

Institution: **Newcastle University**

Unit of Assessment: **6 Agriculture, Veterinary and Food Science**

1. Unit context and structure, research and impact strategy

1.1 Overview: Agriculture and Food Science (AFS) at Newcastle sits within the School of Natural and Environmental Sciences (SNES), in the Faculty of Science, Agriculture and Engineering (SAGe). SNES is the third largest academic unit within the University, with a diverse community of 135 academic staff, 2,045 students and an annual turnover of £35million. Formed in 2017, SNES encompasses the former Schools of Agriculture, Food and Rural Development; Biology; Chemistry; Earth Sciences; and Marine Science. Research is structured through four areas of expertise, each with its own directorate, which broadly align to the REF UoAs. AFS resides within the BioEconomy directorate, with research staff and PGRs managed through academic groups. Crop production and animal science research and teaching are supported by two research farms with a dedicated farm director.

Fundamental bioscience in AFS is campus-based in the Agriculture and Devonshire buildings. Food research is predominantly focussed around consumption relating to food- and agri-business and consumer behaviour and includes a sensory testing suite and experimental kitchen, to conduct sensory and dietary interventions. AFS's expertise in applied social sciences lies within the Centre for Rural Economy (CRE), a cross faculty research centre and includes one of the most significant groupings of rural social scientists in Europe (Queen's Anniversary Prize for Higher and Further Education).

1.2 Research objectives during the REF2021 period. AFS REF2014 strategy followed the University's Societal Challenge Theme of Sustainability, addressing the development and integration of science and technologies to increase resource use efficiency in ethical food provision. Initiatives to revitalize and invest in AFS began with the appointment of new management and a major external review in 2015. Since 2014 investment in AFS increased by 15.8 FTE of new staff to build critical mass in key areas, leading to increased research income (>50%), PhD students (>45%), and a qualitative/quantitative improvement in outputs.

A key area for investment continues to be precision agriculture, with a focus on understanding the underpinning science and building capacity in environmental and agribusiness research linked to food production. AFS at Newcastle has aligned research outputs to the needs of industry and society, and in 2015 was selected as the academic partner for the newly formed Fera Science Ltd., resulting in the formation of the joint Institute for Agrifood Research and Innovation (IAFRI). AFS are founding partners (2016) of two national agritechology centres, Centre for Crop Health and Protection (CHaP) and Centre for Innovation and Excellence in Livestock (CIEL) as well as the N8 Universities £16 million Agrifood Resilience Catalyst award funded by Hefce/OfS (2015). AFS social sciences are sought by national (Defra, FSA, Scottish Gov) and International (EU, EFSA, UN) government in setting policy relating to food safety and the socioeconomics and environmental impacts of farming.

1.3 Interdisciplinarity and partnering: AFS research has the objective of supporting the production of safe and nutritious food within a sustainable and resilient food system. This is achieved through externally-facing partnerships, by conducting research which spans across scales from molecules to entire ecosystems, and from the fundamental science to policy formation. The large and diverse academic base has delivered impactful solutions across industries, Government, NGOs and the wider agrifood community (Figure 1). The formation of IAFRI in 2015 has been particularly formative, allowing AFS at Newcastle to diversify its routes to impact across the agri-food sector.

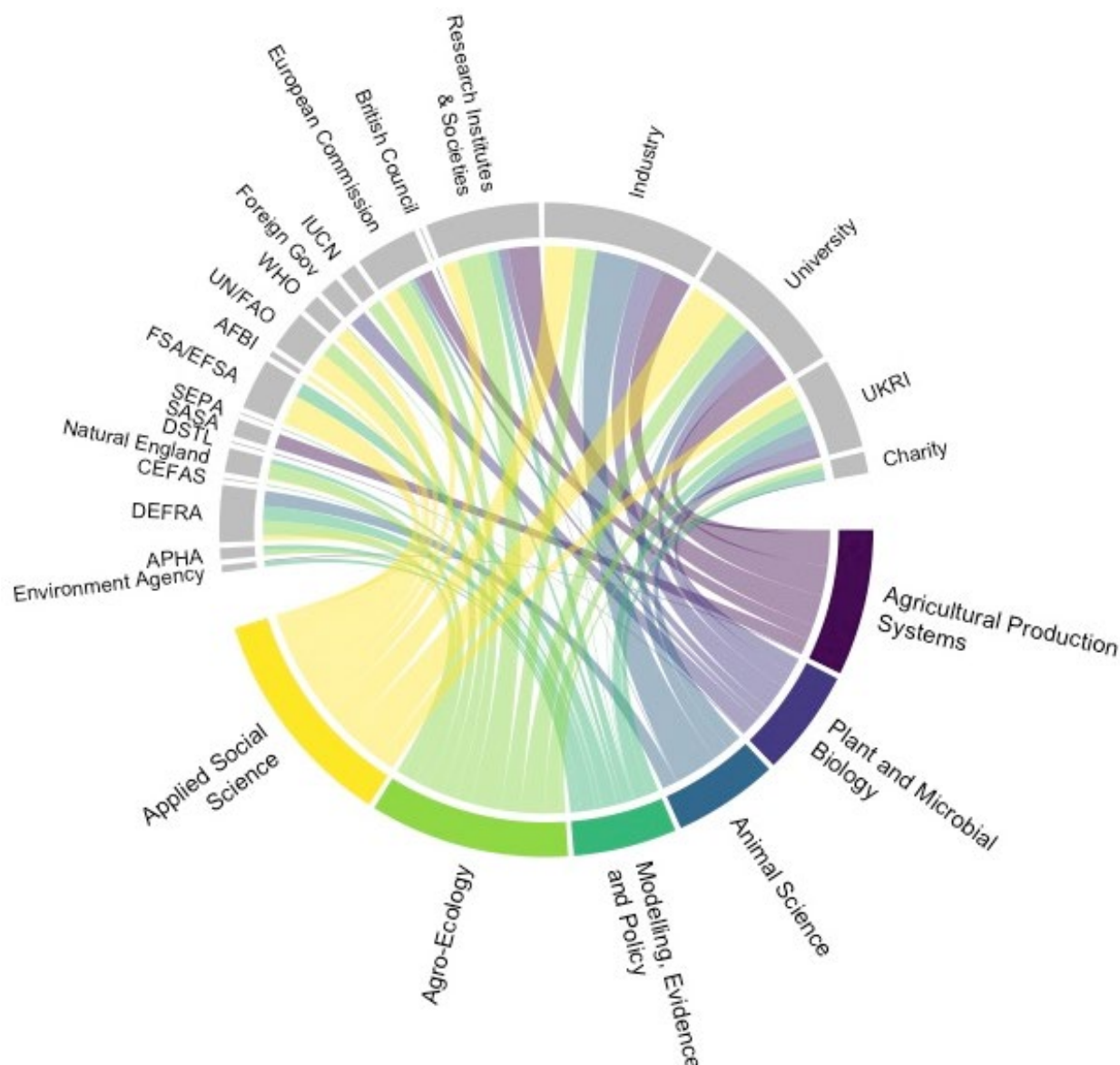


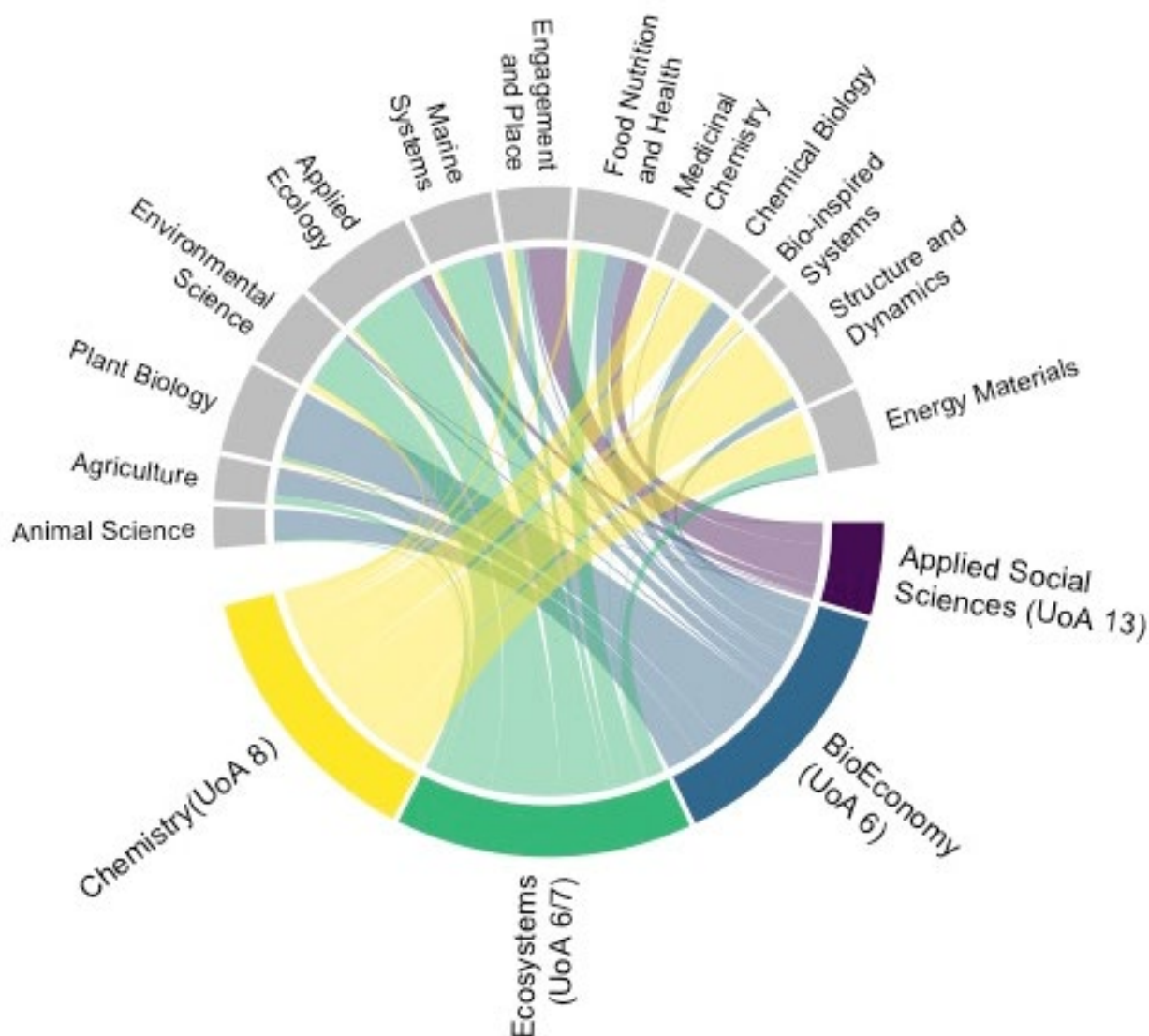
Figure 1. Research Intensity. Research themes within UoA6 (denoted in colour) and their relationship with major funders and collaborating institutions (denoted in grey). Data from 2014-2020 are presented from a topic model, with the width of each link indicating relative level of activity.

