Institution: University of York

Unit of Assessment: 7 - Earth Systems and Environmental Sciences

1. Unit context and structure, research and impact strategy

1.1 Context and structure

The University of York's submission to UoA7 comprises all Category A eligible staff in the Department of Environment and Geography and its constituent research institute, the Stockholm Environment Institute at York (SEIY). This is consistent with the submission to REF2014, although as a result of the strategic broadening of its research base (section 1.2), the Department has been re-named from the Environment Department to the Department of Environment and Geography.

The Department is the focus for environmental sustainability research at the University. Our staff play key leadership roles in the strategic development of this activity across the University. Fazey is a former University Research Champion (REF5a:4) for Environmental Sustainability and Resilience, and Friend has been appointed recently as the University Research Champion for Risk, Evidence and Decision-making. White is Vice Chair of the University's Sustainability Strategy Group and led the development of the University's Strategy for Sustainable Research. The Department has benefitted from a £12.5m investment in a bespoke Environment Building, established in 2016.

The Department's strategic aim set out in REF2014 was to establish York as an international centre for sustainable strategies to manage global environmental changes. Our three Impact Case Studies (ICS) for REF2021 provide evidence of our influence on decision-makers at international, national and local levels, across climate mitigation (ICS1), and marine (ICS2) and terrestrial (ICS3) environmental management. Our impact in these fields is underpinned by rigorous fundamental science. During the REF period, our staff have published >1200 articles in ISI-recognised journals, which have been cited >31,000 times, including 35 articles in Science and Nature-family journals and PNAS.

The Department is closely associated with three Interdisciplinary Research Centres at the University of York. In 2017 the Department co-founded the Interdisciplinary Global Development Centre (IGDC), with the Departments of Politics and History. It is also a key partner in the York Environmental Sustainability Institute (YESI) alongside the Department of Biology (lead), and in the Leverhulme Centre for Anthropocene Biodiversity (LCAB; founded 2019), alongside Biology (lead), Health Sciences and History (REF5a:10,11,42).

1.2 Research and impact strategy

The Department's research and impact strategy was developed following REF2014. It identifies three research themes that guide our research approach: (1) Understanding the causes and consequences of environmental change; (2) Developing innovative solutions to environmental challenges; and (3) Engaging people with environmental challenges and solutions. Research activity to address these themes is coordinated through four research groups: Environmental Chemistry in a Changing World; Conservation in Action; Environmental Change through Time; and People, Place and Planet. The first three groups are similar to the groups presented in REF2014. People, Place and Planet is a more recently-established research group. The research groups are complemented by YESI, LCAB and IGDC. Underlying support for our research activities is provided by built infrastructure including laboratory facilities and field research platforms, development and training programmes, external partnerships, and professional and technical support (Figure 1).

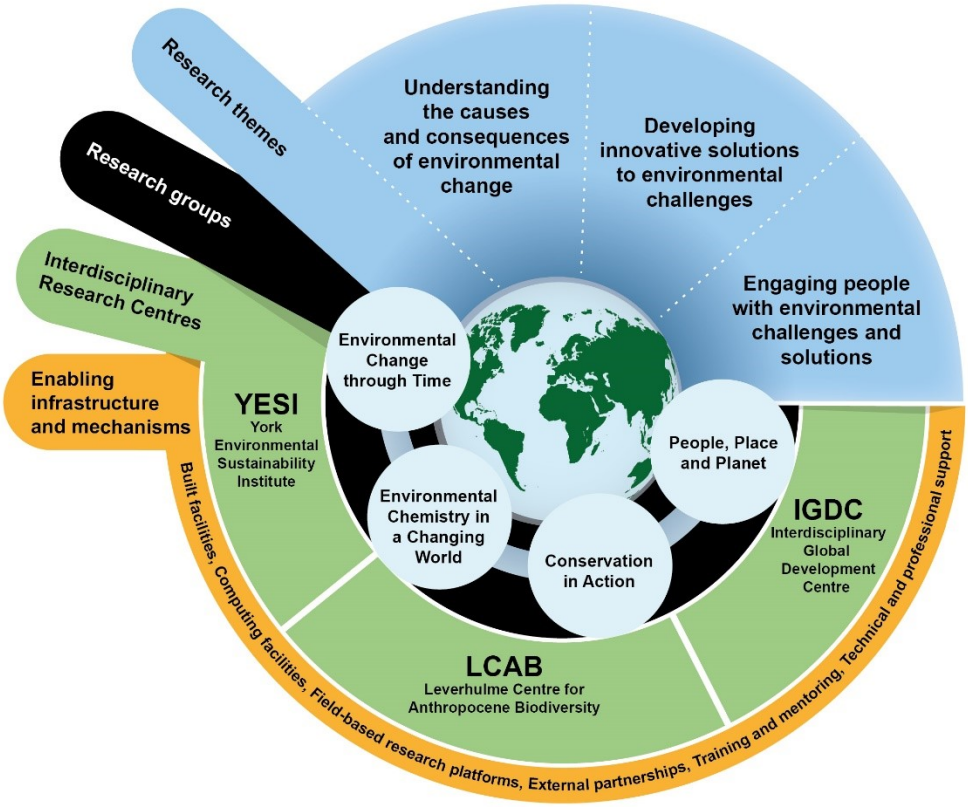

Figure 1: Schematic representation of research themes (blue), research groups (black), Interdisciplinary Research Centres (green) and support mechanisms (orange) in the Department of Environment and Geography.

Alongside the three themes, our Research Strategy focuses on four specific strategic objectives:

1. Invigorate the research culture within the Department, nurturing the development of each member of the Department, and ensuring equality of recognition and opportunity for all.
2. Be proactive in developing interdisciplinary collaborative relationships with decision-makers, business and industry, and third sector organisations.
3. Capitalize on the opportunities afforded by specific research opportunities such as the Global Challenges Research Fund (GCRF).
4. Further strengthen the quality and impact of our research to enhance our reputation and influence nationally and globally.

We have achieved these objectives by providing extensive support for staff, establishing a range of partnerships with users of our research in policy and the public, private and third sectors, expanding our portfolio of applied research including in the area of global development, and increasing the impact of our research on international environmental policy.

All staff are linked to at least one research group but many collaborate across two or more groups. This enables us to: (1) advance fundamental science through developing new understandings of earth and ecosystem processes and human drivers, interactions and responses to these; and (2) increase the impact of our science by working in partnership with users to create innovative solutions to management and development challenges at local, regional and global scales. The primary memberships, foci and key scientific achievements of each research group during the REF period are summarised below.

Environmental Chemistry in a Changing World
[Ashauer (until December 2018), Boxall, Brown, Carslaw, Emberson, Heinemeyer, Hicks, Hodson, Kuylenstierna, Sallach (since September 2019), Toet; currently 7 males and 3 females]. Foci: (1) atmospheric and oceanic processes; (2) emerging contaminants in outdoor and indoor environments. The group has demonstrated how emissions reduction measures can lead to synergies in achieving multiple Sustainable Development Goals (Kuylenstierna, *Nature Climate Change* 2017:7:863) and developed new targets for reducing short-lived climate pollutants to meet the Paris Climate Agreement (Kuylenstierna, *Science* 2017:356:493, ICS1). The group has also highlighted the potential value of biogeochemical removal of carbon dioxide as a climate change mitigation strategy (Hodson, *Global Change Biology* 2020:26:3658). The group's influential work on the ecological and health risks posed by chemical contaminants and microplastics (e.g. Boxall, *Environmental Toxicology and Chemistry* 2018:37:2776; *Journal of Agricultural and Food Chemistry* 2014:62:4227) is evidenced by Boxall's recognition as a Web of Science Highly-cited Researcher and his receipt of the Recipharm International Environment award in 2016.

