Institution: Aberystwyth and Bangor Universities: Biosciences, Environment and Agriculture Alliance (BEAA)
Unit of Assessment: UoA6 (Agriculture, Veterinary and Food Science)
a. Overview

Globally and locally our society faces unprecedented challenges: climate change, biodiversity loss, water and energy shortages, pollution, waste, sustainable land use, and secure food production, all of which impinge on animal and human health and wellbeing. Aberystwyth and Bangor Universities, as the Biosciences, Environment and Agriculture Alliance (BEAA), have a long-standing research partnership that provides innovative solutions to match the pace, unpredictability and scale of these challenges. These generate new knowledge-based products which will in turn generate economic growth, whilst also providing a robust scientific evidence base and framework to drive environmental and land use policies in Wales, UK, EU and worldwide. To achieve these ends BEAA delivers research excellence across two universities in three overarching themes:

- Animal and Microbial Sciences
- Genome Diversity
- Environmental Impact

b. Research Strategy

Changes in research environment during assessment period

The Biosciences, Environment and Agriculture Alliance (BEAA) founded in 2007 is a strategic partnership between Aberystwyth and Bangor Universities. It is the largest multi-disciplinary Agri-Food environment grouping in the UK. The merging of the former BBSRC Institute of Grassland and Environmental Research (IGER) with Aberystwyth University's Biological Sciences and Rural Sciences Departments to form the Institute for Biological, Environmental and Rural Sciences (IBERS), in strategic partnership with Bangor University's College of Natural Sciences (CNS), creates an internationally competitive strategic research and development capacity in Wales to address 21st century grand challenges. The Alliance builds on the success of two joint HEFCW-funded environmental research centres: the Centre for Integrated Research in the Rural Environment (CIRRE) and the Centre for Catchment and Coastal Research (CCCR), representing £5.5M in staff and infrastructural investment (2006-2012). Initial funding for BEAA was provided by Aberystwyth and Bangor Universities, BBSRC and HEFCW (£55M) allowing significant investment in infrastructure, equipment and people, which we continue to build on.

Broadly, Aberystwyth (AU) has prioritised Agricultural Sciences (UoA 6) and Geography (UoA 17), while Bangor (BU) focussed on Environmental Sciences (UoA 7) and Health (UoA 3). This has allowed us to develop our own thematic foci and specialised infrastructures, while benefitting from the considerable synergistic potential of inter-institutional and interdisciplinary collaborations. We make joint submissions to UoAs 6 (led by Aberystwyth) and 7 (led by Bangor), returning individual staff to each as appropriate, however we have not split each universities' research doctoral degrees awarded or income between the two submissions, thus all of Aberystwyth's is reported in UoA6 and Bangor's in UoA7. Together the two submissions comprise a substantial cross-institutional and interdisciplinary research grouping supported by major joint strategic capacity-building and research project grants across the entire REF period, and extending at least until 2019.

The formation of IBERS in Aberystwyth and CNS in Bangor, coupled with the creation of BEAA as a strategic partnership between the two universities, has allowed us to meet and exceed our respective targets presented in the 2008 RAE. Specifically we have:

A] Enhanced collaboration within BEAA (as evidenced by some £16M of income) and with external partners (as recorded in section E)

B] Increased the volume of publications by 8% over the period, doubled the number of joint publications between AU and BU year-on-year. Increased the proportion of our papers that are published in elite journals (as evidenced in REF2; CIRRE's publications had field-weighted citation indices for 2007-2011 that were 97% above the world average)

C] Increased the integration of genomics and genetics into on-going plant, animal and microbial research programs (as evidenced by the recruitment of new staff recorded below) and in the increasing number of our genomics-based publications (recorded in REF2)
D] Strengthened our provision in informatics (as evidenced by staff recruitment recorded below and our involvement in the High Performance Computing (HPC) Wales programme)
E] Developed strategic relationships with key stakeholders to ensure the translation of our research into practise (as evidenced in REF3)

Current and future strategic goals

BEAA has provided an exceptional opportunity to develop the staff base, research infrastructure and inter-disciplinary collaborative research ethos to make us internationally competitive in all aspects of non-arable sustainable land-use, catchment research, and knowledge exchange. Our aim has been to provide a strong collaborative and multidisciplinary base for this research so that it can make a major contribution to the effective management of an increasing range of conflicting demands on a finite and threatened resource. We have built on the strengths and experience of academics at both universities. We control a network of experimental land, freshwater and marine facilities and expertise providing a substantial advance in the capacity and multidisciplinarity needed to provide answers to the major biological and environmental questions underpinning future sustainable use of land and sea resources. BEAA was established to:

- Develop in Wales a world-class, science-led, research, training, education and enterprise cluster for the 21st century Grand Challenges: living with climate change, renewable energy, global food security, and threats such as animal and plant diseases.
- Build on the technical advances in genetics, phenotyping, epigenetics, molecular biology, ecology, conservation, quantitative biology and high-throughput analytical methodology to research key biological, land- and water-use systems. Emphasis is placed on pastoral agriculture, uplands, catchments and coasts. By doing so, to position BEAA as the R&D hub that underpins the next phase of growth in the agriculture, food, fisheries, and bio-renewable and land-based industries.
- Empower BEAA scientists to drive forward major advances in the economic and social impact of research.