1.4 Unit structure and governance: AFS returns 41 independent research-active staff to UoA6. The AFS research community comprises 9 Professors, 2 Readers, 20 Senior Lecturers, and 10 Lecturers. Four Senior Lecturers are joint IAFRI appointments, funded with Fera (Total 36.8 FTE). We also return outputs from 1 Lecturer, 1 Senior Lecturer, 1 Professor, and 2 Emeritus Professors who have left during this REF period. AFS also comprises 11 lecturers dedicated to Teaching and Scholarship and a research community that includes 48 Post-Doctoral Researchers, 284 postgraduate research students, and 34 Technicians (census 2020).

The SNES management structure is designed to facilitate interdisciplinary research and training. All academics, PDRAs and PGRs are managed through their primary membership to an *Academic Group*, led by experienced, research-active academics. Secondary group

affiliations are encouraged to foster cross-disciplinary working. Group leads report to a *Director of Expertise* (DoE), with oversight of research and related training within broad solution-focussed *School Directorates* (*BioEconomy*, UoA 6; *Ecosystems*, UoA 7; *Applied Social Sciences*, UoAs 6/13; *Chemistry*, UoA 8). The DoE has responsibility for managing both research and the delivery of related teaching. This activity is co-ordinated across the Directorates through a school research & innovation committee, with the group leads being supported by the School Executive Board through membership of the School Management Group.

The BioEconomy directorate draws together the skills base in social, agricultural and biological sciences, promoting interdisciplinarity through collaborative grant applications and multiple authored outputs (Figure 2).



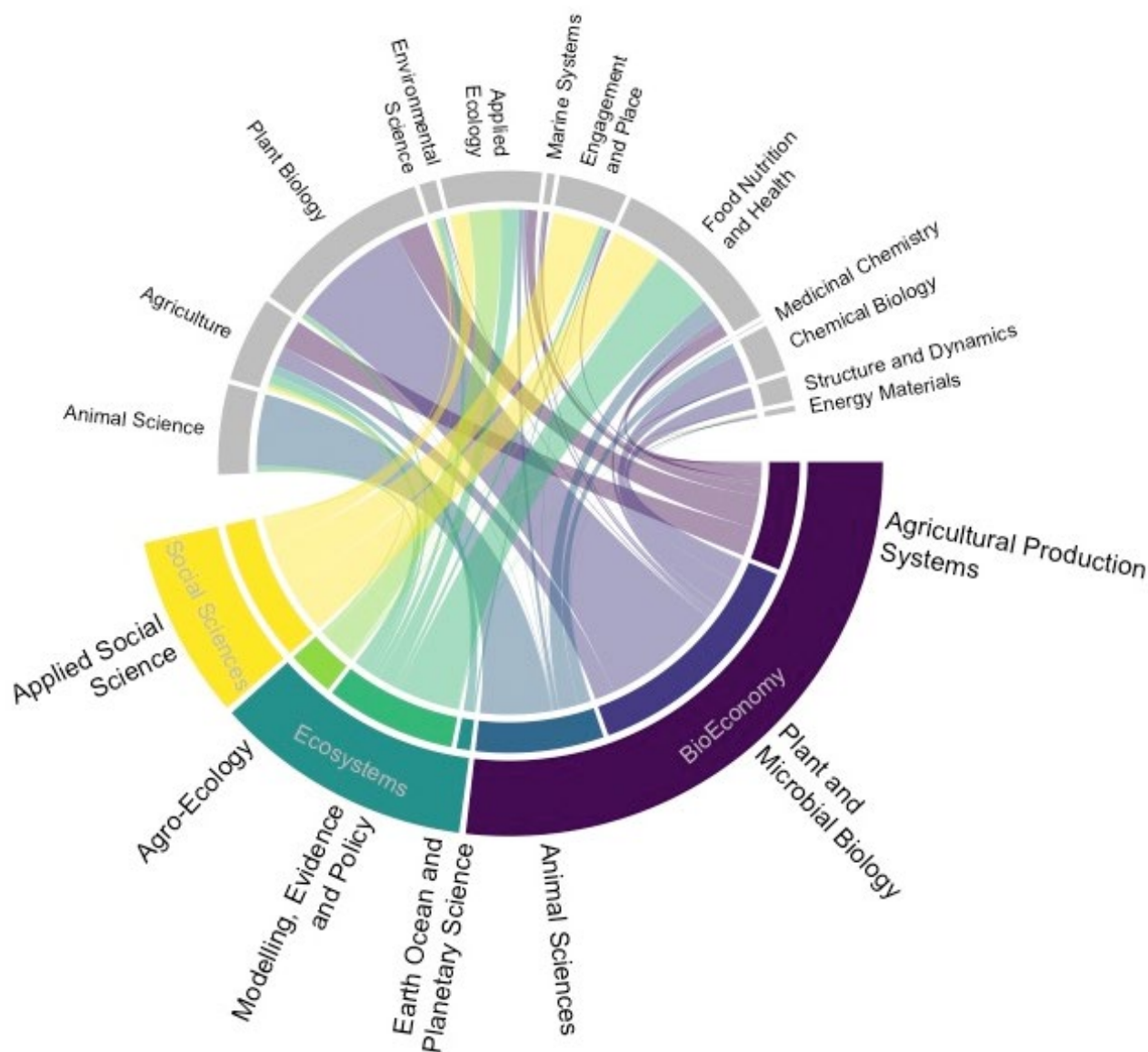


Figure 2. SNES School research themes (grey topics in the top section) and their relationship to the School structure (denoted in colour). Data are presented from a topic model using publication outputs 2014-2020, with the width of each link indicating relative level of activity. Theme contributions are shown by (a) School Directorates of Expertise; (b) Academic Groups showing only staff returned to UoA6.

The four SNES DoEs jointly develop and deliver School objectives through their representation on the School Executive Board and bi-monthly meetings of the *School and Faculty Research and Innovation Committee*. University-wide interactions are facilitated by the *Newcastle University Centres of Research Excellence (NUCoREs)*, with “Healthier Lives” and “Climate & Environmental Resilience” being particularly relevant to AFS researchers. Partnerships with industry and overseas institutions are supported by the business development team and International Office respectively, with the UN SDGs being a prioritised theme for collaboration. The breadth of interdisciplinary working across the school is illustrated using the chord diagram derived from topic modelling of research outputs (Figure 2).

1.5 Research Strategy: AFS scientific and impact goals are to build capacity in world-class agri-food research, through close working with government, industry and the wider community. AFS research strategy is based on three cross-cutting themes:

- (i) **Resilient and efficient agri-food production:** Improving the productivity and health of crops and livestock through precision agriculture and the application of smart surveillance systems.
- (ii) **Sustainable agro-ecological systems:** Managing natural capital to provide sustainable primary production and ecosystem services.
- (iii) **Agri-food system governance and food safety:** Understanding behaviours and interactions within agri-food systems and the role of evidence-based policy mechanisms in enhancing the sustainability, resilience and safety of food production.