Conservation in Action
[Arnold, Stewart, Hawkins (until July 2020), Marshall, Platts, Roberts (until July 2020), White; currently 4 males and 1 female]. Foci: (1) tropical ecosystems and ecosystem services; (2) marine ecosystems and conservation. The group provided first evidence of a global link between biomass and productivity in forests (Marshall, *Science* 2016:354:8957). It has revealed new insights into mechanisms underlying patterns of species diversity (Marshall, *Nature* 2019:569:404) and the use of earth observation data for monitoring biodiversity-ecosystem function interactions (White, *Nature Ecology and Evolution* 2017:1:0176). The group has contributed to revised estimates of global extinction rates (Roberts, *Science* 2014:344:1246752) and has been instrumental in promoting the scientific case for marine stewardship globally (ICS2), demonstrating the role of marine reserves and contributing to the international policy target of protecting 30% of the world's oceans by 2030 (Hawkins & Roberts, *PNAS* 2017:114:6167).

Environmental Change through Time
[Gehrels, Hill, Marchant, McClean, Mills, Payne (deceased May 2019), Rippin, Selby, Stump (from February 2018, joint with Archaeology); currently 7 males and 1 female]. Foci: (1) past environments, specifically changes in sea level and their implications; (2) palaeoecology and environmental archaeology. The group provided the first estimate of global sea-level change over the last 3,000 years (Gehrels, *PNAS* 2016:113:E1434), and has highlighted the role of mangroves in global carbon cycles on geological timescales (Hill, *Nature Communications* 2017:8:15698). The group has provided new evidence of the changing functional role of peatlands in the past and future (Payne, *Nature Communications* 2017:8:1161 & *PNAS* 2019:116:4822; Marchant, *Nature Climate Change* 2018:8:907). It has characterised large-scale transformations in vegetation that are likely to result from climate change (Marchant, *Science* 2018:361:920), and revealed new insights into early transformation of the planet by humans (Marchant, *Science* 2019:365:897 & *Nature Communications* 2018:9:1832). The group's pan-global work on tropical biodiversity and ecosystem services has informed land-use planning in Kenya and Tanzania (ICS3).

People, Place and Planet
[Brookfield, Cinderby, Ensor, Fazey (since May 2019), Friend, Jew (since February 2019), Kenter (since June 2018), Kirshner, Parkhill, Sakai (since January 2018), Stringer (since July 2020), Thankappan, Topi (until June 2020), Touza, C West, S West; currently 8 males and 7 females]. Foci: (1) energy systems and low carbon transitions; (2) environment, resources, health and wellbeing. The group's work across high-, middle- and low-income countries has highlighted barriers to reductions in energy consumption and the introduction of progressive energy policies (Parkhill, *Nature Climate Change* 2015:5:550 & *PNAS* 2014:111:13606), and demonstrated the need for novel methodological approaches to support large-scale, equitable energy transformations (Kirshner, *Nature Energy* 2020:5:419). The group has played a leading role in highlighting the impacts of air pollution on health (Emberson, *Nature* 2017:545:467), and

pioneered new methods to quantify food system impacts on the environment and natural resources (C West, *PNAS* 2019:116:201905618).

1.3 Research integrity and open science

Our research is conducted to the highest standards of ethics and integrity, and our research activities are fully compliant with Universities UK's Concordat to Support Research Integrity. Our departmental Ethics Committee oversees the research activities of staff and students and reports to the University's Ethics Framework Governance Committee to ensure that our research complies with appropriate ethical and legal frameworks, obligations and standards, and is sensitive to different social and cultural contexts (REF5a:14).

We are committed to making our science open and transparent, going beyond the requirements stipulated by funders. As part of a large team that founded Earth Archive, our staff play a leading role in advancing the adoption of open data principles within the environmental sciences (Hill). We ensure that all our research outputs are available through the University's repository (White Rose Research Online; REF5a:15-17), and that products from our research such as decision support tools are, wherever possible, freely available and therefore of benefit to wider society. Examples over the REF period include LEAP (C West), SEI Climate Calculator (C West), INdoor Detailed Chemical Model (INDCM; Carslaw), Measuring Ecosystem Services Evidence Review (MESER; White), Solar Park Impacts on Ecosystem Services (SPIES; White), Natural Capital Indicators and Metrics Evidence Review (White); Natural Capital Assessment Gateway (White), DO3SE user interface model (Emberson) and Map Your Heritage (Kenter).

1.4 Future strategic aims and goals for research and impact

The Department's new 10-year Research and Impact Strategy, developed following a series of workshops and consultations with all staff and external advisors, is geared towards our goal of being a UK Top 5 department by our 40th anniversary in 2032. To help achieve this, the Department is at the centre of a major new research investment in Sustainability at the University of York. Benefiting from substantial University support, this will include developing new mechanisms (e.g. shared staff time across departments, fluid budgets) and structures to draw environmental and sustainability research expertise from all departments, professional services and a host of Centres and Institutes. This will create a step change in our capacity and scope for interdisciplinary research through integrating and building on research strengths in the Department and the wider University, in areas such as food security, regenerative economies, and climate change.

In order to facilitate interdisciplinary working and enhance our research leadership, we have established a system of Special Interest Groups (SIGs). SIGs are flexible, forming as required from staff across our research groups as well as from other University Departments and external stakeholders. The SIGs will enhance our agility in creating and responding to new research opportunities, facilitate the generation of research of high quality and impact, and act as a primer for the activities of the new Sustainability initiative. We have created a new role of Director for Engagements and Partnerships (Stewart) to enhance our visibility and collaborations with stakeholders.

In response to the urgency of many environmental challenges, we will create a new solutions-focused research area in Systems Transformations, focusing on solutions in systems such as food and water governance. This new challenge will build on research in the Department (Fazey), and extend it to address global challenges such as the climate emergency and the need to go beyond carbon neutral futures. In addition, we have proposed a new interdisciplinary Hub for the Built Environment. This initiative is led by Carslaw, building on her work as PI of the Chemistry of Indoor Environments (CIE) modelling programme funded by the Alfred P. Sloan Foundation since 2017 ($3m) and the EPSRC-funded IMPacts of Cooking and Cleaning on indoor Air quality: towards healthy BuiLdings for the future (IMPeCCABLE) project; £1.5m). The Hub will involve staff across our Environmental Chemistry in a Changing World and People,

Place and Planet research groups and bring together researchers from 15 Departments and Centres across the University.

2. People

2.1 Staffing development in relation to research and impact strategy

In line with our strategic aims, we have invested significantly in new staff at both senior and junior levels since REF2014 to deepen existing areas of strength, develop the potential for interdisciplinary collaboration across our research groups, and enhance investment in future research capacity. Our Category A submitted staff has grown from 24.1 FTE at REF2014 to 34.9 FTE at REF2021. Over the same period, overall staff numbers have grown from 68 FTE staff (including 23 ART and 33 research staff) to 104 FTE staff (including 29 ART and 46 research staff). We have appointed 9 academics to the People, Place and Planet research group (2 Professors, 1 Senior Lecturer and 6 Lecturers). This is the fastest-growing area of research activity in the Department, with research income from projects in ODA-listed countries via the Global Challenges Research Fund and the Newton Fund representing 18% of all our research income over the REF period. We have also made 3 Lecturer appointments into the Environmental Change through Time group (one joint with the Department of Archaeology), and 1 Professor and 1 Lecturer appointment into Environmental Chemistry in a Changing World.