To achieve these aims we have and continue to:

- Build on our reputation and expertise in public-good plant breeding (through staff appointments and investment in facilities) to create national capability to address global challenges in food security, climate change and renewable energy.
- Likewise, build on our reputation and expertise in rumen microbiology and animal science to establish international leadership in the science underpinning our understanding of greenhouse gas emissions from ruminants.
- Design domestication programmes for *Miscanthus* that build on our world-leading genetic resources to create novel energy grass ideotypes.
- Continue our current rapid progress of strengthening expertise in the land use-water quality interface (especially on macronutrient cycles in collaboration with the NERC Centre for Ecology and Hydrology) to establish UK-leading capability in rural catchment management.
- Consolidate our inter-disciplinary capability for tackling the interaction of agriculture, the environment and human health, based on our fundamental science of carbon, nitrogen and pathogen cycling, with an expansion of life cycle assessment to evaluate socio-economic and welfare, as well as environmental, sustainability through the whole production chain.

Organizationally we have ensured that we:

- Maintained the capacity to take the outputs of mechanistic studies on model plant-animal-microbe systems through enabling, strategic and applied research on to direct commercial and social application.
- Sustained the health of the agri-environment science area by nurturing the development of the next generation of creative and technically-equipped researchers to carry out high quality rural science.
- Increased and strengthened our effort in bioinformatics through new appointments and coordinated collaborations.

- Developed an effective programme of knowledge exchange and commercialization delivered through partnerships with commercial, regional development agencies and other agency, governmental, charitable and international (e.g. CGIAR) organisations.

Research groupings

Over the last five years we have developed three research themes around which we have defined the scientific mission of BEAA, provided the structure for our research groups across the two universities and from which we continue to develop new initiatives and directions.

Animal and Microbial Sciences: The aim of this theme is to improve understanding of the interactions between farmed animals, the plants they eat and the microbes living within them. We carry out strategic research on:

- Enhancing the quality of animal products to meet the rapidly changing requirements of consumers for food, which is safe, healthy, traceable, of consistent eating quality, diverse and convenient.
- Understanding the molecular and environmental processes that shape microbial population structures that both drive co-evolutionary relationships between taxa and govern microbe/fungal/parasite pathogenicity.
- Identifying the environmental and societal impact of animal agriculture on soil, water and air quality and their associated environmental services.

Genome Diversity: In this theme we research the biology of the land, freshwater and sea undertaking multidisciplinary studies of ecology and evolution in wild species. This research addresses the major challenge of the sustainable intensification of agriculture: enhancing production whilst reducing environmental impacts, particularly with respect to grassland dominated systems. We carry out strategic research on:

- Developing predictive understanding of the mechanisms underlying variation in plant and animal phenotypes arising from changes to the structure and function of the genome. The global effort in sequencing and re-sequencing of genomes, to which we make a major contribution, has established new tools and knowledge that are creating new options for intervention in biological systems. This enhanced understanding of plant/crop genomes will be used to establish breeding programmes for in-breeding and out-breeding crops that address the needs of climate change mitigation and adaptation, and food security.
- Using studies of genetic diversity and inter-specific hybridisation to identify, characterise and utilise novel alleles for deployment in knowledge-based breeding programmes that generate new traits and products.
- Understanding the effect of abiotic stress on population structure and function in aquatic and land-based ecosystems.

Environmental Impact: The aim in this theme is to understand how ecosystems work and in particular how they are affected by environmental change. A specific focus is how climate change can be mitigated through bioenergy and industrial biotechnology, and through improved soil, farm, forest and wetland management. We carry out strategic research on:

- The impacts of environmental change on plants including the development of a mechanistic understanding of plant stress tolerance focusing on signalling mechanisms; impacts on plant interactions and identifying predictive metabolite biomarkers for environmental stress.
- Providing practical solutions for the mitigation of climate change including the development of high-yielding dedicated energy crops adapted to current and future environments and conversion technologies.
- Developing a greater understanding of the lignocellulose complex and biopolymers in plant biomass to promote the extraction, modification and exploitation of chemicals and fibres.
- The development of new techniques for bio-refining and fermenting biomass to produce energy and high value chemicals.
- Improving fundamental understanding of carbon, nitrogen and phosphorus cycling in soils, agricultural, forest and catchment systems, then developing and testing new management methods to sequester carbon, mitigate greenhouse gas emissions and improve water quality.
- Determining how land and resource use, and environmental change, impact on biodiversity, and developing new approaches to best combine conservation and food security objectives.