1.6 Research structure: AFS research spans three cross-cutting themes.

Cross-Cutting Research Themes	UoA6 Academic Groups: Strategic Aim, Achievements and Future Vision
Resilient & Efficient Agri-Food Production	The <i>Animal Sciences</i> (AS) group (Asher, Beard, Boswell, Butler, Chaudhry, Guy, Leach, Velazquez) use precision methods and informatics to address global challenges in the welfare, health and physiology of livestock, laboratory and companion animals. The AS group overlaps with APS (see below), with Butler and Chaudhry members of both. In the REF2021 period, the group has expanded with the appointment of Asher (precision livestock technologies) and Velazquez (reproductive physiology). Asher, Leach are Category A members of the CIEL agritech centre, and the Centre for Digital Innovation Applied to our Livestock (C-DIAL) facility at the Cockle Park research farm. C-DIAL utilises sensor-based, automated imaging and audio technologies to monitor performance, health and welfare of livestock. C-DIAL also houses a large animal gait facility with state-of-the-art motion capture technology, climate controlled, HO-licensed livestock facilities. Asher's use of automated sensors has led to the commercialisation of technology linked to animal welfare monitoring. Asher also operates the world's only mobile canine research unit. Access to facilities in the Comparative Biology Centre, underpins research into improving the welfare of laboratory and companion animals (Leach, Flecknell see Impact Case Study [ICS]), which have resulted in improvements in pain management of laboratory and companion animals through veterinary practice at an international level. Research with Noble Foods Ltd & DSM UK Ltd., has led to the development of 'Sunshine Eggs' enriched with Vit D (see ICS; Hill, Kyriazakis, Hubbard), accounting for 60% growth in the free-range egg market. In collaboration with Carrs-Billington, Chaudhry was involved in the development of Crystalyx, as a supplement for ruminant diets and working with LanXESS (Virkon products) and has developed commercial alternatives to antibiotics to reduce disease in chickens. Future strategic priorities are focussed on maximising animal welfare in intensive production system and growing capability in precision livestock management through developing new digital technologies.
	The <i>Plant and Microbial Biology</i> (PMB) comprises 19 members returned to UoAs 5, 6, 7 & 8, with Andriotis, Audsley, Borland, Edwards.M, Gatehouse, Howard, Kapralov, Willats, Wakefield returned to UoA6. Plant science research centres on understanding fundamental biological processes that underpin crop productivity. Strengths lie in carbohydrate metabolism (Andriotis, Willats), photosynthesis (Kapralov) and links to water use efficiency (Borland), with long-term funding from the US

	Department of Energy. Wakefield, who has brought a biocontrol agent to market, and Audsley (both IAFRI) bring additional expertise in biopesticide development and delivery to well-established programmes manipulating plant-pest interactions and in biotechnology applied to insect-pest control (Gatehouse, Edwards.M; H2020-EcoStack; BBSRC-LINK). Expertise in microbiology focuses on biotechnological applications for sensors and diagnostics (Howard, Willats), utilizing novel approaches including synthetic biology, with application to plant disease surveillance. These have influenced policy development in Defra (Plant Health), EU commission and the European Food Safety Authority (EFSA). Borland, Kapralov and Andriotis are leading research in plant cell biology that underpins productivity traits. The appointment of Willats and his development of high-throughput microarrays based glycomics technology, has led to the development of novel diagnostic approaches for plant and soil health. Future research will build synergies between microbiology and plant sciences in the use of bioinoculants to manipulate the microbiome to enhance crop resilience to climate change, productivity and disease tolerance. Biotechnology programs will focus on bioprospecting for veterinary medicine discovery and developing diagnostic tools and novel smart materials for applications in crop disease, vector detection and assessing food quality and authenticity.
	The Agricultural Production Systems (APS) group (Bilsborrow, Boonham, Butler, Cooper, Edwards.R, Franks, George, Prashar) focuses on integrated farm management in sustainable and low input arable and pasture production, making extensive use of the two research farms. The group and research farms have undergone a major realignment in interests. Low input agriculture (EU-Ecobreed) (Bilsborrow), soil health (Cooper) and sustainable ruminant nutrition through pasture management (SusCatt) (Butler) build on the long-term factorial QLIF experiment established by the Nafferton Ecological Farming Group (Leifert). George brings expertise in integrated pest management and links to the CHaP agritech centre, extending capability in arable farming. George leads the NU Farms Academic Strategy Group working alongside new farm director (Standen) to merge commercial operation with research themes. The farms are also used as a business performance resource relating economics to changes in management practice (Areal, Franks). A new theme supporting sustainable input management, with significant crossover with PMB (Willats/Howard), is the development of in-field diagnostics to generate real-time data to better guide pathogen/pest/weed control. Based on molecular diagnostics (Boonham, Edwards.R) and remote imaging (Prashar), work has led to early identification of disease (Innovate UK-InFarm 2.0) in vertical farming systems (Boonham/Prashar) and resistance status to fungicides (Boonham), and herbicides (BBSRC-Lola) (Edwards.R). The work of this group has resulted in the commercialisation of in-field diagnostics (BReD, MoLogic) for weed control. At the international level, field diagnostics work extends to virus disease problems (BBSRC-CONNECTED) in sub-Saharan Africa (Boonham) and herbicide resistance detection in Australia and Canada (Edwards.R). Future research will focus on low input farming systems, (including integration with other groups); carbon impact of crop production; improving ruminant productivity and meat/milk quality through controlled pasture nutrition (EOPS), diagnostics and sensors (PMB) and the interface of

	farming and the environment (IAFRI/Ecology). The research farms will be developed as an industry demonstration platform (Farm Zero) to investigate how farming systems will meet the strategic needs of UK agriculture, environment and NetZero policies over the next 25 years.
Sustainable agro-ecological systems	Expertise in this theme is drawn from the <i>Ecology</i> (Cooper, Evans, Franks, George, Port, Sanderson, Whittingham), <i>Modelling, Evidence and Policy</i> (Stewart, Budge) and <i>Applied Social Science</i> (Reed) academic groups, reflecting their multidisciplinary research interests. The appointments of Evans, Budge and Reed have all been made in the REF2021 audit period. Research focuses on investigating the interactions between natural biodiversity in the landscape and agriculture and is based on the University farms where there is opportunity to integrate ecological research with agricultural practice. Notably, the 120-year old Palace Leas experiment provides a unique resource for investigating ecosystem functioning of the above and below ground flora and fauna. Research is geared to landscape stakeholders, IPBES, Defra, Scottish Government, UNEP and UNCCD with direct impact on policy and is grouped in two major themes: i) Investigating agro-ecosystem function and the interactions between different components of biodiversity and agricultural practice. Focus is on pollination biology (Budge, Evans); natural pest control (George) and the role of arbuscular mycorrhizal fungi in plant nutrient dynamics (Cooper). The group use biomolecular approaches to investigate system functioning using bar coding, e-DNA to generate data in evaluating hypotheses of ecosystem functioning. ii) Investigating the impacts of management on ecosystem services in agricultural systems. Budge researches bee disease and the role of pollinator sources on bee health whilst Whittingham seeks to quantify ecosystem services provided by farmland bird species. Port and Sanderson investigate invertebrate systems. Research is directed at studying and quantifying the delivery of ecosystem services within multifunctional landscapes (Whittingham, George, Reed, Evans), including systems level e.g. farmland ecological networks (Evans, Franks). The research outputs have been used in policy making including: the design and implementation of the UK's first ever and world-leading private-public Payment for Ecosystem Service scheme to restore damaged peatlands (Whittingham, Reed; ICS) and sustainable use of forests in Nepal (Whittingham). Future work will focus on maximizing ecosystem services across a range of metrics (e.g. achieving zero carbon farming while enhancing the environment using the university farms as demonstration platforms) using digital technology for real time environmental monitoring as developed by the AS group.
Agri-food System Governance and Safety	This theme has two foci: Resilient Food Systems and Food Safety and Policy (Areal, Frewer, Hubbard, Jones, Kuznesof, Panzone, Reed, Souza-Monteiro). Transdisciplinary research spans primary production through businesses in the supply chain to the end-consumer. They include consumer behaviour and quality and safety attributes of food. The group uses co-production and knowledge exchange with stakeholders, including

	partnerships with regional, national and international collaborators (e.g. National Centre for Innovation and Rural Economy and United Nations' Global Peatlands Initiative, Reed). The group have leading roles in the N8 Universities Agri-resilience initiative, and the N8 policy hub in addition to active input to NU's Policy Academy and the Centre for Rural Economy (CRE). Hubbard researches future economic performance of UK agriculture under a range of post-Brexit scenarios whilst Shortall analyses the role of under-represented groups in farming; ICS). The outputs inform policy makers (Defra, the Scottish Government, the Welsh Assembly and DAERA), National Farmers Union and AHDB to inform the design of future agricultural support mechanisms. Research into Food Production Systems addresses barriers to diversification of aquaculture (Panzone); understanding conflict and cooperation in the supply of sustainable food (Souza-Monteiro); consumer perspectives of farm animal welfare and animal production diseases (Frewer); and Resilient Dairy Landscapes (Reed). Outputs from these projects have influenced EU and UK policy on sustainable cropping systems. Kuznesof has evaluated interactions between food production, the environment and the valuation of ecosystem services in the water, energy and food nexus, while the work of Frewer, Whittingham, Reed, George, Evans has focussed on Upland farmed landscapes e.g. Glen Finglas the largest upland grazing area in Europe. These projects deliver evidence to public and private sectors including Defra, and DG-AGRI on future policies. Frewer and Jones collaborate with China aimed at understanding stakeholder and consumer perspectives on technology innovation for improved food safety and quality. They investigate the adoption of precision agriculture in China and the identification of societal concerns linked to the virome in agriculture and food authenticity (Frewer, Kuznesof). Digital technologies are being explored to aid healthy consumer choices (Souza Monteiro), whilst virtual supermarket platforms are used to investigate how information on environmental impact provided in retail spaces impacts on consumer choices (Panzone). Future research focuses on developing models for investigating structure in rural systems, and their application to policy scenarios and how food systems can deliver equitable and healthier diets whilst reducing Greenhouse Gas emissions. Behavioural drivers in farmers, food-business-managers and consumers will be studied in developing improved sustainability indicators for land management practices supporting post-Brexit "payment by results", as well as climate-change mitigation.
	Food Safety & Policy is a multidisciplinary sub-theme delivered by members of ASSG (Frewer) and the Modelling, Evidence and Policy group (O' Brien, Rushton, Shirley). Research is focused on understanding the underlying biological processes determining the epidemiology of food borne disease, spanning the molecular bases of pathogenesis, host-pathogen interactions and the epidemiology of disease in animal and human populations. Modelling is used to predict epidemiological processes across spatial and temporal scales, to develop strategies for enhancing food safety through mitigating pathogen spread. In the REF2021 period work focussed on <i>Campylobacter</i> (Rushton, Shirley), with research in the underlying mechanisms of pathogenesis, host responses as well as the environmental and social ecology of human infections. The group's work has contributed to the research agenda and