Our strategic plan includes further investments of ca. 10-12 Academic, Research and Teaching (ART) staff in the next 7-8 years. This will be funded through a 5% increase p.a. in research income and increased student numbers from our BA in Global Development (first intake 2020), and a new suite of Masters programmes in Sustainability starting in 2021 (MSc Sustainability Science, MA Sustainability Studies, and MSc Sustainable Business, the latter taught in partnership with Maastricht University; REF5a:6). This investment in ART staff will enhance our existing strengths in ecotoxicology, air pollution, tropical ecology and management, and global development, as well as making 3-4 appointments in the areas of systems transformations. The employment of additional Teaching & Scholarship (T&S) staff, including 5 by 2022/23, will ensure that current and planned ART staff have sufficient protected time to contribute to our research ambitions.

2.2 Support for academic staff

2.2.1 Workload allocation

We operate a Workload Allocation Model (WAM) which helps us to: accommodate research buyouts effectively and fairly; ensure that all staff on ART contracts have protected time for personal research; manage the development of our professional services capacity to meet our target of reducing administrative workloads of academic colleagues to <20%; and build capacity to react to opportunities and challenges at short notice without overloading staff. The WAM has been developed through consultation with colleagues at all levels in the Department, and is underpinned by considerations of equality, diversity and inclusion. It is transparent and visible in full to all staff in the Department.

All academic ART staff are guaranteed a minimum of 24% of their time for personal research, covering writing and submitting proposals, research group participation, participating in conferences/scholarly activity, publishing high-quality journal papers, and working on projects that do not provide funded staff time. ART staff on their first appointments are given a lighter teaching load for the first 1-2 years to give them time to develop their research. ART staff receive buy-outs from other duties based on external funded support for their time. The average total research time across our ART staff is 41%.

2.2.2 Research priming

Staff have access to departmental (£20k p.a.) research priming and travel funds in addition to central University research priming funds. Within SEIY, staff can access SEI-wide institutional funding for cross-disciplinary research projects; SEIY staff contributions to such projects provide approximately £400k per annum benefit to the Department. To further develop our partnership with SEI globally, we have set up a process whereby staff from across the University can access joint University-SEI funds via collaborative schemes, such as a SEI-funded 'rural transitions' initiative in 2019, and a joint York-SEI research priming fund in 2020.

2.2.3 Research sabbaticals

Our fully funded sabbatical system provides staff with a term free from teaching and administrative duties to focus on developing research ideas and external collaborations; 14 staff have benefited from this during the REF period. We also support our staff to pursue opportunities for interaction with industry and government, e.g. NERC Knowledge Exchange fellowship with the Scottish Environmental Protection Agency (Payne); Defra secondment, as Head of EU exit strategy for resources and waste (Arnold).

2.2.4 Performance and Development Reviews

Our annual Performance and Development Reviews (PDRs) provide staff with a supportive mechanism to develop their research ambitions and meet our research expectations: (i) to submit at least one high quality journal paper per year equivalent to or better than REF 3* quality; (ii) to submit at least one significant (i.e. of a value that can support a PDRA) research proposal per year to an external funder; and (iii) to endeavour to translate their research so that maximum impact can be achieved. These expectations are reduced pro rata for part-time staff, and there is flexibility for staff with other significant roles or particular circumstances.

2.2.5 Training and support

All our staff have access to the highest quality training and support. All new ART, research and technical staff are matched with a mentor. ART staff benefit from courses in Impact and Public Engagement, Research Integrity, Leadership, Open Access and Research Data Management, provided through the University's Research Excellence Training Team (RETT; REF5a:32). We also operate a research buddy system for ART staff, which is a temporary arrangement pairing up staff with different levels of experience, and provides one-to-one support in producing specific outputs or grant applications. Twice-yearly Research Away-Days encourage networking and new research collaborations. The Chair of the Departmental Research Committee (DRC) and Research Facilitator provide additional one-to-one support to ART staff and Postdoctoral Researchers to assist with proposal development and research networking.

2.3 Support for Postdoctoral Researchers

We value the contribution that Postdoctoral Researchers make to the vibrancy of our research environment. They participate actively in the research groups, coordinating three of them, and played a full role, through workshops and working groups, in the development of our research and impact strategy. At the REF census date, we had 25 Postdoctoral Researchers (18 Research Associates and PDRAs, 3 Research Fellows, 4 Marie Skłodowska-Curie Fellows). Postdoctoral Researchers have access to all the training and support available to ART staff, are members of a departmental Postdoctoral Researcher group and have a representative on the DRC.

2.3.1 Research Fellowships

We have a scheme to attract Research Fellows, and have been successful in appointing 5 externally-funded Research Fellows, including 3 of our 4 Marie Skłodowska-Curie Fellows (Hibbert, Joly, Sallach), 1 ESRC COP26 Fellow (Omukuti) and one Royal Society Dorothy Hodgkin Fellow (O'Leary). We have invested in our own funded Research Fellowship scheme, with Platts being the first appointment. We are committed to investing long-term in other ECRs and supporting them in obtaining long-term academic posts; Sallach was appointed to a Lectureship in the Department in 2019.

2.3.2 Postdoctoral Researchers mentoring and coaching

Postdoctoral Researchers are supported through the Department's internal mentoring scheme and the University's mentoring scheme (REF5a:22), which matches mentors and mentees across different departments. They can also benefit from the University's coaching scheme, a more intensive one-to-one experience that supports individuals in acquiring the knowledge, skills and techniques to help them achieve to their full potential.

2.3.3 Research funds for Postdoctoral Researchers

The Department has a dedicated bridging fund to support early Postdoctoral Researchers between contracts. They are also able to apply as Principal Investigators to internal Departmental and University research priming schemes (REF5a:10), supported by a permanent ART staff member as Co-Investigator to provide mentoring during proposal development and project management.

2.4 Support, training and supervision of PhD students

PhD students are a key part of the Department's research environment, and are co-authors on 6.3% of our submitted outputs. During the REF period, the Department provided PhD scholarships contributing to tuition fees to 10 PhD students, equating to an investment in PhD-level research of £120k. All of our PhD students are part of the University's Graduate Research School (YGRS); one of our staff (Arnold) was appointed as Dean of YGRS in July 2020. The YGRS defines research student supervision and progression regulations and procedures, ensuring that students receive the highest quality supervision and have access to training and personal development through RETT (REF5a:30-34). Our PhD students can obtain the 9-month postgraduate York Learning and Teaching Award, which makes them eligible for professional recognition as an Associate Fellow of the Higher Education Academy.

Over the REF period, a total of 168 PhD students have been registered in the Department, with 56 (34 home, 22 overseas) registered on 01/12/2019. We averaged 1.67 PGR students per FTE in 2018/19, which places us 12th in the Russell Group under the Earth, Marine and Environmental Sciences HESA code (16th overall). The on-time completion rate of our PhD students is high (91%), indicative of excellent research support and the strong research culture.