Dissemination of research

Our Knowledge Exchange and Commercialisation strategy aims to enhance the economic and social impact of our research by stimulating the linkages between research, enterprise and innovation; ensuring that research is both informed by, and informs, the needs of key stakeholders. We aim to utilise these linkages to understand market needs and to rapidly inject high-level research into policy, industry and the research community at UK, EU and global levels. Fundamental science provides the building blocks for this process; however it is within the area of translational science that knowledge transfer opportunities are vastly increased. The major conduits we have and continue to develop for knowledge exchange within BEAA have 4 foci:

The public-good plant breeding programme focuses on genetic improvement to support multifunctional land-use and alleviate environmental impacts as well as coping with problems associated with climate change. The program includes scientists and plant breeders developing new varieties of forage and amenity species, cereals and energy crops. For its achievements in this area, AU has been awarded the Queen's Anniversary Prize for Higher and Further Education in 2009 for combining fundamental research on plant genetics with plant breeding techniques to develop commercial plant varieties that help meet the challenges of food, water and energy security, which are facing communities across the world. AU has also been shortlisted for the Times Higher Education Awards 2013 for the outstanding contribution to Innovation and Technology of our work on the potential of High Sugar Grasses to transform pastoral-based livestock agriculture.

The Centre of Excellence for UK Farming (CEUKF) is a pioneering agri-food supply chain partnership initially established by Waitrose, BEAA and NIAB to deliver on the current and future requirements for sustainable UK food supply. We have expanded the partnership research base with emphasis on securing the participation of leading UK institutions with excellent track records in applied research and knowledge exchange through the addition of the Scotland Rural University College, Agri-Food and Biosciences Institute (AFBI) Northern Ireland and Harper Adams University. Additional teams that are sub-sections of the CEUKF within BEAA include:

Grassland Development Centre (GDC) – a dedicated extension team translating research into practice focussing on optimising economic, environmental and/or societal benefit by helping to develop research outcomes across Wales and UK

Farm Business Survey (FBS) – gathering, analysing and reporting data from Welsh farms

Advanced Training Partnership (ATP) – providing high level training opportunities in sustainable and efficient food production for those working within the UK food supply chain at 'decision making' level.

BEACON – builds integrated 'Green Supply Chains' with a focus on developing new routes to functional, cost-competitive products using biomass rather than oil. The intention is to understand and engage with businesses, so we cultivate and then deliver 'Green Technology Solutions' to benefit industry across a range of sectors. To facilitate this we have a network of scientific expertise based at Aberystwyth, Bangor and Swansea Universities with capacity to provide solutions from bench to demonstration scale.

WISE: we have established the Welsh Institute for Sustainable Environments with significant EU-funded investment in fermentation technology and analytical chemistry at both universities allowing us to help SMEs exploit joint research activity in support of the green economy.

Future plans

Future plans are driven by our vision to convert the 21st century's grand challenges of food, water and energy security into sustainable and prosperous opportunities for society, recognizing that innovation in agriculture, forestry and aquaculture will play a critical role in fostering a knowledge-based bio-economy. We will focus on trade-offs and synergies in the delivery of different ecosystem services on land and in the coastal zone (including ecosystem health and biodiversity). Our strategy maps onto the ambition to explore the interfaces between traditionally separate UK Research Council areas of environmental science (especially NERC and BBSRC, but also EPSRC and ESRC). The strategy is ambitious and will be progressed via a linked structured set of funding applications (e.g. to EU Horizon 2020 and Structural Funds). The successful formation of BEAA has provided an outstanding opportunity to build a state-of-the-art **Innovation and Diffusion Campus** which is focused on the accelerated translation of biosciences and other research for the agri-technology and primary production sectors in the UK to benefit and help

rebalance the UK economy. Our Innovation Campus activities will drive culture and behaviour change to maximise opportunities for impact by ensuring that excellent research makes a contribution to society and the economy. The Innovation and Diffusion Campus will become an important ***destination campus*** for investment and entrepreneurs to drive and capture new economic opportunities through new partnerships, companies and collaborations delivering food, fuel, fibre, feed and chemicals. The Innovation Campus will link to and include the following Flagship Initiatives.