strategy of the Food Standards Agency (FSA) and includes collaborators at Liverpool, Leicester, UEA, Manchester, Lancaster, Swansea and Aberdeen, as well as Nercita and CAAS in China. This network of collaborations has been further strengthened by the recent appointment of medical epidemiologist **O'Brien** through an endowed Chair funded by the Elizabeth Creak Charitable Trust. In addition to strengthening links with FSA, this new post aligns to the interests of the AS and APS groups in livestock health, with its research focus on pathogens such as *Campylobacter* entering the food chain on the farm. The work further links to expertise of members of ASSG in studying behaviours in farmers that have a major role in determining pathogen infection of livestock through management practices. Social science interests in food safety through perceptions of risk across the food chain and to consumers (**Frewer, Kuznesof**) include the use of citizen science and expert elicitation in emerging food risk identification and extend to responses to food integrity.

Food safety research will extend the modelling of immunological interaction between livestock, pathogens and an ageing and immune-compromised human population. We will research risk mitigation in existing and emerging pathogens and the consequences of societal adoption of technological innovations in mitigating risk in food safety.

1.7 Research Vision: AFS continues to grow by investing in the underpinning natural and social sciences that support a growing reputation in responding to the translational research needs of the agrifood sector. Interdisciplinary links with computer science, engineering in the SAgE faculty and with the NUCoRE “Healthier Lives”, hosted in the Faculty of Medical Sciences (FMS) will be supported through joint appointments in digital technologies, precision agriculture and food technology, respectively. In response to the institutional-level plan of growing research intensity and power (35% increase in research income over 5 years; 20% increase in researcher capacity over 10 years), SNES will deploy a two-pronged approach to build strengths in AFS. Firstly, the development of staff in post, especially the recently appointed ECRs, as successful researchers will be targeted through collaborative working, grant writing skills development and an active sabbatical programme. Secondly, a series of staff appointments are planned at mid-career level. Both elements of the staffing plan will increase the size of the future professoriat in response to staff retirements post-2021. This will include sourcing additional external sponsorship for key Chair and advanced fellowships building on the recent successes of attracting funding from the Elizabeth Creak Charitable Trust, the John Oldacre Foundation and the Duke of Northumberland bequest. Specific growth areas building on the themes above (see Cross-Cutting Research Themes) and responding to the future needs of the agrifood sector include:

- **Agri-technology in crop production:** Increased capability in both fundamental sciences and translational platforms in crop-related biotechnology and precision agriculture to further develop arable sustainable production systems needed for future farming.
- **Precision digital technologies applied to animals:** Increased capability responding to the rapid changes in policy and practice in animal health, nutrition, welfare and productivity anticipated in the coming decade.
- **Agro-ecology:** Responding to the global needs of farming for the environment, expanding the use of the University farms as demonstration platforms for sustainable agriculture and extending research capability in the governance of ecosystem services in agri-food systems, so embracing diversity to achieve production.
- **Food and health:** Building on strengths in food safety to encompass the social science of valorizing food based on provenance, quality and dietary health. Furthermore, capacity in nutritional composition and food safety will be developed jointly through IAFRI and Fera Science Ltd., enabling closer links with HNRC researchers.

In each case, academic appointments to these areas will continue to be supported by investments in instrumentation and support staff, to facilitate the effective establishment of their research. With the realisation that staff performance is under-pinned by research culture the School will support:

- *Staff enablement*, equipping staff and students at all career stages with the training in the skills needed for research and development in the academic, commercial, public and voluntary sectors.
- *Investment in infrastructure* both on campus and at the farms, by continually reviewing and strategically investing in equipment and facilities that enable staff to work across academic boundaries and respond to funding opportunities.
- *Influence national and international research agendas* using group and Personal Development Reviews (PDRs) to encourage staff to apply for memberships of national and international programmes steering committees, scientific working groups, advisory committees, secondments and policy bodies relevant to AFS.
- *Strategic partnering*. Enhancing external connectivity, visibility and knowledge exchange by encouraging staff to initiate new interdisciplinary partnerships nationally and internationally, supported through central budgets strategically managed at Directorate and Academic Group levels.
- *Expanding Doctoral Training* through collaborative networking with industry (IAFRI) and by increasing our engagement with UKRI (e.g. through recent and new DTP awards, e.g. NDL BBSRC DTP3).

1.8 Research Culture, Integrity, and Ethics: The ethos of our research culture is built on the pillars of creativity, transparency, multidisciplinary and collaboration. It is supported by community-building events, PGR and PDRA forums, biannual SNES symposia and seminar series overseen by a dedicated Associate Director of Research Culture (**Boonham**). Research integrity is governed through: (1) compliance with the Home Office and the ethical and welfare standards that are applied to animals used in research through NU Animal Welfare and Ethical Review Board; (2) a mandatory requirement for ethical approval for all research involving humans subjects; and (3) compliance with Defra and HSE regulations with work involving licenced/contained organisms (e.g. exotic pests, pathogens and GMOs). All researchers are required to comply with the University Code of Good Practice in Research, which codifies expectations relating to integrity, conduct and professional standards. Health and Safety is embedded in our research-culture with PIs reporting to DoEs who sit on both the School H&S and Executive Committees. The Chair of H&S sits on Faculty H&S.

Open access of all published work is facilitated via an on-line publications management system (*MyImpact*) in which the accepted manuscript in its final submitted form is openly accessible. Data management is mandated through the use of the Research Data Service, an institution-level, open data repository for documenting, archiving and publishing datasets. The repository supports data management plans for projects ensuring archived data are *FAIR* (Findable, Accessible, Interoperable and Re-useable) and retained for at least 10 years in an openly accessible format.

2. People

2.1 Staffing strategy and staff development

Staff appointments are directed by strategic objectives defined by the School. Over the REF2021 period, twenty-two staff have been appointed, replacing those who have left/retired increasing the UoA6 FTE return from 21.0 in REF2014 to 36.8, building research capacity across the themes:

- *Resilient and Efficient Agri-Food Production*: 13 members of staff appointed: **Asher** (SL, Animal welfare, 2018); **Audsley** (IAFRI SL, Plant-insect interactions, 2018); **Boonham** (Professor Applied Crop Science, 2015); **Budge** (Professor Bee Health, 2015);

Edwards.R (Professor Crop Protection, 2014); **Howard** (SL, Plant & Microbial Sciences, 2015); **Prashar** (L, 2016); **Andriotis** (L/ECR, Metabolic Biochemistry, 2017); **Kaprov** (SL, Genome Editing, 2017); **McInness** (Fellow/ECR, 2019); **Willats** (Professor Molecular Agri-Diagnostics; 2016); **Wakefield** (IAFRI SL, Plant insect interactions, 2019); **Velasquez** (L, Animal Sci, 2015).

- **Agro-ecology: 2 members of staff appointed: Evans** (Reader Network ecology, 2016), **George** (Reader Precision agronomy, 2019).
- **Agri-Food Systems Governance and Safety: 7 members of staff appointed: O'Brien** (Professor Translational Agritechology, 2019); **Reed** (Professor Socio-Technical Innovation; 2016); **De Souza-Monteiro** (SL, Agri-Business Management, 2014); **Areal** (SL, Agricultural economics, 2019); **Panzone** (L, Consumer behaviour, 2014); **Jones** (IAFRI SL, Environmental economics, 2015), **Shirley** (L, Modelling, 2017).

Academic Leadership: Senior appointments made in the REF2021 period have strengthened leadership in AFS, with **Edwards.R** appointed as Head of School, **Gatehouse/ O'Brien** as Directors of Expertise and **Budge, Boonham** and **Howard** as group leads.

Staff Development: NU's *Skills Academy* supports researchers at all levels (see IES, 2.2.5) to develop research, management and leadership skills. Interaction with external businesses and government is supported by the Faculty HEIF Business Engagement Fund. HEIF funding in AFS (15 @ totalling £30k), have supported workshops, partnering events, seedcorn activities and business case preparation. Staff have also been supported in working on secondments into government (Defra), to support evidence gathering for policy. To support staff skills development during lockdown/home working, SNES has run Zoom "Masterclasses", available to all researchers (PIs, RAs, PGRs) on topics including "Building consortia with government" (attended by ~50 academics, and leading to an RA gaining a collaboration with the Scottish government) and "Demystifying UKRI grant panels", where senior staff shared their experiences of being on UKRI panels with ECRs.