The Department's participation in a number of doctoral training programmes contributes to a diverse and dynamic PhD student community. The Department is part of the NERC-funded Adapting to the Challenges of a Changing Environment (ACCE) Doctoral Training Programme, held by the Universities of York, Sheffield and Liverpool with the Centre for Ecology and Hydrology and the Natural History Museum, and now in its second phase of funding. The Department has provided the primary supervisor for 15 NERC ACCE DTP studentships with cross-institutional supervision since 2014. The Department is part of the ESRC White Rose Social Sciences DTP, incorporating the Universities of Leeds, Sheffield, York, Bradford, Sheffield Hallam, Hull, and Manchester Metropolitan, and also part of the University's EPSRC DTP, which provides opportunities for our staff to co-supervise PhD research with staff in the Departments of Chemistry, Computer Science, Electronic Engineering, Mathematics and Physics.

PhD opportunities in the Department benefit from our extensive research partnerships, with 6 CASE studentships over the REF period through NERC (4) and BBSRC (2), with CASE partner contributions from Syngenta, AstraZeneca, Unilever, Yorkshire Water, Natural England and Yorkshire Peat Partnership. Building on these and other external partnerships, in May 2020 we applied for, and were subsequently awarded, a £3.5m NERC grant for the Ecotoxicological Risk Assessment Towards Sustainable Chemical Use (ECORISC) Centre for Doctoral Training (PI: Boxall), to fund 39 new PhD studentships over 2021-2027.

We provide £1,500 p.a. to cover research expenses for self-funded students, who do not have financial support through a DTC or CDT. Each of our PhD students is provided with a networked PC and office space, with access to free high-quality laser printing and secure wired and wireless networking to central servers. Our PhD students are members of our research groups and participated fully in the development of our research strategy. The Department encourages joint supervision for all PhD students, both within the Department or with supervisors from other Departments, most frequently Archaeology, Biology, Chemistry, and Politics. The Department awards the Kathleen Mary Stott Prize annually for outstanding PhD theses, and PhD students also lead the organisation of the annual 2-day PhD student conference, supported by the Chair of the departmental Graduate Committee.

2.5 Support for equality, diversity and inclusion

The Department values the diversity of its students and staff and is committed to a positive environment that is fair, welcoming and inclusive. Our open and collaborative ethos is demonstrated by the diverse mix of individuals in leadership roles. Female staff members hold important leadership roles in the Department, e.g. the Directors of Research (Carslaw), Learning and Teaching (Hughes) and Students (Thankappan). Both Deputy Heads of Department (Carslaw, Hughes) are female, and female staff played a key role in two of our three Impact Case Studies.

The Department was re-awarded an Athena Swan Bronze in 2017 for its equality and diversity policies and actions. The departmental Equality and Diversity Committee comprises academic staff, support staff, technical staff, postdoctoral researchers and two PhD student representatives. The Athena Swan ideals are embedded fully within departmental processes. The Chair of the Equality and Diversity Committee sits on the Departmental Management Team and the Departmental Research Committee. Equality and diversity is a standing item on both Departmental Management Team and staff meetings, to ensure that considerations of equality and diversity are applied to all our key strategies and processes. Since REF2014, we have introduced a number of policies and processes to enhance equality, diversity and inclusion within the department, including flexible working and the opportunity for staff to input into decisions on who carries out their annual performance review. All staff undertake unconscious bias training. We have ensured there are clear guidelines of behaviour expected and clear pathways to reporting incidences of harassment and bullying. We highlight the importance of women in science through displays and videos, and promote staff engagement with the International Day of Women and Girls in Science and Women in Science and International Women's Day. In 2016, Stringer participated in the Homeward Bound training course in Antarctica, a targeted Women in Science Leadership training programme.

The majority of the Department's submitted staff are aged 35-54 (25-34, 7%; 35-44, 39%; 45-54, 46%; 55-64, 7%), with 7% of staff identifying as disabled, 86% as White and 8% as BAME. Of 42 submitted staff, there are 11 Professors, 5 Readers, 13 Senior Lecturers, 5 Lecturers, 7 Senior Research Fellows and 1 Research Fellow. Overall, 29 of submitted staff are male (m) and 13 are female (f) (Figure 2a). Senior staff are responsible for a relatively higher proportion of submitted outputs (Professors and Readers comprise 38% of staff and 54% of submitted outputs), but there are no strong or consistent gender-related biases in submitted outputs in relation to grade (Figure 2b).

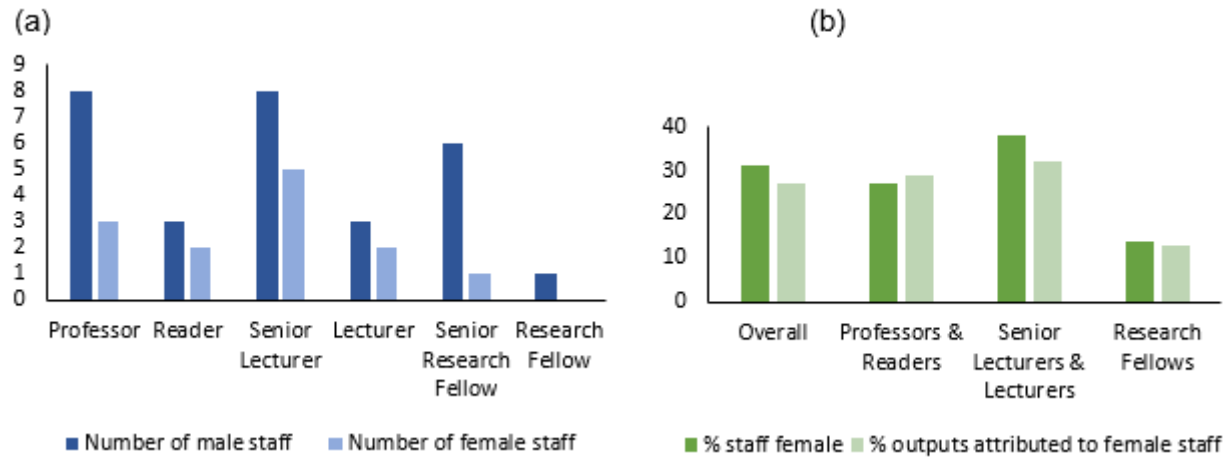

Figure 2: Percentage of females on staff at different levels (a) and contribution to submitted outputs (b).

Submitted outputs were selected by a departmental reading panel comprising 6 Professors (4m, 2f), two of whom read all papers proposed by staff. Two readers from other Departments (1m, 1f) were also consulted on outputs with more specialist content, and three critical friends from three other institutions (2m, 1f) also read a selection of shortlisted outputs based on the initial assessment by the departmental reading panel. Where two outputs were rated equally, outputs from female staff were selected preferentially to reduce impacts of unconscious bias against female-led outputs.

3. Income, infrastructure and facilities

3.1 Income

We have a highly research-active staff; all our eligible staff have submitted UKRI research grants as PI or CoI during the REF period. Research income for the Department has increased since the last REF period; average annual income for REF2014 was £2,860,511 compared with £3,426,016 for the current REF period (HESA data). Our overall market share over the REF period has been consistently 2% (in 2018/19 our market share was 2.5% charities, EU 1.3%, 1.2% industry/commerce, 1.1% UK research councils, 1.1% UK government, and 9.4% 'other' sources). Our funding base is diverse, comprising 33.0% from the UK Research Councils and Royal Society, 8.8% from UK Central Government, 4.4% from UK Charities, 3.7% from UK industry, 17.7% from EU sources, 24.4% from other EU sources, and 8.1% from other overseas sources.