A new **Science Park** will be focussed on research and development with the low carbon/ renewable energy sector providing facilities to attract and incubate SMEs through close integration with the Anglesey Energy Island and Enterprise Zone. The Park will link closely with BEAA research, including the biotechnology and green chemistry of processing biomass and waste from agriculture and forestry into advanced materials, products and energy; with life cycle assessment of the sustainability of the whole production chain. **The Marine Innovation Centre** sited on the School of Ocean Sciences campus in Menai Bridge is designed as a hub to foster collaborative research with the commercial marine sector, providing business access to expertise, laboratory and ship facilities, and including space for 10 new collaborative business-university projects. **An Upland Research Platform for the UK** is being established across the two universities. The uplands have the potential to be at the core of resolving the grand challenges of food, water and energy securities and living with environmental change. This platform will address how upland landscapes should be managed to provide food and fuel whilst maintaining ecosystem services in the face of environmental and societal change. We will incorporate our existing Henfaes Research Centre and in the coming years we will create a Chair in Upland Research which, coupled with the leasing of the Pwllpeirian estate from the Welsh Government, provides an opportunity to establish the UK Research Platform for Upland Farming. This will help define new environmentally sustainable farming systems that protect and enhance upland biodiversity and ecosystem services whilst providing farmers with sustainable incomes.

To create impact from science requires not only technical solutions but also mechanisms to bring products and processes to market. We therefore propose, in collaboration with the AU Schools of Management and Business, International Politics, Law, and Film and Theatre, to create an **Interdisciplinary Centre for the Bio-economy**. In parallel, BEAA will partner with the £46M **University innovation centre** “Pontio” in BU, due for completion in 2014 to provide an innovation facility for interdisciplinary research as well as a base for theatre, arts and community engagement. Together these centres will not only develop the innovative new technologies to tackle global challenges but also innovative mechanisms to bring products to market and therefore span the notorious technology “valley of death”. We will draw on good examples of translation of university science into successful business opportunities, creating jobs and economic growth, outside the UK, e.g. the Fraunhofer Institutes in Germany and in Silicon Valley in the USA.

The product-conferring capabilities of BEAA through the breeding of new varieties of forage grasses, legumes and oats is widely recognised with a significant number of varieties from the breeding programmes grown in the UK and overseas. Expansion of the **National Plant Phenomics Centre (NPPC)** and development of the “plant breeding hotel” concept to provide high throughput phenotyping, and chemotyping through analytical chemistry methods, will provide the focus whereby the plant breeding skills and underpinning genetic technologies and expertise within BEAA can be used by SMEs for pre-breeding of specific crops and by those industrial partners seeking to apply this technology within their breeding programmes. The NPPC will be expanded to enable the rigorous and independent evaluation of new GM products that are anticipated to enter the EU market over the coming years. In addition to phenotyping plants in pots in the controlled environment of the NPCC we recognise the importance of phenotyping plants as crops under field conditions. We are therefore developing the tools necessary to perform high-throughput phenotyping in the field including using unmanned vehicles and aircraft deploying a range of imaging techniques and associated informatics.

BEAA **Bio-banks** and global reach in genome-knowledge plant breeding in crops for human food, livestock feed and industrial biotechnology will be exploited within the Innovation Campus. Genetic resources are an important source of novel alleles that are increasingly important for plant breeding programmes as breeders seek to increase the efficiency of crop production, through improved water- and nutrient-use efficiency, better disease resistance or improved nutritional capacity through modified metabolomic composition. Improved technology for accessing

novel genes and introducing them into appropriate breeding programmes, without the negative effects associated with such approaches in the past, are becoming increasingly important. The BEAA "Biobank" currently holds a considerable range of plant genetic resources (greater than 25,000 accessions) and our vision is to enhance the capacity and accessibility of the facility to align with the future needs of plant breeders and collaborators. BEAA also seeks to expand the Biobank to include other organisms, e.g. the extensive collections of micro-organisms it holds which can be mined for agri- and bio-technology applications. Within the **Interdisciplinary Centre for the Bioeconomy** the international agreements and legislation necessary for their legal use, commercialisation and deployment will also be studied.

A new **Sustainability Hub** at AU and BU will link the research expertise within BEAA to quantify carbon and nutrient cycling at multiple scales. Investment in equipment to quantify greenhouse gas emissions and carbon stocks, livestock movement and grazing behaviour, at a landscape scale, will be required. The capacity to manipulate land use systems at the smaller scale (plot) to simulate environmental change (climate, enhanced nutrient deposition) and innovations in livestock, land and nutrient management is an important approach to provide evidence for sustainable production for the farming community in terms of mitigating against, and adapting to, drivers such as climate change. Our expertise in life cycle assessment and carbon footprinting will allow the wider effects of food-, energy- and fibre-based production systems to be evaluated (from cradle to grave), and indeed validated using data generated within the programme. Enhanced collaboration with the NERC Centre for Ecology and Hydrology (CEH, which has a major base in the Environment Centre Wales building, shared with BEAA, at BU) will provide depth in research understanding of how land management impacts on above-ground biodiversity and soil carbon. We will also further advance **the Centre of Excellence for UK Farming (CEUKF)** through new partnerships with the retail sector and supply chains bringing together scientists and stakeholders in the agri-food-retail sector with their supply chain partners. This will provide powerful opportunities to address research needs across the 'producer-processor-retailer-consumer' spectrum. CEUKF will drive knowledge exchange, translational research, professional training and best practice in the land-based industries and create new understanding and relationships with retailers and their suppliers to develop sustainable and resilient food chains. The CEUKF will provide leadership in the development and application of sector-specific **Sustainability Metrics** which are essential to support progress in sustainable efficient agriculture and assist in the realization of sustainable intensification.