Promotions are awarded on defined performance criteria communicated to all staff, on a non-quota basis. Cases are made with the support of line managers and senior management. During the REF 2021 period 23 staff have been promoted: 3 to Professor (**Asher, Evans, Finlayson**); 9 to Senior Lecturer (**Beard, Boswell, Cooper, Stewart, Hubbard, Kuznesof, Leach, Stewart, Panzone**) and 11 to Lecturer (**Adamson, Christensen, Collins, Douglas, Edwards.M, Hall, Parker, Peacock, Shirley, Simkin & Taybi**).

The Academic Group structure has underpinned a policy of ensuring that staff are able to take sabbatical leave on a rotational basis. Staff development is supported by annual 1:1 PDRs that identify individual staff strengths through agreeing realistic, yet challenging, targets whilst identifying training needs through institutional courses in IP, grant-writing, science communication and outreach. The School operates peer review panels mirroring UKRI committees, providing critical feedback. Academic Groups support the development of colleagues at all career stages, with active mentorship of ECRs. SNES has implemented Academic Group PDRs, to enhance collaboration and devolve collective responsibility for performance delivery in research and teaching.

Academics are allocated a personal budget, with additional strategic funds administered at Group Lead and DoE level for essential equipment purchase and maintenance, and support of collective activities with a focus on the research needs of ECRs, PDRAs and PGRs. AFS promotes joint appointments with industry and third sector organisations (TSOs) as evidenced by joint appointments of lecturing staff (**Wakefield, Audsley, Jones, Donarski**) with Fera Science Ltd and NU, and a sponsored lectureship by Proctor and Gamble (**Jones**). AFS make active use of the Knowledge Transfer Partnership scheme with active joint appointments with Coastal Grains (**Bilsborrow, Borland**) and P&G (**Willats**).

New lecturers are required to study the *Postgraduate Certificate in Advanced Studies in Academic Practice* (NU's Continuing Professional Development Scheme). They are allocated an academic mentor, given a start up funding package and are allocated a carefully designed and ramped allocation of duties in teaching and administration to help them establish and consolidate their research. Further, all new academic staff are given a travel budget and preferential access to funded PGR studentships.

2.2 Postdoctoral Researchers are key to the School's research culture and productivity and are full members of Academic Groups, with career progression monitored through PDR review. NU is committed to the *Concordat to Support the Career Development of Researchers* and was one of the first to be awarded a HR Excellence in Research Award by Vitae in 2010 (renewed twice during this REF cycle). A PDRA network has been established, with peer mentorship facilitated by a postdoctoral society organised through the SAgE faculty. PDRA development is supported through a dedicated annual conference and workshops in grant-writing, teaching and science communication. All PDRAs are actively encouraged and financially supported to present their work both internally and at international conferences.

The future five-year plan is to increase numbers of postdoctoral and Independent Fellows in the School, supported through the institutional NUACTION scheme, which will act as a catalyst for attracting additional applications from national schemes funded by UKRI, charitable trusts (e.g.: John Oldacre Trust, **McInness**) and industry.

2.3 Technical Support is organised at School level, with 34 staff (5 with PhD) providing support for researchers including centralised molecular and analytical facilities and maintenance of plant, insect and pathogen culturing facilities. Technical support also provides services in purchasing, safety, waste- disposal and building management. Five dedicated animal and crop technicians are based at the farms, farm staff also support researchers through the commercial operation of crop trials and the dairy and pig, and poultry units. Six technical staff are dedicated to teaching. IT support is provided by a central unit, with 3 University staff embedded within the School. Specialist bioinformatics support is provided by a dedicated unit: <https://www.ncl.ac.uk/bsu/> together with access to the University HPC facility <https://services.ncl.ac.uk/itservice/research/hpc/>.

NU is committed to the professional development of our technical teams, being a founder signatory of the national Technician Commitment. An active apprenticeship (**Ashpool, Fortescue**) and career development programme is in place overseen by a Training Co-ordinator to ensure succession planning and continuity. Staff development in acquiring new qualifications is supported (MBA; **Bal & Whitaker**) and has led to leadership roles e.g. **Lamb**, is now the SNES Safety Officer and **Whitaker** is responsible for all technical staff within the Faculty.

2.4 Administrative Support for Research is provided by Professional Services (PS), a Faculty funded and managed team that supports all operational needs and teaching support. PS are grouped into specialised teams, facilitating support for multidisciplinary research and enhancing opportunities for the professional development of staff. Support for research is divided into Research and Impact, Project Support, Research Funding Development and Business Development. Specialist services include support for embedding impact and maximising the value of research outputs in policy, industrial innovation, sustainability and societal benefit. Intellectual Property (IP) from commercially linked work is regularly assessed by the business development team and protected by patent filing. All relationships with industrial partners are subject to detailed legal agreements as to disclosure and IP ownership.

2.5 PGRs

Doctoral training is overseen by a Doctoral College (see Ref5a 3.22), with bespoke training through 1+3, 3.5 year and part-time options. The AFS PGR community has increased over the present REF period by 45% (Table 1), through new CDTs and DTPs (Section 3) and ongoing collaboration with industrial partners (Fera, Tesco, P&G, KWS, CPI, Syngenta, Bayer, AIMES, AHDB). AFS also attracts high numbers of international students funded by their own governments/institutions. Our objective is to continue to increase PGR numbers, while enhancing the supportive, stimulating and multidisciplinary environment needed to support their development.

Table 1: PhD students (FTE) during the current REF

Year	2013/ 14	2014/ 15	2015/ 16	2016/ 17	2017/ 18	2018/19	2019/20
Total PhD students (FTE)	72.71	81.06	87.72	97.61	99.78	104.09	102.95

PGR recruitment and progression: Applications to AFS for PGR positions have been buoyant over the REF2021 period with international students from the Global South sponsored and recruited to research projects through targeted seminar programmes (**Shortall**). PGRs have high completion rates (95%), in a supportive training environment with modules covering research skills, ethics and safety and maximising impact from research (**Reed**). There is a school-wide seminar programme. Each PGR student is assigned a primary and secondary supervisor. They attend [Induction](#) on commencing their studies, followed by a 80-credit PGR training support programme over the first two years. PGRs and their supervisory teams sign a [Learning Agreement](#) prior to Project Approval, that includes a detailed work plan with jointly agreed Training Needs Analysis Checklist. All students are assigned to a [Progression Panel](#) that provides additional pastoral support, with progress reports at 9, 21, 33 and 42 months managed electronically (*e-portfolio*) by the Postgraduate Director (**Cooke**). In addition to presenting at Faculty and School PG conferences, all students are funded to attend at least one international conference (>50 in REF2021 period) and take part in global workshops (e.g.: African Research Universities Alliance, Accra-Ghana, 2019). Opportunities are provided for outstanding students to receive fully funded training in overseas laboratories, with Professional Internships offered via the BBSRC-DTPs. AFS PGRs regularly take part in external competitions, including the prestigious International Genetically Engineered Machines (iGEM) competition (**Howard**), with SNES students winning a Gold award in 2019.

2.6 Equality, Diversity and Inclusion: EDI is a core value of the University and SNES continues to embed an ethos of equality, inclusivity and mutual respect in all its activities. SNES is a diverse community (with 26 and 66 different nationalities across staffing and student categories, respectively) and our commitment to developing an inclusive and supportive environment was recognised when AFRD achieved an Athena SWAN Silver Award (November 2016 submission). The new School is pursuing a move from Bronze to Silver following restructuring.

Leave and Flexible Working: UoA6 has seen formalised flexible working increase from 0% in 2014 to 14.6% in 2020. To support research, T&R staff can request teaching free days and consolidate teaching into one semester. A formalised policy to work from home was in place pre-COVID and we expect to offer increased flexibility in working patterns post-COVID. We have a revamped school-wide sabbatical policy that will be instigated following the end of lockdown whereby each group always has one member on sabbatical at any one time. **Conference Attendance and Travel:** Staff receive an annual £500 allocation into personal academic support accounts (ASAs) with an additional £1,000 per staff member into a central research group fund to support strategic initiatives which could be at an individual or group level. These funds are used for personal development and conference attendance. PGRs may attend at least one UK and one international conference. For attendees with

caring responsibilities, an additional fund has been provided. The provision of childcare facilities available for on-site participants at the International Designer Biology conference 2019 hosted at Newcastle University has provided best practice guidelines for the wider University.

Recruitment: All adverts have EDI statements, gender decoded text, diverse recruitment panels all with unconscious bias and EDI training. Remote interviews of applicants are used where appropriate. These processes were developed and piloted with our IAFRI PGR recruitment.

Career Support: To support ECRs, teaching loads are low during their first year and probationary period; mentors and higher funding allowances are provided. Development needs are discussed at Annual PDRs. Sabbatical opportunities and University level mentoring are also available to all staff. The Academic Groups provide the forum for mid-career researchers with reduced research income to become actively involved in grant development and paper writing. Group-run 'away days' are used to 'brain-storm' collaborative grants. Open competition for leadership positions available to lecturer grade has provided leadership opportunities. Within AFS, 2 female staff (**Kuznesof, Hubbard**) have been supported on the Aurora Programme (Advance HE's leadership development programme for women). Staff attendance at personal development training (e.g. Skills in Public Speaking; H&S; Unconscious Bias; Leadership etc.) has increased >4-fold since REF2014.