We are 9th among the Russell Group universities (11th overall) in the Earth, Marine and Environmental Sciences HESA code for total research income over the REF period (HESA data). In terms of research income/FTE, our 2018/19 level of £107,933 p.a. places us 11th among the Russell Group universities (13th overall) in this HESA code. As an interdisciplinary Department, we straddle this HESA code and the Geography and Environmental Studies HESA code; we have requested 34 of our submitted outputs to be cross-referred to the Geography and Environmental Studies Panel (UoA14). Our 2018/19 income/FTE would place us 4th among Russell Group universities (5th overall) in the Geography and Environmental Studies HESA code.

We have led major interdisciplinary research programmes and projects around our first research theme of understanding the causes and consequences of environmental change. We provided the Directorate for the £13m NERC Biodiversity and Ecosystem Service Sustainability research programme between 2012-2017 (White; NERC, £1.5m), which addressed fundamental questions about the functional role of biodiversity in ecosystem processes and services at the

landscape scale. We provide theme leadership (Brown) on risk and flood management for the £5.3m NERC-funded Yorkshire Integrated Catchment Solutions Programme (iCASP). We also led a Marie Skłodowska-Curie International Training Network on resilience and innovation in East African landscapes (Marchant; EC, REAL ITN, £1.1m), and coordinate the York Institute for Tropical Ecosystems (KITE; PI Marchant), which was launched in 2005 as a Marie Skłodowska-Curie Excellence Centre. We are currently developing new commercialisable technology for the monitoring of trace gas fluxes between soils and the atmosphere (Toet; NERC GREENHOUSE large grant, £2.4m overall).

In relation to our second research theme on innovative solutions to environmental challenges, the European CAPACITIE project (Boxall; EC, £4.5m) developed new approaches for monitoring pollution in cities at high temporal and spatial resolution, working with a range of industrial partners including NIOSH, IBM, Markes International Ltd., Arup and Partners Ltd. and PerkinElmer Inc. Carslaw's work on indoor air pollution has received extensive support from the US-based Alfred P. Sloan Foundation ($3m across four projects) and she also leads the £1.5m EPSRC-funded IMPeCCABLE project, which includes a partnership with Reckitt Benckiser. In the Intelligent Assessment of Pharmaceuticals in the Environment project (iPiE, £10m) (Academic Coordinator: Boxall), we worked with 13 of the biggest pharmaceutical companies in the world (2015-2019) to develop new standardised frameworks for evaluating environmental risks of pharmaceuticals.

In our research theme on engaging people with environmental challenges and solutions, we are playing a leading role in the recently-funded £10m Leverhulme Centre for Anthropocene Biodiversity (C West, Stringer). The role of natural environments in enhancing people's mental health is a key theme in the ESRC Closing the Gap Network+ project (White; ESRC, £1.1m). Our research is highlighting the importance of cultural heritage in sustainable resource exploitation through the EU PERICLES project (Kenter; €2.5m). We were also awarded a major ESRC project to co-develop water sensors to reduce water-borne disease risk in Vanuatu (Ensor; EPSRC, £1.2m), and provided social science leadership in two major BBSRC projects: I Know Food (Ensor; BBSRC, £2.3m) and Resilient Rice (Thankappan; BBSRC, £1.7m).

3.2 Infrastructure

3.2.1 Research groups and Departmental Research Committee

The research groups and Interdisciplinary Research Centres provide staff with the support to ensure that the Department delivers world-class research across our full remit of activity, serving as fora for the conception of initial research ideas and enabling us to respond effectively to challenge-led calls from funding bodies. Where there are institutional quotas in relation to specific calls, the DRC coordinates an internal selection process based on presentations and/or draft proposals.

3.2.2 Professional and technical support

We maximise research time for our academic staff by providing them with high-quality professional and technical support. Our academic appointments have been supported by three new laboratory technician appointments during the REF period in the areas of environmental geography, ecotoxicology, and chemical analysis including chromatography, HPLC and GC-based analysis, as well as a dedicated 50% FTE IT technician. Technical staff are monitored through annual PDRs and are encouraged and supported to undertake training within their specialisms, both within and external to the University where appropriate, to keep their expertise current. We have also added to our professional support team by investing in a 50% FTE Research Administrator, a Research Facilitator (initially 50% FTE, 100% FTE from January 2020) and PA support for the Directors of Research (Carslaw) and Strategy (Fazey). We also now benefit from a University management accountant and finance assistant, both embedded in the Department. In addition, since REF2014 we have appointed a PGR administrator, an industry liaison officer, a Research Manager, a Project Manager and a Communications

Specialist. We will continue to increase administrative and technical support alongside the planned increases in ART staff, including 2 FTE administrative staff and 1 FTE technician over the next 2 years.

3.2.3 Interdisciplinary Research Centres

Our capacity to undertake the fundamental and solutions-focused research that is needed to address global challenges is enhanced by our role at the heart of three Interdisciplinary Research Centres: YESI, IGDC and LCAB. YESI was established in 2012 as a pioneering interdisciplinary partnership generating the evidence for sustainable solutions to global challenges. Boxall was YESI theme lead for urban systems until 2020, Marchant is lead for YESI's Tropical Ecosystems Network and Parkhill is lead for YESI's Interdisciplinary Plastics Network. YESI provides our staff with support for research networking across the University, including team-building for large grant proposals and costings of complex projects. IGDC was formed in 2017 by a £1.5m strategic cross-Faculty investment by the University. White is one of three Co-Directors. IGDC brings together 105 members drawn from 20 Departments across the University to promote interdisciplinary approaches to address global challenges, and has generated £17m research income for the University since 2018. Income from IGDC's PhD and BA programmes supports the appointment of new academic staff, including Jew and 2 further staff for the Department over the next 6 years. IGDC provides one-to-one support sessions to staff with one of the Co-Directors (White) and the Research Facilitator, to assist staff with proposal development and partnership building. LCAB was established in 2019 to examine the changing relationship between humanity and the natural world, and provides important networking opportunities for our staff. Stringer's appointment is joint with LCAB, and Stringer and C West are on LCAB's Research Strategy Group. The LCAB PhD programme (24 PhD studentships available across member Departments) and the new ECORISC CDT, which also draws on staff in the Departments of Biology and Chemistry, highlight how our Interdisciplinary Research Centres have helped to strengthen our PhD programmes.

3.3 Facilities

3.3.1 Built facilities

The Environment Building includes a 90-seat auditorium, three meeting rooms, and one floor dedicated to open-plan working, which are invaluable resources for collaboration and engagement for social science research, as well as for conferences, and events for postdoctoral researchers and PhD students. The laboratory wing contains field stores and sample reception areas, clean areas for analytical work, and a 100 m^2 open plan laboratory space used for research project working by Masters and PhD students.

Our research on fate and behaviour of pesticides and pharmaceuticals, which attracts industry support (e.g. CAPACITIE, £4.5m, iPiE, £10m) draws heavily on the HPLC, GC and GCMS capacity in our Chromatography Laboratory and the liquid scintillation counter and dedicated HPLC in the Radioisotope Laboratory. Our capacity in this field will be enhanced in 2021 by delivery of a new Agilent Infinity II HPLC-PDA-MSD (£88k; funding confirmed in 2020 via the Institutionally-awarded Research England World Class Labs fund). Research in this area also benefits from the University's Centre of Excellence in Mass Spectrometry, providing access to a solariX XR FTMS (a very high-performance hybrid Qh-FT-ICRA), an Orbitrap Fusion Tribrid (a hybrid mass spectrometer) and a TSQ Endura triple quadrupole LC-MS/MS, the latter two together with a Waters Synapt G2Si Instrument representing c. £1.5m investment since REF2014. Many of the PhD students associated with the CAPACITIE and iPiE projects work in our Ecotoxicology Laboratory which houses a Loligo system for O_2 analysis and a Cell3Imager for video analysis, both of which are used to develop novel methods for high throughput ecotoxicology studies on aquatic micro- and meso-fauna.