c. People, including:

I. Staffing strategy and staff development

To achieve BEAA's scientific goals we not only need to be strategic in our research but also in our human resources strategy. The staffing strategy of BEAA is to recruit, develop, retain and reward active and skilful researchers with a commitment to undertaking high quality, agenda-setting research and communicating findings to academic and non-academic audiences. Investment over the period has allowed us to make substantial strategic investment in new posts with 28 new academic posts of which 9 were at reader or professorial grades. This has allowed us to provide renewed research leadership in the areas of phenomics, metabolomics and genomics (Doonan, Ellis, Powell, Shingfield, Shaw) and informatics (Creevey, Fernandez-Fuentes). We have strengthened our Genome Diversity theme in the areas of population genetics (Hegarty, Powell, Shaw, De Vere, Wilcockson, Steele, Purdy) and genomics (Doonan, Ellis, Hofer, Hegarty, Powell). We have similarly strengthened our environmental impact research theme (Chadwick, Withers, Cross, Fenner, Ravella, Roberts, Hayward). In the animal and microbial science theme we have created a group taking a systems-based approach to animal-microbial interactions (Creevey, Shingfield, Pinloche, Huws, Golyshina) together with further strengthening of our parasitology and immunology capacity (Chalmers, Morphew, Jackson). Finally, over all 3 themes we have recruited both academic (Fuentes, Narcis, Swain, Slavov, Creevey) and support (8X) staff for a major expansion in our informatics capacity.

All new staff are allocated a peer-group mentor and all Early Career Researchers are assigned a senior member of staff as Research Mentor. Early career researchers are also encouraged to contribute to the weekly research seminar series, the annual BEAA Research Conference, and to become actively involved in the work of at least one of our Research Groups.

The universities' three-year probation schemes ensure that appropriate, realistic and manageable research targets are set and attained by the staff entering the employment of both universities without significant independent research experience. All academic staff – including early career and fixed-term staff – have equal access to research support and professional development opportunities, including research planning and monitoring meetings, research surgeries, internal peer review processes, research leave scheme, professional development courses, apportionment of overheads from research grants, university conference fund, university research fund and annual departmental conference/research fund allocation. In addition, the discretionary research fund provides funding for conference participation, research development meetings, publication charges and activities to facilitate research impact. Early career researchers (including fixed-term staff) are also supported by mentoring and encouraged to apply for research grants (including from the university research funds, which prioritise applications from early career staff) and fellowships, and to contribute to larger grant applications as co-applicants with established staff. AU and BU are active participants in **Welsh Crucible**, a pan-Wales initiative that supports the development of future research leaders through a series of 2-day workshops covering media, policy development, creativity, collaboration, leadership, international collaborations and communication. Success in staff development is evidenced by promotions during the REF period of 3 professors and 10 readers/ senior lecturers.

Research concordat: Both Universities have achieved the Human Resources Excellence in Research award, which acknowledges BEAA's alignment of our policies with the Concordat to support the career development of researchers. This is supported by Researcher Concordat Groups at each centre which oversee the annual review of the Policy Statement and manage the implementation plan. We have utilized both the CROS (Careers in Research On-line Survey) and PIRLS (Principal Investigators and Research Leaders Survey) together with researcher focus groups to ensure that our provision meets the needs of research staff and addresses the objectives of the BEAA research strategy.

Performance Measures: Responsibility for staff development and training is shared between BEAA and the universities. Development is delivered (1) through centrally resourced activities, advice and support, (2) as a direct line management responsibility for each Head of Theme and (3) as an individual responsibility. Members of staff are expected to share responsibility for their training and development by actively engaging with the training and development opportunities provided. The identification of training needs is an important part of the Staff Development and Performance Review (SDPR). The SDPR is about recognizing achievements over the previous year and reaching a common understanding of what is expected over the coming year.