Promotion: The School has adopted a positive action approach identifying and encouraging staff to plan and apply for promotion (see 2.1). Since REF2014, 11F and 12M have been promoted. We are aware of the unequal impact of COVID on colleagues and plans are being discussed to ensure probation and promotion is not adversely impacted. The Unit also recognises and rewards staff for research and impact by providing discretionary awards and one-off payments (e.g. **Gatehouse** on receipt of her international award).

Extended Leave: Return from extended leave, including for caring responsibilities, illness, maternity and parental leave are supported with flexible working opportunities. Academic staff can apply for up to £10k to support research through the Returners' Support Programme, which is being extended to PS staff.

Inclusivity: School EDI Committee has direct reporting lines to the School Executive Board where EDI is an agenda-standing item. EDI and unconscious-bias training is integrated into induction programmes.

Wellbeing: To provide an environment where all staff and students have a sense of belonging, SNES has worked to improve parity of esteem between PS and academic staff, operates core-hours of 10am-4pm for meetings, encourages working within formal hours, discourages the sending of emails out of hours and supports flexible working. During COVID, 'quiet Fridays' were encouraged. An Employee Assistance Programme provides 24/7 support line for all staff and PGRs. For all academic staff, the move to working within disciplinary groups where research and teaching are discussed have increased a sense of belonging and work allocation models and teaching allocation groups have reduced staff with work over-commitments. These groupings, which all meet weekly, provide an ideal forum for supporting staff/students mental health. We will train mental health first aiders throughout SNES to work alongside first aiders.

3. Income, infrastructure and facilities

3.1 Research Income Strategy: The focus over the REF2021 period has been to increase and diversify research income (Figure 3). Following restructuring, performance in teaching and research has become the responsibility of the Academic Groups, allowing the flexing of resources across the group to allow specific staff to focus on research. This has enabled AFS researchers to respond to major funding initiatives and build multidisciplinary networks. This policy has fostered greater collegiality and increased co-writing of project proposals, resulting in an overall increase of > 50% in income (Tables 2,3), and major funding successes notably:

- N8 Agrifood Resilience Initiative (**Edwards.R**),
- BEIS agritech centre bids CHaP (**Edwards.R, Boonham, George**)
- CIEL (**Asher**)
- Elizabeth Creak Research Network (**Edwards.R, O'Brien**)
- EU H2020 on “EcoStacking” (**Gatehouse, Edwards.M, Evans**)
- New from 2020, National Innovation Centre for Rural Enterprise (**Phillipson**).

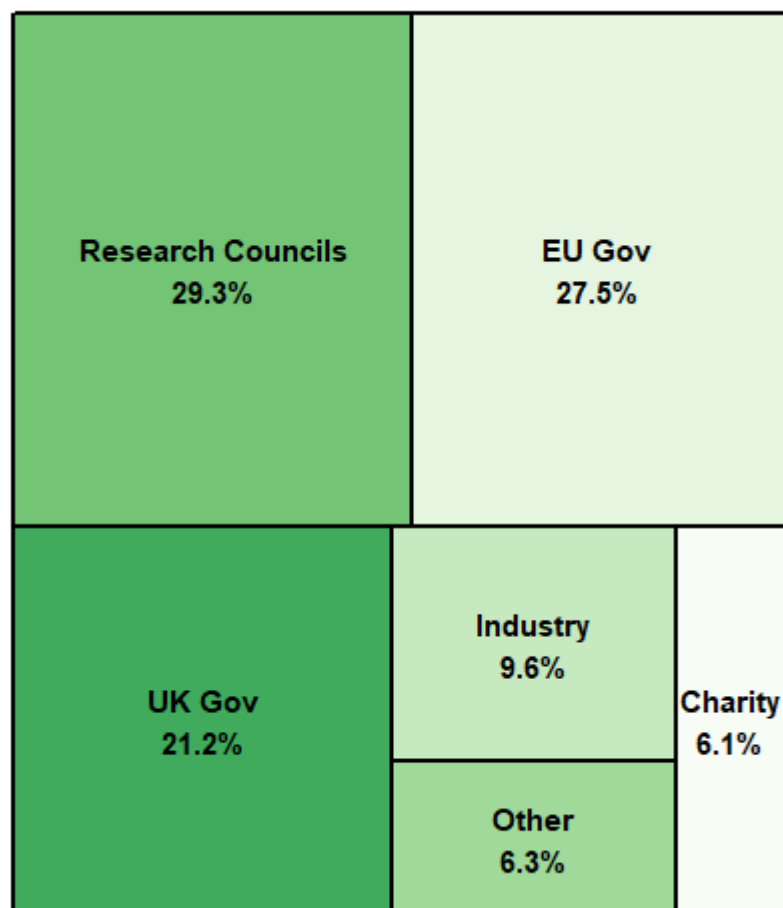


Figure 3: Treemap showing diversity of expenditure in UoA6. Areas represent percentage of grants by funding source between 2014 – 2020.

Table 2: Income Allocation

2013/14	2014/15	2015/6	2016/17	2017/18	2018/19	2019/20
2,685,645	3,301,874	3,234,622	3,738,668	3,886,009	3,653,263	3,679,828

Table 3: UoA6 Grants >£0.5m awarded & Patents over the REF cycle

Cross-Cutting Research Themes	PI	Funder	Patents
Resilient & Efficient Agri-food Production	Asher	Innovate BBSRC LINK	
	Bilsborrow	EU FP7	
	Boonham	Innovate UK BBSRC-GCRF BBSRC EU MC-ITN	
	Budge	BBSRC/Defra Vet Med Directorate	
	Butler	EU FP7	
	Edwards R	BBSRC-Lola BBSRC-Syngenta IPA Elizabeth Creak Charitable Trust John Oldacre Foundation N8 Agriresilience Programme North of Tyne ACE award	1
	Gatehouse	EU Horizon 2020 BBSRC LINK	1
	Edwards M		1
	Howard	EPSRC-dstl	
	Kyriazakis	FP7	
Sustainable Agro-ecological Systems	Evans	Royal Soc BBSRC-GCRF BBSRC-SPF	
	Frewer/Whittigham	EU Horizon 2020	
	Taylor	STFC Newton	
Agri-food System Governance & Safety	Reed	GFS UKRI/Scottish Government	
	O'Brien/Rushton	MRC (ESEI)/NERC/BBSRC/ESRC/ Food Standards Agency	
	Hubbard	S2F	
	Frewer/Jones/ Boonham	EU Horizon 2020 MC ITN	
	Frewer	BBSRC Innovate	
	Garrod	H2020 x 2	
	Panzone	GFS UKRI/Scottish Government	

3.2 Doctoral Training Centres: The forming of IAFRI in 2015 was associated with the establishment of a doctoral training account, jointly funded by NU and Fera, which has supported 6 students p.a. each jointly supervised by staff from the two partner organizations over the last 5 years. The IAFRI agreement has recently (2020) been renewed along with the continuation of the doctoral training centre. In 2019, together with FMS, AFS researchers were awarded the 3rd successive BBSRC DTP “NLD DTP in BioSciences” with

the Universities of Durham and Liverpool and six industry partners (NU Co-I **Gatehouse**; £7.4m+matched funding). The DTP covers 5 intakes of students between 2020-2025 with a normal intake of 28 (20 standard, 8 CASE) 4-yr studentships/annum and additional studentships awarded in 2020-21. Each student is supervised by a member of academic staff from two partner universities, with 32 % of the total student cohort dedicated to the BBSRC theme in Agriculture and Food Security. AFS staff (Director **Asher**) also lead in the Leverhulme Trust Doctoral Training Programme in *Behaviour Informatics* (**Asher**; £1.05m) that supports 15 PhD studentships over 3 cohorts (5/ann.). AFS staff also contribute to the NERC ONE PLANET CDT (which provides a total of 13/year over 5 years, split between Newcastle and Northumbria), and the DTPs IAPATUS (NERC) and the NU EPSRC DTP. Finally, the School also hosts the ESRC NINE Doctoral training programme through CRE (**Panzone**).

3.3 Infrastructure and facilities AFS on campus are housed in the Agriculture and Devonshire buildings, with resources such as the analytical suite in the adjacent Chemistry building. AFS infrastructure on campus includes a suite of crop growth rooms, an insectary (including a Defra-approved pest containment facility), soil processing and analytical equipment, fermentation suite for metabolic engineering, bioinformatics suite, a sensory laboratory and research kitchen for dietary trials. The research farms are located in the Tyne valley (Nafferton Farm, 314Ha) and at Morpeth (Cockle Park Farm 271Ha), with additional land at Ousten (207Ha). The farms are managed as a single commercial unit by recently appointed Director (**Standen**); both operate as mixed farming enterprises, with the dairy herd (320 cows) operating at Nafferton and the pig (140 sows plus finishers) and poultry units at Cockle Park. Arable production is dominated by cereals and oilseed rape, with potatoes also grown at Nafferton. The farms regularly host crop trials and demonstration events. The farms operate within the top quartile of national productivity and are Red Tractor and Leaf registered. Specialist capabilities include contained and replicated hydrological plots (0.24Ha x 9) and the Palace Leas long-term (c1896) pasture experiment (Cockle Park) and the replicated factorial QLIF trial site (3.8Ha) at Nafferton.