Our Chromatography Laboratory houses our FTIR spectrometer, used in ongoing NERC and Commonwealth funded PhD projects for characterising microplastics. Our microplastic work also

uses facilities in the JEOL Nanocentre (part of SuperSTEM, the EPSRC National Research facility for Advanced Electron Microscopy), which supports a range of electron microscopes including a JEOL 7800 F Prime with EDX chemical analysis and a JEOL 2200FS Ultra high resolution (1Å) transmission electron microscope, together with sample preparation facilities such as a FEI Nova 200 Dual Beam Focused Ion Beam miller.

Research projects that generate data to inform land-use management, such as the stakeholder-funded Peatland–ES-UK project (£2m to date since 2012) and NERC-funded Soil BioHedge (£345k to York, 2015-18) make extensive use of ion chromatographs, autoanlaysers and elemental analysers. We purchased a new Bran+Luebbe AA3 autoanalyser (£30k) in 2019 as part of a rolling instrument upgrade programme. In 2021 we will take delivery of a new Vario MACRO CHNS elemental analyser (£66k funding confirmed in 2020 via the World Class Labs fund) in our Spectrometry laboratory and a Netzsch - Agilent TGA-GC-MS system (£135k, funded via EPSRC core capital funding in 2020) that will support ongoing work on both microplastics and carbon storage in soil (e.g. NERC 'Functional Ecology of Alpine Systems, £81k, 2019-22). Our Spectrometry Laboratory also hosts our iCAP 7000, Thermo Scientific ICP-OES used primarily for analysing metals in water and soil fate and behaviour studies in a wide range of projects and, two GC-IRMS used for palaeoecology.

In addition to analytical equipment, e.g. Metrohm voltameters used to determine the impacts of plankton on elemental speciation (e.g. NERC, 2016-19, £431k), our Biogeochemistry Laboratory contains facilities such as autoclaves, laminar flow cabinets and -80 °C freezers for preparation of samples for analysis in the centrally supported Bioscience Technology facility (e.g. Library preparation and Illumina sequencing of microbial and fungal communities in relation to biogeochemical cycling and environmental stressors; fluorescence microscopes for sample preparation and electron microscopy (JEOL JSM-6490LV with cryostage) and confocal microscopy for characterisation of biofilms on microplastics extracted from environmental samples) which has attracted c. £3.8m funding in 2015-20 and hosts over 90 key instruments with a value of £10m. Collaborations with instrument manufacturers have brought in new concepts to beta-test systems on a regular and long-term basis to internal users.

The Richard Payne Environmental Geography Laboratory houses a particle size analyser, ovens and furnaces and sieve sets used for preparation of peat and sediment samples prior to analysis of microfossils for palaeosea level and climate reconstructions, for example in the NERC funded C-SIDE project (£630k, 2018-22) and the NERC funded iGlass consortium (£2.6m, 2011-2015). The laboratory supports fossil pollen work for Oxford Archaeology on a consultancy basis and pollen analysis conducted on behalf of the Met Office. Our Gas-Flux Analysis Laboratory houses a suite of cavity ring-down (LGR isotopic N_2O analyser, greenhouse gas analyser) and infrared (LI-8100) gas analysers for CO_2, CH_4 and N_2O flux measurements. The analysers can be connected to an automated 24-channel gas flux system (EGA60, ADC) enabling real time monitoring of up to 24 test chambers under controlled conditions or alternatively be used in the field with manual and automated chambers. This laboratory has been supported by, and enabled a number of, NERC grants in the REF period (e.g. GREENHOUSE, 2013-17, £2.4m; 2017-19, £280k; 2017-18, £97k).

Further laboratory space provided in our new building includes a plant growth laboratory containing a number of controlled temperature cabinets, a microscopy laboratory that houses a number of research grade optical and digital microscopes used in a variety of projects, from the characterisation of microplastics in soil to the identification of microfossils, four constant-temperature rooms, used for a wide variety of plant growth and microbial work, two walk-in cold stores for long-term storage of samples such as sediment cores, a sample drying room and a soil preparation laboratory.

3.3.2 Computing facilities

The Environment Building provides all researchers with 24/7 access to a resilient, high-speed IT network and equipment. Our researchers also have access to the University's High Performance

Computing Facility, a £2.5m investment (REF5a:41). Researchers across our four research groups (e.g. Emberson, Hill, McClean, White) use the enhanced capacity and speed of this facility to run models and simulations, for example into numerical simulations of tides and tsunamis and for biodiversity futures modelling (White, NERC ColombiaBio project, £1.2m). Alongside this investment, the University provides user support and a comprehensive training programme, ensuring that staff are up-to-speed with the latest developments in hardware and software. Staff also benefit from free data storage and the University's web hosting platform, which allows interaction of researchers and the public with ongoing research activity.

3.3.3 Field-based research platforms

The Department is at the forefront of establishing and benefitting from long-term field-based experimental research platforms, recognising (1) their unique value in providing critical insights on atmospheric and oceanic processes, climate change, ecosystem and land-use change, and socio-ecological interactions, and (2) their particular strength in enhancing engagement and impact, through their immediacy with people and communities.

With funding from the Australian Research Council (the FORCE project), we have been establishing a unique pan-global network of long-term plots to underpin a new global resource to study changes in tropical forest ecology and restoration (Marshall; 150 sites in East Africa and 60 in Australia established, further sites in SE Asia and South America to follow). We have also been coordinating data collection since 2011 from 25-50 km transects across Tanzania, Kenya and Ethiopia as part of the CHIESA and AFEIRA projects (Marchant). Boxall is directing a new Global Pharmaceutical Monitoring project, working with 62 partner organisations to monitor levels of pharmaceuticals in 80 river systems in 65 countries on every continent. The database already contains 60,000 data points, and will represent the first ever global database on pharmaceuticals in the environment, with the potential to inform new standards in risk modelling and assessment globally.

The Peatland-ES-UK project (Heinemeyer) was established in 2012 and has attracted £2m funding to date, initially from Defra (2012-2016, £979k) and subsequently from stakeholders and industry (including Yorkshire Water, United Utilities, Yorkshire Peat Partnership, Moorland Association, British Association for Shooting and Conservation, Heather Trust; 2017-2022, £855k). The project has been supplemented by two NERC iCASE PhDs from 2019 with CASE partners (Natural England, Yorkshire Peat Partnership) and is part of the Ecological Continuity Trust's long-term monitoring network. Further involvement with the Trust in this REF period is via the Cors Fochno long-term experiment (Payne, Toet, Gehrels), which monitors peatland response to climate change, focusing on the combined impacts of drought and warming, and is the only experiment globally to include both long-term warming and active simulation of realistic summer drought by pumping.

The Department's SkyLine platform (Toet) is a unique NERC-funded greenhouse gas flux platform (2 grants in assessment period worth £380k total, 2017-2019), developed with the Departments of Biology and Electronic Engineering. NERC-funded research using SkyLine has led to important new discoveries regarding diurnal variation of N_2O emissions that will reduce the uncertainty in N_2O budgets and national GHG inventories. SkyLine is now being developed as a 3D version (NERC, 2021-2024, £316k, funding awarded July 2020) based around a novel roving eddy covariance, in collaboration with the Universities of Gothenburg and Lund, and will provide the first ever high-resolution spatio-temporal data on large-scale methane fluxes at a lake-wetland transition.