Development of Women in Science: Bangor University achieved an Athena SWAN Bronze award in 2011. The University has an active Athena SWAN Group that is developing interventions to better support women working in the sciences in the university. The university has also developed a new senior academic promotions policy and process, agreed a new policy to improve gender representation on decision groups and is now looking at enhanced career break provision for academic staff. At Aberystwyth IBERS is working with the university on an Athena SWAN submission. The creation of theme leaders, theme deputies and research group leaders has created more career development opportunities for BEAA staff. Currently one theme leader, one theme deputy and two of the research group leaders are female.

Succession Planning: We recognise that succession and workforce planning need to be an integral part of strategic human resources policy. This process has already identified a number of areas within bioinformatics and biomathematics where new staff were appointed. In addition, the creation of theme leaders and theme deputies and research group leaders has created the structure and internal opportunities for science leadership development.

Support for Research: Standards of research quality and integrity are articulated in the universities' Policies on Safeguarding Good Research Practice and Statements of Ethical Practice in Research and maintained through ethical approval procedures for research involving human subjects, internal peer review of research proposals, and research planning and monitoring meetings, with 'substantial assurance' of compliance with RCUK conditions on research integrity confirmed in February 2013. Good practice in research management is also reinforced through compulsory training for principal investigators and project initiation meetings for new grant awards. Research development and management across BEAA is supported by the Universities' Partnership Office, established in 2010, and BEAA research development officers embedded in

each theme. The Partnership Office has organized meetings and events, including a monthly Research Café and interdisciplinary workshops around funding opportunities, run a Researcher Development Programme, including a new researcher welcome day and a new researcher induction pack, and individual support for research grant preparation. Joint activities include reciprocal visits of staff between the 2 universities, annual BEAA research conferences and more focused subject-specific research workshops plus logistic support to help boast research activity.

c. II. Research students

A strategic aim for BEAA is to increase numbers and quality of our PG research student cohort. Our objective is to increase numbers to generate a greater culture of PG research activity and of international excellence. We will improve training of existing students and enhance diversity of new recruits, to ensure outgoing students generate research publications of high quality and impact, and to spread the reputation of IBERS and CNS. Our current cohort comprises 95 PG research students (including 10 MPhil), which we aim to build to 125 students during 2013-16. Research PG intake rose from 20 in 2011-12 to 33 in 2012-13. Funding sources for these students included NERC, BBSRC iCASE and Leverhulme Trust. As of November 2013 we are on course to at least match these numbers for 2013/14. Since 2008 BEAA has increased funded PhD numbers through four major innovations: (i) A joint PhD programme with CATIE, the Tropical Agricultural Research and Higher Education Center, which is the leading institution in land-use environmental research and postgraduate education in Latin America. Since 2008, 7 students have been awarded PhDs on this joint doctoral programme, which has now completed 12 years. (ii) An Erasmus Mundus Joint Doctoral Programme “Forests and Nature for Society (FONASO)” of 7 university partners commenced in 2010, supported for 10 years by €6.7M of EU funding. (iii) Using EU regional development funding for research skills training through industrial PhDs in the £33M Knowledge Economy Skills Scholarship (KESS) programme, led by BU. Of the 230 PhD studentships awarded by KESS 73 were in Bangor and 39 Aberystwyth (total value £11.2M). This programme also supported 100 MRes/MPhil studentships across the 2 institutions. (iv) Links with CEFAS have allowed us to co-fund 3 joint PhD studentships working on marine shellfish resources, benefitting from research placements in the CEFAS lab and from courses on advanced analytical methods. Capitalising on BEAA’s strong record of NERC research grant capture, PhD training and institutional collaboration, we played a core role in the formation of a successful consortium just funded as a Doctoral Training Partnership by NERC (with Lancaster and Nottingham Universities, CEH, the British Geological Survey and Rothamsted Research) providing 12 PhD studentships per annum.

Looking to the future, funding secured from Welsh Government for the BU/AU-led NEXUS Wales research network will support 58 PhD studentships over the next 5 years to join a unique interdisciplinary research and training programme in the areas of environment, bioscience and energy. We will also target the next rounds of BBSRC Doctoral Training Partnerships, RCUK iCASE awards and Levy Body awards to capitalise on our exceptional research links with industry: we increased applications (to 8) in the last iCASE round. Our BBSRC Advanced Training Partnership (ATP) Professional Doctorate scheme started in June 2013 and already has 2 applicants. To further increase international Research PG numbers we are targeting the Science Without Borders scheme with Brazil: in the first phase 1 PhD student will join BEAA in September. 2013, and we are developing a BEAA-led strategy for promoting our links with Brazilian agriculture centres. To improve success in all of the above planned activities, we need to improve the BEAA culture of application for PhD funding, recruitment of quality students, and development of these students to generate high quality outputs: mentoring of supervisors will be undertaken, to recognise the valuable contribution of PhD students. We are improving advertising and recruitment procedures to enhance diversity and quality of our intake and reduce dependence on AU and BU graduates: this was illustrated by success of the recent BEAA studentship round where 6 of 7 scholarships were secured by non-home candidates (including 2 EU and 4 UK).