Infrastructure strategy and investment: AFS capabilities in infrastructure have seen significant expansion and reorganization during REF2021 with an investment of >£9.5m. Major areas of investment include: (i) the expansion of capabilities in precision agriculture at the research farms; (ii) improvements in Laboratory facilities and (iii) co-location of central research and support facilities in dedicated refurbished space.

Investments in the research farms include £2m from the University for the development of laboratories, seminar facilities and a dedicated glasshouse at Cockle Park Farm (2014). Investment at Cockle Park followed in 2016, as part of the establishment of the agritech centres for which AFS researchers were founding partners; CHAP; £0.5m from BEIS + matched funding from NU) and CIEL (£0.75m from BEIS + matched funding from NU). CHaP funding founded a bespoke on-farm plant health agri-diagnostics facility supported by four mobile research labs deployed across the north of England. While the CIEL funding developed the world-class Centre for Digital Innovation Applied to Livestock (C-DIAL), a digital research facility to support animal welfare alongside a pig research unit with NEDAP feeders was established (£958k). A further funding of £0.4m from CIEL was awarded in 2018 to further develop digital and hyperspectral imaging technologies (Total CIEL £3.3m).

Investments on campus. The physical infrastructure supporting AFS has seen University investment of £2.8m in the Devonshire Building as an integral part of a 'BioSystems Science and Engineering' project. While the Agriculture Building saw investment of £650k on open office and meeting rooms (2014) and £100k on lab and research office refurbishment (2017) to establish a Molecular Diagnostics Facility supporting agroecology (**Evans, Whittingham**) and plant health (**Boonham, Budge, Edwards, Gatehouse**). Additional investments have seen the establishment of Comparative Physiology Lab (£40k) and an analytical facility

(£100k) housing mass spectrometers supported by dedicated technical staff. External funding through the BBSRC-ALERT scheme has provided automated micro-arrayer for carbohydrate analysis (**Willats**), and robotics for small-scale laboratory automation that permits higher throughput, standardised workflows and reproducible experiments (**Howard, Evans**). Jointly with researchers in the medical faculty, AFS are developing specialist small molecule analytical facilities (**Howard**) and *in vivo* imaging capabilities (**Andriotis**) to complement recent School investment in fluorescent microscopy facilities.

Future investments in infrastructure are focussed on animal science, with £0.4m committed in 2020 to the provision of a livestock technical facility in support of animal welfare work in C-DIAL and plans to extend our controlled environment and plant growth facilities. The latter will support Newcastle's contribution to the future of N8 agrifood research initiative the Crop and Soil Pipeline (CSIP), an innovation platform that integrates fundamental crop and soil science and state of the art farms with translational expertise in support of work with the crop protection and plant breeding industries.

No Category C staff are returned in our submission.

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

The AFS community at Newcastle is highly collaborative and has hosted ~50 academics with official visiting researcher status over the REF2021 period (Table 4; Section 1.3).

Table 4: UoA6 REF2021 collaborations and contributions to the research base, economy and society.

Invited External Presentations	Workshops Organised	External Panels	Inter-national Partners	Incoming Visitors	Lead PhD supervisions	PhDs co-supervised with other HEIs
147	33	26	43	47	110	39

PhD co-authorships	Awards, Prizes etc.	Editorial Boards	Major Grants	Spinouts	Collaboration Agreements	Esteem Indicators
155 of 396	15	17	33	1	9	41

Policy and Impact – Examples include:

National: Member, Food Standards Agency Science Council; Chair, Advisory Committee on the Microbiological Safety of Food (**O'Brien**). DEFRA workshop (**Butler**). AHDB Scientific Board Member for Protected Ornamentals (**George**). Member of FSA Advisory Committee on Novel Foods and Processes (**Wakefield**); Vice-Chair British Ecological Society Policy Committee (**Evans**). Member, FSA Social Science Advisory Committee (**Frewer**); Member, UN IAEA /WHO expert group, Food Safety Risk communication following a nuclear incident (**Frewer**). Council member British Ornithologist's Union (**Whittingham**).

International: Advisory group member for the EUH2020-Valitest project (**Boonham**); Steering group member for the development of the US Diagnostic Assay Laboratory Network (**Boonham**). Member of Conservation Science Advisory Council for A Rocha International (**Evans**). Member, Scientific Advisory Board, European Joint Programming Initiative, "A Healthy diet for a healthy life"; Member, working group on animal genomics, Nuffield Council on Bioethics (2018-); Chair, Science Foundation Ireland Food Challenge, Science Foundation Ireland (SFI) 2020 (**Frewer**); Member of Conservation Science Advisory Council for A Rocha International (**Evans**); Round-table discussions with Minister

for Science and Technology and Director General of Fisheries, Pakistan (**Chaudhry**). Co-author on Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) European and Central Asian Regional Assessment (ipbes.net/assessment-reports/eca) (**Whittingham**); International expert (funded by United Nations Development Programme grants) and co-author of 6th National Report of Iraq (reporting process for Convention on Biological Diversity) (<https://www.cbd.int/doc/nr/nr-06/iq-nr-06-en.pdf>) (**Whittingham**). Council Member of International Congress of Entomology (**Gatehouse**).

Collaboration Agreements include: AnimalCare and CVS Ltd (**Leach**). Joint Faculty Appointment with the Oak Ridge National Laboratory, USA (**Borland**). Procter and Gamble Ltd (**Willats**).

4.1 Leadership, Awards/Scholarship, Esteem:

Awards for contributions to the discipline include:

- International: **Gatehouse**, Certificate of Distinction in Recognition of Outstanding Achievements in Entomology (2016); elected an Honorary Member of the National Italian Academy of Entomology, (2015); **Flecknell**, SGV prize for Animal Welfare, (2014); **Nouioui**, Skerman prize for best young international microbial taxonomist (2019); **Howard** Supervision of iGEM team winning 2xGold and 1xBronze awards; **Evans** 2016 joint-winner of the RES Journal Award for the Best Paper in Ecological Entomology; **Souza Monteiro** 2020 joint-winner of the European Association of Agricultural Economists Quality of Research Discovery Award for 2019.
- National: **Edwards R.** (RASE Research Medal 2019); **Flecknell** (Honorary UK Fellow of the Institute of Animal Technology, 2017).

Named Lectureships and Visiting Professorships:

- **Edwards.M** (Visiting Professor, Shanxi Academy of Agricultural Sciences 2019 - 2024);
- **Gatehouse** (Visiting Professor, Shanxi Academy of Agricultural Sciences 2019 - 2024);
- **Frewer** (Visiting Professor, Swedish Agricultural University 2019-22; Distinguished Professor, University of Kuala Lumpur, Malaysia, 2020);
- **Hubbard** (Visiting Professor, Mediterranean Agronomic Institute, Zaragoza, Spain since 2014; Visiting Professor, Pontificia Universidade Católica do Rio Grande do Sul, Brazil 2020-2025)
- **Leach** (Visiting Lecturer, Karolinska Institute since 2018).

External Advisory Panels

- National: Validation Panel Harper Adams University & Accreditation Panel BSAS-Royal Society of Biology (**Chaudhry**). Member of Animal Welfare Research Network panel (**Asher**). British Veterinary Association (**Leach**). Member of the BBSRC Agriculture and Food Security strategy panel, and the SAGE advisory group to UK government; Chair of the Elizabeth Creak Trust Research Network, 2018; Panel Chair BBSRC Excellence with Impact National Competition, 2016; Council member Yorkshire Agricultural Society; Member of BBSRC Excellence with Impact Panel, 2015 (**Edwards.R**). Member UK Innovate Grant Panel for Agriculture Innovation Centres, 2014 (**Gatehouse**). NFU, AHDB, Tyne Rivers Countryside Stewardship Facilitation Fund (**Standen**).
- International: Polish Ministry of Science and Higher Education (**Franks**). Chair of External Scientific Advisory Board of Agrotecnio (designated a Centre of Excellence for Agrifood sciences, Spain), 2013 – present (**Gatehouse**). Grant panel member Academy of Finland (2016-2018) and Swedish Research Council (FORMAS) (**Whittingham**). Member of BBSRC/FCO-sponsored USA/UK 2016 'Plant Health' Mission (**Edwards.R**).

Learned Societies: Fellow Royal Society of Chemistry (**Edwards.R**); Trustee, Stockbridge Technology Centre Research Foundation; Vice President, Royal Entomological Society (**George**); Fellow Royal Society of Biology (**Borland**; **Gatehouse**; **Whittingham**);

4.2 Collaborations

Academic Collaborations:

NU: AFS staff work regularly with SNES colleagues engaged in environmental research, global ecology, and analytical chemistry. Within the SAgE faculty, interactions include computer science on machine learning applied to animal welfare, with engineering on precision agriculture and with mathematics, statistics and physics on Bayesian networks applied to modelling. Across faculties, interactions with FMS staff are directed to the Human Nutrition Research Centre (nutrigenomics and big data analytics in relation to consumer food choices) and in Neuroscience (animal behaviour, welfare and behavioural informatics). CRE is run jointly with the Faculty of Humanities, & Social Sciences, with additional links to the business school in marketing and consumer research.