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

We place high strategic importance on partnerships with policy and decision-makers, the public sector, industry, their sector organisations, and the public, engaging with these organisations in

all stages of the research process to enhance the relevance and impact of our research; 14% of our publications include non-academic co-authors.

4.1 Collaborations with academia and research institutes

The Department has Memoranda of Understanding formalising research and teaching collaborations with ten different institutions across the world, including Seoul National University (Korea), Chiang-Mai University (Thailand), Universidade Federal de Minas Gerais (Brazil), Universidad Católica "Nuestra Señora de la Asunción" (Paraguay), Universidad Nacional de Misiones (Argentina), the Korean Environment Institute, and the Humboldt Institute (Colombia). Our staff hold Visiting Professorships and Fellowships at South China Normal University (China), University of Canterbury (New Zealand), Victoria University of Wellington (New Zealand), Arizona State University (USA), Universidade Federal do Pará (Brazil), and University of Sydney (Australia). In addition we have funded collaborations with >30 leading Universities and research institutes throughout the world.

Our staff include Editors-in-Chief of Climate and Development (Ensor), Toxics (Boxall), Sustainability Science (Kenter) and Wildlife Research (White) and are on the Editorial Boards as Associate Editors of Animal Conservation (Fazey), Elements (Hodson), Ecosystem Services (Kenter), Environmental Toxicology and Chemistry (Boxall), Open Quaternary (Hill), Atmospheric Environment (Carslaw), Quaternary (Marchant), Tropical Conservation Science (Marshall) and Peer J. (Carslaw). Our staff also contribute to the research base through their roles as Panel members and programme reviewers, e.g. Deputy Chair of UOA7 for REF2021 (Hodson), Chair of NERC Panel A 2021-2025 (Hodson; appointed 2020) , Chair of NERC-NRF Plastics in South-East Asia Grant Assessment Panel 2020 (White), Chair of NERC Towards a Sustainable Earth Grant Awards Panel 2018 (White), Reviewer for BBSRC Insect Pollinator programme 2016 (White), Steering Committee for the ‘Clean Air’ Strategic Priorities Fund programme (Carslaw), and as advisory board members (e.g. Centre for Dryland Agriculture in Nigeria, and the Centre for Environmental and Marine Sciences (CESAM) in Portugal (Stringer).

4.2 Partnerships with policy and decision-makers

The Department plays a leading role in influencing policy and practice at national, regional and global scales. Our staff advise global policy-makers internationally including UNEP, UNDP, UNECE, UNCTAD, FAO and WHO, national Government Departments such as Defra, FCDO (formerly DFID), BEIS and DHSC in the UK and GIZ and BMZ in Germany, support international NGOs such as WWF, IFRC and Oxfam, and sit on national and international expert committees. Stringer’s research has informed guidance published by UN Women, IUCN and the UN Convention to Combat Desertification’s Global Mechanism on gender-responsiveness in tackling land degradation. Gehrels was a Contributing Author to the IPCC 5th Assessment Report, and Stringer is a Lead Author for the IPCC 6th Assessment cycle. Our staff are also working with the United Nations Environment Programme to develop novel approaches to link commodity producers and consumers to specific on-the-ground impacts on biodiversity and ecosystems (C-West).

Our reputation and influence in equitable environmental sustainability policy and practice continues to be enhanced through our institutional partnership with the Stockholm Environment Institute (SEI). SEI was ranked as the world’s top think tank on environmental policy issues in the University of Pennsylvania’s 2019 Global Go-To Think Tanks Index. Collaborations between staff from the core Department and SEIY have been influential on the global scale, e.g. playing a key role in UNECE Long-Range Transboundary Air Pollution Convention and working with the Task Force on ICP Vegetation to develop air quality guidelines for vegetation for application across Europe (Emberson).

Emberson and Kuylenstierna were founding members of the Climate and Clean Air Coalition (CCAC), which supports Governments in 16 countries across Central and South America, Africa and South-east Asia. Hicks and Kuylenstierna led and worked on major UN reports on curbing

air pollution in Latin America, the Asian Pacific region and most recently the African regional assessment, and continue as members of the Science Advisory Panel for CCAC. They have also set up the Global Panel on Chemical Pollution of the Environment, a chemicals equivalent to IPCC. Working in collaboration with UNEP and APCAP, Kuylenstierna, Hicks and Emberson have led regional assessments and helped to change national agendas to include mitigation of Short-Lived Climate Pollutants (SLCPs) for Latin America, Asia and the Pacific, supporting 16 national governments to develop integrated air quality and climate strategies, with political endorsement of six national action plans to reduce SLCPs in Nigeria, Cote d'Ivoire, Mexico, Bangladesh, Maldives and Togo. The underpinning research is cited by the IPCC 1.5ºC Special Report and described in ICS1. Emberson has also contributed to the development and application of air quality guidelines for vegetation across Europe as part of the UNECE LRTAP Convention (Emberson, Hicks). Staff led by C West have developed the LEAP-IBC tool, which includes an integrated calculation of the economic benefits from air pollution mitigation. Emberson and Kuylenstierna sit on the Advisory Panel of the International Union of Air Pollution Prevention Associations, and Hicks is the European Director for the International Nitrogen Initiative.

Our staff have contributed to the development of global biodiversity policy through the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), as Coordinating Lead Author for Governance options in the Africa Regional Assessment (Stringer), Lead Author of the Values Assessment (Kenter) and Lead Author for decision support tools and processes for the IPBES Land Degradation and Restoration Assessment (Stringer). Staff are also involved in the Climate Change Specialist Group of the IUCN Species Survival Commission (Platts) and have contributed to a WHO report on biodiversity and human health (Cinderby). Staff research on future land-use scenarios for Eastern Africa generated through a WWF REDD project (Marchant) has contributed to the development of national carbon monitoring in Tanzania through the MRV portal, which is being used within the Tanzanian National Carbon Monitoring Centre (NCMC). Our research in East Africa has also involved collaboration with the African Conservation Centre in Kenya, ICIPE, UN Environment, Kenya Wildlife Service, the Tanzanian Forest Agency and TANAPA (Marchant, Marshall, Jew, Platts). Our work on climate change mitigation across Brazil, Argentina and Paraguay has led to the creation of the first tri-national development council, made up of government, business and civil society groups, focused on climate change adaptation in the Latin American region (Sakai).

Energy-economy modelling by Sakai has been used by the Department for Business Energy and Industrial Strategy to develop UK energy scenarios. Carslaw serves on the UK Government's Committee on the Medical Effects of Air Pollution, and chaired a COMEAP report on air quality on the London Underground. Carslaw has also served on Defra committees concerning air quality modelling and contributed to the SAGE Environmental Modelling Group report on air cleaning devices, as part of the Government's Covid-19 response. Boxall contributed an air pollution chapter to the Annual Report of the Chief Medical Officer in 2017. Brown is a member of Water-Friendly Farming, a landscape-scale experimental and demonstration platform with multiple stakeholders, which has given three all-party parliamentary group presentations and is influencing policy development on nature-based flood prevention. Selby is the official provider of pollen counts for the Met Office for the Yorkshire region. Payne (deceased) had been invited to be an author of the 2019 IUCN Commission of Inquiry on UK Peatlands. Staff are involved in advising Defra and Natural England on the implementation of the Government's 25-year Environment Plan, developing indicators and metrics around sustainable consumption and production (C West) biodiversity and ecosystem services (White), and fisheries policy post-Brexit (Stewart). White also sits on Natural England's Science Advisory Committee.