Training and support mechanisms

Development of postgraduate training in IBERS is driven by the RCUK/Vitae 2010 Researcher Development Framework (and particularly the BBSRC-oriented 2011 Skills Statement), which builds on the Research Councils’ Joint Skills Statement (2001) and the Quality

Assurance Agency's Code of Practice for Postgraduate Research Programmes (2004). Our aim is to provide training in multi-disciplinary research and development of transferable skills sets to suitably equip modern biosciences researchers. Our training and progression requirements are frequently reviewed to respond to the diverse funding sources of IBERS-hosted studentships and the non-traditional IBERS combination of fundamental and commercially-linked research, with their own emphases and training needs. A flexible approach to the provision of training maintains a cohesive postgraduate research body that is integrated with IBERS' research excellence and ethos, and ensures consistency in access to high-quality training opportunities and monitoring procedures. In line with the university-wide Continuing Professional Development (CPD) compact, students undertake an annual training needs assessment with their supervisory team, identifying their generalist and specialist needs, to generate an individual development plan maximising their benefit from the diversity of IBERS- and AU-based training opportunities. Students are required to review and report on their progress periodically as part of the progression process. Training is continued throughout the PhD as the students' needs change (e.g. initially to develop understanding of project design, ethics and intellectual property; later to develop communication and writing skills, and careers development; latterly to develop publication and funding skills).

The AU Graduate School oversees IBERS provision and runs its own quality-assured courses as well as induction events, postgraduate conferences and access to a range of personal development workshops across the University CPD scheme. Regular multidisciplinary workshops provide organised intellectual and social contact between students of different disciplines and from many different backgrounds and countries. Parallel developments in Bangor are clarified in UoA 7 REF 5, and NEXUS Wales will enhance integration between the 2 universities.

The core of specialist research training is organised through the supervisory team, consisting of 2 (or more) Principal Supervisors and an internal Academic Assessor. Supervisors are expected to undertake Graduate School workshops in research student supervision, and a mentoring scheme for staff new to PhD supervision is in place. Formalised compulsory training for IBERS PhD students includes: (i) health & safety; (ii) statistics; (ii) research ethics; and (iv) transferable skills and project development, and evidence of immersion in Institute-wide research culture (via seminar series). Research presentations are required in years 1, 2 and 3 at annual Institute PG Symposia. In addition the AU Graduate School offers specialist research training modules in four key skills clusters to address the domains of the RCUK Researcher Development Framework: Research Management; Communication Skills; IT; Career & Personal Development. Students on the KESS programme, and on RCUK iCASE and Levy Body awards, have additional training through internships with industrial partners and an intensive enterprise programme leading to a Postgraduate Skills Development Award (PSDA). These Business-University partnerships closely match the HEFCE Wilson review recommendation.

Progress monitoring

Monitoring of research student progress takes place at 3 levels: the supervisory team, the Institute and the University. At least fortnightly supervisory meetings are expected, and monthly progress meetings are recorded centrally. At months 9, 21 and 30 formally-recorded supervisory team reviews decide on student progression based on assessment of the student's defence of their progress report and completion of required training. Reports from all supervisory teams, including feedback from and interviews with students, are reviewed centrally by IBERS PG Committee and progress decisions reported to the University Progress Monitoring Board. When there are concerns, these are followed up with individual students by the Progress Monitoring Board through the Institute Director of PG Studies. Postgraduate students have input to systems and procedures through Staff-Student Consultative Committees at both Institute and University level, which report to the Senate Research Degrees Committee (RDC). The University also participates in the Postgraduate Research Experience Survey (PRES), a report of which is considered by the Quality Assurance Committee and Senate RDC.

Research student monitoring systems established in recent years continue to improve the quality of training and successful student progression. Completion rates (i.e. successful submission of thesis within 4 years for PhD) during 2009-12 were 90-100%; of the cohort due to complete between Sept. 2012 and Sept. 2013, 8 have been awarded their PhD and the other 8 are on track for successful submission, which again would achieve a rate of 94% (1 technical fail due to special circumstances extension beyond 4 years), well above the 70% RCUK acceptable minimum.

d. Income, infrastructure and facilities

Research Income

We maintain a diverse funding portfolio in 2013/14, with 30% being strategic BBSRC funding, 20% responsive mode funding from UK research councils, 17% from DEFRA, 20% from various Welsh Government sources (including EU regional funding), 8% from EU framework projects and 9% from industrially funded research (in total circa £12-13M/ year). Of particular note is the renewal of 3 BBSRC strategic program grants in Rumen Systems Biology, Energy Grasses and Biorefining, and Crop Genetics, Genomics and Germplasm in 2011 for the next 5 years, together with The National Capabilities funding for the National Plant Phenomics Centre. Strategic BBSRC program grant funding is embedded in each of our 3 research themes and, when combined with the investment in infrastructure and staffing outlined elsewhere in this document, provides a solid base on which to grow and expand our funding over the next assessment period.

