadamia Trust and Malawi-based growers cooperative Highlands Macadamia Cooperative Unions Limited to develop climate-

smart macadamia nut production. Their engagement with smallholder farmers in Malawi promotes and facilitates the exchange of growth, yield and climate data and analysis, that allows the farmers to identify the best varieties to grow in their area.

Unit researchers provide two or three research experience opportunities to Year 12 school and undergraduate students each year through the Nuffield Research Placement and NERC Research Experience Placement schemes respectively. During these placements, the students make a meaningful contribution to active research projects. Since 2014 the Unit has hosted 21 students on a range of projects related to palaeoclimate change; all the Nuffield students have gone on to study STEM subjects at university.

4.5 Contribution to sustainability

Within the Unit and across the sector a strong track record demonstrates a commitment to research discipline sustainability.

Strategic internal appointments, investment in laboratory infrastructure, technical support staff, and investment in digital resources support long-term sustainability of Earth and Environmental Sciences research at the OU. ECRs are supported with targeted provision of research pump-priming funding and provision of research student posts. The success of our PGRs in finding meaningful employment in both academic and non-academic fields after their PhDs is a further marker of success. Embedded support for developing interdisciplinary networks is described in Section 1.2 and the results evidenced in Section 4.1.

Externally, our researchers contribute to national and international funding panels, committees and advisory boards (Section 4.6), shaping decisions on evolving research priorities and equality, diversity and inclusion initiatives that identify and resolve leaks in research career pipelines. The Unit also contributes to the science, publishing and outreach strategies of two professional bodies: The Geological Society of London and The British Ecological Society. We contributed to the business case and development of the new Geological Society of London open access journal Earth Science, Systems and Society ("ES cubed") focussing on cross-disciplinary research that showcases the relevance of geoscience to sustainability in society. We also contribute to sustaining research-informed careers advice through the Teaching and Learning Special Interest Group and Education and Careers Committee of the British Ecological Society.

4.6 Wider influence and contributions to the research base

The Unit contributes to a wide range of activities that support and steer wider national and international research communities.

Journal editorship: Unit researchers edit Geochronology; Journal of Metamorphic Geology; Animal Behaviour; Functional Ecology; Frontiers: Extreme Microbiology; Plant Systematics and Evolution.

Participation on grants committees: The Unit is represented across the remit of **NERC panels,** with academics holding (vice)-chair roles and panel memberships on the Highlight Topics, Large Grants, Standard Grants, Innovation Scheme, Latin American Biodiversity Programme, and Independent Research Fellowships.

Other **national panels** we contribute to include the UKRI Future Leaderships panel (Deputy Chair), and service on **International panels** including: European Commission, Horizon 2020; Research Council of Norway; Natural Sciences and Engineering Research Council of Canada; and the Swedish Research Council.

Fellowships: Unit academics hold Fellowships of the Royal Geographical Society, The Geological Society of London, the Geological Society of India, the Institute of Physics, the Astronomical Society, the Linnean Society of London, the Institution of Chemical Engineers, the

Chartered Institution of Waste Management and (senior) fellowships of the Higher Education Academy.

Prizes: Since 2014 our staff have been awarded the Barrow Award, Metamorphic Studies Group UK (2020); Geologist's Association Richardson Prize (2015); Early Career Award, Geological Society of America (2015); the WISH national prize for best COVID response (2020).

Membership of Research Council and national and international committees: Unit academics hold **leadership positions** within many organisations including **President** of the Geological Society of London (GSL), **Committee Chair** of the International Subcommission for Jurassic Stratigraphy; Joint Committee for Palaeontology; Acting Chair of the Stratigraphy Commission of the Geological Society, London; Joint Technical Advisory Committee for the Great Fen (Natural England/Wildlife Trusts); Geological Society Library Review Working Group; Geomicrobiology Network; Metamorphic Studies Group; Geological Society Higher Education Network; the Chartered Institution of Wastes Management (CIWM); Health and Safety National Special Interest Group, and **Committee Secretaries** for the International Subcommission for Jurassic Geology; Waste Industry Safety and Health Forum; and the Palynology Group and **Membership Secretary** of the Micropalaeontological Society.