4.3. Links with industry and business

We recognise the private sector as an increasingly important player in environmental management and sustainability initiatives. Our staff have close working relationships with a number of the major global pharmaceutical companies including Pfizer, AstraZeneca, GSK, Merck, Eli Lilly, Sanofi, Reckitt Benckiser, Bristol Myers Squibb, Teva, Boehringer Ingelheim,

Johnson & Johnson and Bracco. Boxall's ECORISC Centre for Doctoral Training includes 28 external partners from industry, government, research and third sectors. Boxall is working with AstraZeneca and Simomics Ltd to develop a virtual pharmaceutical laboratory for designing testing strategies for pharmaceuticals in the environment, in order to reduce the need for animal testing. This virtual system is now being further developed, in collaboration with pharmaceutical companies, in the €9.76m Euro IMI PREMIER (Prioritisation and Risk Evaluation of Medicines in the Environment) and the £100k Innovate UK-funded MERMAS (Manufacturing Effluent Risk Modelling and Assessment System) projects. Boxall and Sallach also advised the American Personal Care Products Council, the European Cosmetics Foundation and Beiersdorf on the sustainability of consumer products and the environmental fate of chemicals and microplastics. Boxall has participated in a KTP with Pyropure to adapt a hazardous waste treatment system for use on pharmaceutical waste and advised Medisort on a new technology for pharmaceutical waste treatment. Boxall is a member of the Antimicrobial Industry Alliance strategic advisory board, providing expertise on issues around antimicrobial contamination of the environment. Hodson is on the stakeholder panel for Allerton Waste Recovery Plant, a major new waste treatment facility for York and North Yorkshire, as well as on the Technical and Research group of CL:AIRE (Contaminated Land: Application in Real Environments). Two Innovate UK partnerships with Syngenta in the UK and a collaboration with CIAT in Colombia (Brown) have promoted greater efficiencies and precision in the use of agrichemicals and water in food production.

White has worked on two NERC Innovation projects on solar parks and ecosystem services with the Solar Trade Association and the National Farmers Union (2016-2020, total £170k); the resulting toolkit on enhancing natural capital and ecosystem services in solar parks has been featured in SolarPower Europe's Operation and Maintenance Best Practice Guidelines. The Department has a long-standing formal relationship with Flamingoland, with Marshall being its Consultant Conservation Director. This collaboration, initiated through a KTP in 2011-2013, has been worth £1m to the University to date. C West's TRASE project engages with the major buyers of soy and palm oil such as COFCO, the Soy Buyers Coalition (400 member organisations) and Tesco, with strong engagement particularly in Latin America and Indonesia. New work in this project enables the linking of downstream consumer goods companies via their supply chains to specific locations of deforestation and biodiversity risk, focusing on Brazil, Indonesia, Congo Basin, Tanzania and China. This work is informing risk profiles for the UK Round Table on Sustainable Soya and the development of overseas impact indicators as part of Defra's 25-Year Environment Plan. Recognising the commercial value of some of our research, we are working to commercialise some of our products over the next few years. One example is provided by Toet's SkyLine system which is the focus of a University Enterprise Fellowship project.

4.4. Collaboration with third sector organisations and foundations

Staff have held influential positions on a number of foundations. Roberts is a WWF-UK Ambassador and has been on the Board of Blue Marine Foundation and acted as advisor to the Pew Bertarelli Global Ocean Legacy Program, and Stewart is working with Make Stewardship Count. The work of Stewart, Roberts and Hawkins, described in more detail in ICS2, with various third sector marine organisations including Blue Marine Foundation and the Community of Arran Seabed Trust (COAST), has been instrumental in the development and demonstration of marine protected areas in protecting marine biodiversity and fisheries in the UK and globally.

Discoveries through the AAREA project (Stump; ERC, £850k) and two subsequent Marie Skłodowska-Curie Individual Fellowships (Stump; tRRACES and MATRIX) on the function of agricultural terraces as sediment traps to improve soil development have led to discussions with Oxfam and Water Aid concerning implications for development practices in East Africa. Marshall's work with Flamingoland has resulted in the establishment of a number of important conservation projects in Tanzania, including the Udzungwa Forest Project (UFP) which is carrying out ground-breaking research into forest restoration techniques (ICS3). Flamingoland continues to support this work, contributing 25% of Marshall's salary to support UFP. The work

has also led to the development of an NGO, Reforest Africa (Director: Marshall), which is now registered as a Charity in the UK. Reforest Africa works in partnership with the Tanzania Forest Conservation Group, Plant for the Planet, the Rainforest Trust, and the Global Forest Biodiversity Initiative, and receives additional sponsorship from IUCN's Sustain Initiative, African Wildlife Foundation, the United Bank of Carbon, and Greenpop.

4.5. Public engagement and media

Our Research and Impact Strategy emphasises the importance of engaging people with environmental challenges and solutions for developing meaningful mitigation, adaptation and remediation strategies. Our staff have been at the forefront of promoting participatory techniques in research. The Department was one of the lead organisations in the UK-wide Big Lottery-funded Open Air Laboratories (OPAL) Project (S West, White). The £3m second phase, which ran from 2014-2016, included formal partnerships with Cofnod, the Field Studies Council, Glasgow City of Science, National Museum Wales, North Wales Wildlife Trust, and TCV. OPAL has engaged more than 1 million participants across the UK, with over 3,900 schools taking part, many from socio-economically disadvantaged areas, producing 1.5 million data points and 20 scientific papers.

Cinderby has used participatory techniques within the AHRC-MRC Air Network Nairobi project, to enhance communication between community, authorities and industry around air pollution in Nairobi, and he has worked in a British Academy-funded Cities and Infrastructure project on pedestrian-friendly urban co-design in Nairobi (Kenya) and Kampala (Uganda). The resulting installation of a 3-dimensional pedestrian crossing in Nairobi was cited as an exemplar of community-based street planning by UN Environment in the 2018 annual report for their Share the Road programme.

The Department has active and well-followed social media activity. Work by our students and staff was featured an average of 13 times per month across national and international TV, radio and print media in 2020. One of Gehrels' papers, published in PNAS, was tweeted by Barack Obama and cited during debates on climate change in the US Senate, finishing as the 3rd-ranked climate paper in 2016 for news and social media attention. Stringer appeared on BBC Breakfast and the BBC News Channel in 2019 to talk about the IPCC Special Report on Climate Change and Land and has been interviewed by other media outlets including BBC Radio, BBC Futures, Flash Forward, Japan Times, Canada Mail and Reuters. Marshall's creation of Magombera Nature Reserve in Tanzania led to a live interview on the BBC Radio 4 Today Programme, and a session of music dedicated to forests on Steve Lamacq's show on BBC Radio 6 Music. Stewart's research on Brexit and fisheries policy has attracted a range of media attention and his work on Marine Protected Areas around the Isle of Arran was featured on BBC Springwatch in 2018, as well as in numerous other media articles, nationally and internationally. Roberts featured on The Life Scientific in 2018 and was chief scientific advisor to the BBC Blue Planet II, which was the most-watched British TV show of 2017, with 14 million viewers in the UK and many millions more globally, including 80 million in China alone.