Regional: AFS staff are integral to the N8 Universities Agri-Resilience programme that has influenced change in agrifood policy and practice both in the UK and globally in sustainable food systems. Since 2015, related N8 projects have attracted a total of £40 million of external funding. AFS have research links to many food and farming businesses in the regions including Greggs (**Panzone, Souza-Montiero**), and through farm director **Standen** and academic coordinator **George** with Thomas Sherriff, John Deer, Allflex, i2L and ADAS.

UK: AFS staff (**Edwards.R**) are linked to HEIs delivering agriculture programmes in the UK through the Agricultural Universities Council, with strong links to the Universities of Reading and Warwick, HAU and RAU through the Elizabeth Creak Research Network (**O'Brien, Edwards.R**). Additional links through joint partnerships in the agritech centres include Cranfield and Rothamsted (**Boonham, George** CHaP), Nottingham, Aberystwyth, Reading, SRUC, Leeds (**Asher**, CIEL). Sheffield, Rothamsted and the Institute of Zoology were Col partners on the BBSRC funded Black-grass Research Initiative (**Edwards.R**) and with Rothamsted on H2020 projects (**Gatehouse, Edwards.M, Evans**).

International: CRE staff are founding partners of Trans-Atlantic Rural Research (TARRN), a collaborative network of social scientists in North America (e.g. Cornell, Penn State) and Europe conducting research on rural transformation and policy, hosting annual meetings in 2014 and 2020. Several strong collaborations with Chinese academic institutions resulting in REF outputs include Zhejiang University and CAAS (crop protection; **Gatehouse**); Huazhong University (**Frewer**) Tsinghua University (synthetic biology; **Howard**) with funding from the Biochemical Society and the Society for Experimental Biologists and **Souza-Monteiro** has collaborated with researchers at ESALQ University of Sao Paulo (Brazil) and Universitas Gadjah Mada (Indonesia), The University of Kuala Lumpur, Malaysia, and SLU, the Swedish Agricultural University (**Frewer**). **Pfeifer** with Sokoine University of Agriculture is training assistants in Tanzania to support the Agrisys Tanzania project.

Non-Academic Collaborations:

AFS have a number of key collaborations with NGOs/TSOs and government. **Leach** and **Flecknell** have a longstanding relationship with National Centre for the 3Rs relating to experimental animal uses, including guidance on pain assessment and alleviation (ICS), and extensive e-learning resources in laboratory animal care and management. **Frewer** is a member of the Nuffield Council of Bioethics working group on animal genomics and farmed animals and has been involved the WHO/FAO panel 'Global Food Risk Communication with Consumers. Frewer chairs the INCA Institute National de Cancer) steering group on pesticide exposure and prostate cancer in the French Antilles. Strategic inputs to the UN Convention to 'Combat Desertification' and the 'UN Global Peatlands Initiative' (ICS), is led by **Reed**. **Edwards.R** is the Chair of the Farmer Scientist Network operating through the Yorkshire Agricultural Society, promoting knowledge exchange between farmers and academics and supported by European Innovation Programme funding.

AFS plays an influential role in informing policy both at national and international level. Partnering activities include developing network ecology to 'Understand and secure resilient food systems' (Royal Society; **Evans**), 'Peatland Tipping Points' in collaboration with Defra, Natural England and the Committee on Climate Change (**Reed**), designing sustainable management solutions for permanent grasslands across Europe (EU; **Frewer**, **Whittingham**) and 'Stacking biodiversity service providers to develop ecologically, economically and socially sustainable crop production strategies' (EU; **Gatehouse**). AFS have also influenced efforts to achieve gender equality between people working in the Scottish agricultural sector (ICS; **Shortall**) and informed policy briefings (Scottish Government and Welsh Assembly, **Hubbard**) and civil society (EURACTIV high-level Stakeholder Workshop, **Hubbard**) on the impacts of Brexit on agriculture. In 2016, **Hubbard** contributed to the drafting of the EC's Cork Declaration on Rural Development. **O'Brien** serves as a resource advisor for the WHO's Food Epidemiology Reference Group.

4.3 Contribution to the research base

Many academics are members of UKRI peer review panels/pool of experts contributing to national science governance. **O'Brien** is a current member of the Science Council of FSA, whilst **Frewer** sat on the FSA advisory committee for social science and Observer to the EFSA 'Emerging Food Safety Risk' working group (2017-2019). **Edwards.R** has worked with BBSRC as a member of Review Board 'Synthetic Biology' (2018), the Steering Group 'Understanding the challenge of resistance in agriculture' (2016) and panel member of the Agriculture and Food Security committee (2014-18). **Hubbard** sits on Animal Welfare Committee, UK, **Asher** the Animal Welfare Research Network panel and **Leach** the British Veterinary Association and National Centre for 3Rs. **Frewer** is member and interdisciplinary advisor on the UoA6 REF panel.

AFS staff play **multiple** editorial, or advisory board roles including: Journal Agricultural Science (**Bilsborrow** Chief Editor); Cell Surface (**Willats**); Journal Animal Ecology (**Evans**); Journal of Food Products Marketing (**Souza-Monteiro**); PLOS one (**Frewer**), Journal of Insects and Food and Feed (**Frewer**); Conservation Biology (**Reed**); Eurochoices (**Areal**, **Hubbard**); Journal of Agricultural Economics (**Hubbard**), Scientific Reports (**Leach**); Plant Physiology (**Edwards.R**); Global Change Biology (**Borland**); Frontiers Plant Sciences (**Gatehouse**); Journal Applied Ecology (**Whittingham**). **Areal** is a member of OECD's Network for Farm-Level Analysis; **Souza-Monteiro** chairs the Mentoring Committee, Agricultural and Applied Economists Association, USA and **Gatehouse** chairs Agrotecnio, Spanish Centre of Excellence for agriculture, animal production and food technology.

In the REF2021 period there have been >150 invited presentations from AFS staff at major international conferences, many as Plenary or Keynote Lectures. Staff have also contributed to a national/regional meetings and been involved in organising > 50 conferences/workshops during the REF2021 period across the AFS remit. Formative AFS-hosted conferences include 2018 'Measuring Behaviour', with Swiss group at Agroscope (**Asher**); the 2019 Rank Prize Fund Mini-Symposium 'New Crop Protection' & 2014 OECD International Conference 'Global Plant Health Risks and Consequences: Linking Science, Economics and Policy' (**Edwards.R**); Design of Experiments workshop run 5x over 4 years since 2016 (100 participants, 17 universities; 8 companies; 3 government supported R bodies) funded by BiolC and BBSRC (**Howard**); New Phytologist Tansley 2014 Symposium, Ecology and Systems Biology of CAM Plants (**Borland**); 2018 European Congress of Entomology and 2016 International Congress Entomology "Novel Biopesticides" (**Gatehouse**); 2019 Royal Society Resilient Futures symposium (**Evans**). 'Credibility of scientific expertise and decision-making: New challenges for health risk governance in a changing world' 2020 (**Frewer**).

4.4 Contributions to the economy

Newcastle has a long history of research that leads to translation into products, services or policy that benefit society, being in the top 25 Times Higher Education impact rankings.

Within AFS, the REF2021 period has seen an increase in funded research and consultancy with industry and the filing of three patents, including on novel methods for pathogen resistance in cereals (PCT/EP2017/057333; **Gatehouse, Edwards M**); herbicide resistance diagnostics (WO 2018/138498; **Edwards R**). These patents have resulted in the development of commercialised products, such as the world's first pocket herbicide resistance Diagnostic BReD (**Edwards.R**), developed as a joint venture with MoLogic Ltd and undergoing national and international trials with Adama. In other cases, AFS research expertise has resulted in the development of products by industry partners. These include development of algorithms with industry partner VetSens which are now being used commercially for veterinary/companion animal application and with ALIS Chirpy & ALIS Cluster used commercially to monitor health and welfare of intensively produced broilers (**Asher**); commercialisation of Vitamin D enriched eggs (ICS; **Hill**), the animal feed supplement Crystalyx with global sales of £2.5m (**Chaudhry**) and automated plant pathogen detection (**Boonham**). Our wider impact and engagement also includes spinout companies. For example Geneius Labs (**Barnes, Borland, Stach**), which is a molecular diagnostics company aimed at servicing the food and drink safety sector employing >40 people. This was recently sold to SynLabs, an international medical diagnostics provider for human and veterinary medicine as well as environmental analysis for £6M.

4.5 Contributions to society

Research from AFS has positively impacted on society through improving the health of consumers through vitamin biofortification (**Hill**), redressing gender inequality in farming (**Shortall**), improvements in animal welfare (**Leach**) and global food safety policy (**Frewer**). These studies have formed the basis of public lectures, debates (Café scientifique) and other outreach activities extending their reach to the wider community. Further, AFS staff have been involved in citizen science projects delivered through the Natural History Society of Northumbria (**Port, Whittingham, Evans**) and the Plant Health Initiative (**Jones, Boonham**). AFS regularly participate in international Summer Schools including the 'Genetically Engineered Machines' (iGEM) competition (**Howard**); the Open Air Laboratories (OPAL) programme (**Borland**), inspiring local communities, in particular school students, to appreciate the natural world. AFS also regularly participate in agricultural shows across the country (**Edwards.R, George, Boonham, Gatehouse, Edwards.M**) such as Yorkshire Agriculture Show, Cereals, CropTec and AHDB-sponsored field demonstrations using their trailers to showcase research to farmers and the general public.