The Unit has **council and committee members** on a diverse range of professional bodies. Two Unit academics have been elected to council of the GSL and one has served on the Science Committee and Publications and Information Committee.

Other local, national and European bodies include the committees of the Society of Microbiology; Astrobiology Society of Britain; European Astrobiology Network Association, the European Astrobiology Institute Executive; the Institution of Environmental Sciences Heads of Environmental Science and the EU COST Action SENSECO management; the Board of the Mineralogical Society of Great Britain and Ireland; UK Space Agency Space Environmental Working Group; Environment Agency Bioaerosols Regulation and M9 Industry Standards; and the Earthwatch Scientific Panel. We have or have had **board trustees** on the International Polar Foundation, The Geological Society of London, and the Ecological Continuity Trust.

The Unit has strong representation on **science education committees**, with the Coordinator for Earth Science Teachers' Association Higher Education section and committee members on the International Commission for Distance Education; British Ecological Society Teaching and Learning Special Interest Group and the Education and Careers Committee; GSL Geoscience degree Accreditation Review Committee; and GSL Education Committee.

Representation on Advisory Groups: Unit researchers contribute to local, national and international advisory groups aligned with their research expertise, advising governments and society across a range of specialist topics. Representation includes the IUCN Species Survival Commission Asian Wild Cattle Specialist Group, the Panel for Planetary Protection within the Committee on Space Research, the Natural Environment Advisory Group for the National Trust and the Ecology Advisory Group for The Parks Trust, Milton Keynes.

Invited keynotes addresses, lectures and conference leadership:

Keynote addresses have been presented at the Geological Society London Lecture (2015); Thermo (2018), Goldschmidt (2017 x2); Geological Society of Canada (2017); Himalaya Tibet Karakorum conference (2016); Variscan Conference (2015); Nordic Winter Conference (2014); and Geological Society Year of Resources conference (2018).

Invited talks have been presented at more than 20 national and international conferences and events, including the European Geosciences Union, Geological Society of America, Royal Society of Chemistry 'Science at Stormont', Crafoord Prize awards ceremony, Tupper Seminar, Smithsonian Tropical Research Institute, International Jurassic symposium, Womens' Fellowship, and the Geological Society of London.

Conference leadership roles include **organising committee** membership for >10 national and international conferences, including the Geological Society Lyell Meeting (2015); International Geological Congress (2020); Lunar and Planetary Science Conference (2019), Himalaya-Karakorum-Tibet conference, Switzerland (2018); Daphne Jackson Conference (2019); UK Astrobiology conference (2017).

Unit staff have been **conference session convenors** for the European Geological Union Annual meeting, International Congress on Stratigraphy STRATI, Goldschmidt, Astrobiology Society of Britain, British Organic Geochemical Society Annual Meeting, Lunar and Planetary Science Conference, and the Geological Association of Canada.

Refereeing academic publications or research proposals: Five Unit members contribute to the **national** NERC peer review college and three have reviewed STFC, MRC, and the UKRI Future Leaders Fellowship proposals. Unit academics have reviewed proposals for about 20 different **international funding agencies**, including the European Science Foundation, European Union, Swiss Academy of Arts & Sciences, Czech Academy of Science, Swiss National Science Foundation, Social Sciences & Humanities Research Council of Canada, Research Foundation Flanders, Israel Science Foundation, Marsden Fund (New Zealand), USA-Israel Binational Science Foundation, Doctoral Fellowship Programme of the Austrian Academy of Sciences, Organisation for Tropical Studies (USA), Deutsche Forschungsgemeinschaft (Germany), Research Council of India, the French Polar Institute, National Research Fund South Africa, National Science Centre Poland, Fundao para a Ancia e a Tecnologia (Portugal) and the Fulbright Commission (Czech Republic).

Unit academics review outputs for >30 international journals, with the range reflecting the full diversity of our expertise and research interests.

Associate positions at other institutes: Our external recognition includes associate positions both nationally and internationally, including the Cambridge Centre for Environment, Energy and Natural Resource Governance (Fellow); Dalhousie University, Canada (Adjunct professor); Cranfield University (visiting professor); Department of Environmental Sciences of Xian Jiaotong-Liverpool University, China (Visiting Scholar); and University of Exeter Medical School (Honorary Senior Research Fellow in Climate Change and Human Health).