Infrastructure and facilities

Over the 2008-13 period we have implemented changes to provide the research infrastructure that underpins sustainable land and water use in the presence of climate change and a range of conflicting demands. Specific examples of investment in the last 5 years include:

National Plant Phenomics Centre. The NPPC is a BBSRC-supported national Infrastructure that provides a step change in the way plant biology is implemented. The application of high throughput automated phenotyping allows whole populations of plants, such as breeding populations, mapping experiments, natural diversity collections and mutant collections, to be analysed in parallel and under multiple defined environments. Automated imaging chambers record from infra-red to ultra-violet light to provide information on the physiology of plants, such as organ temperature, water content and photosynthetic activity, as well as their shape and size. This large-scale facility has 880 carriages (for up to 3400 plants) and five imaging chambers working simultaneously. A key NPPC activity is the identification of useful alleles [gene variants], or more likely combinations of alleles, that produce desirable physical traits (phenotypes). Tracking these and other genetic markers of known DNA allows molecular breeding techniques to be applied to a wider range of traits, and for this reason the NPPC is located next door to the Translational Genomics Lab where plants are genotyped using the latest technology.

Translational Genomics. The Translational Genomics facility provides next-generation DNA sequencing and high-throughput genotyping in addition to dedicated high quality molecular biology laboratories for both existing BEAA staff and visiting academics.

Bioinformatics Hub. We have established a bioinformatics hub allowing us to implement a hub-and-spoke model for informatics' challenges centred around integrating, data mining, and exploring massive data sets from a wide variety of biological systems and modeling interactions between these systems. Staff both spend time within a dedicated bioinformatics hub to benefit from interchange of ideas and techniques and also embedded within the relevant "wet chemistry" laboratories to ensure a close linkage with on-going laboratory- and field-based experimentation.

Dairy. We have installed a new 50-point rotary parlour and additional cubicle housing at the Trawsgoed Farm to support a milk herd of 500 cows. The unit incorporates electronic identification of cows linked to a computer database, facilitating automatic milk yield recording at every milking, pedometers to assist in heat detection, and automated gait analysis to facilitate research into pasture-based dairying.

Wolfson Carbon Capture Laboratory is a purpose built facility providing space for a dozen scientists to improve scientific understanding of carbon capture and sequestration and provide estimates of national and global peat carbon sequestration potential.

Aquaria. Dedicated research aquaria at Bangor and Aberystwyth fed by seawater are used to study marine organisms in an aquatic environment chemically similar to the one from which they were removed, so that habitats and environments can be reconstructed to suit experiments investigating the effect of environment and nutrition on function and behaviour. We have also refurbished bioscience and environment research laboratories and built new freshwater aquaria and reptile house facilities.

Environment Centre Wales (ECW). This co-location of BEAA and CEH provides international-level multi-disciplinary expertise (of 60 scientists) and laboratory facilities spanning

biogeochemistry, microbiology and genomics. ECW's way of working across disciplinary boundaries is providing novel solutions for environmental challenges, e.g. through the new BU-CEH joint project under the NERC macronutrient cycles programme. To turn our research into the evidence base for policy development, the Welsh-Government-funded Wales Environment Research Hub is also housed within ECW. Notable capacities of the ECW equipment base include microscale metabolomics and chemical analysis of environmental materials; measurement, tracking and visualization of stable and radiolabelled isotopes; and measurement of greenhouse gas fluxes in the field and laboratory across terrestrial and aquatic ecosystems. Experimental facilities include fully environmental-controlled growth rooms and human pathogen handling facilities. Analytical facilities include: a suite of stable isotope mass spectrometers notably a continuous flow isotope ratio mass spectrometer; HPLC with multiple detectors; GC-MS; total reflection X-ray fluorescence (TRXF) for metal analysis; three multichannel soil gas analysers; eddy flux equipment to measure fluxes of CO_2, CH_4 and N_2O (using quantum cascade lasers); as well as standard analysers for water and soil chemistry nutrients and for molecular biology.

Public space. To promote engagement with the public and other stakeholders we have developed exhibition spaces, a café, meeting rooms and seminar facilities to allow us to interact with large and small groups.

Laboratory refurbishments. All our laboratories have been refurbished to a high standard and staff now enjoy access to a formidable range of state-of-the-art equipment.

This recent investment adds to our key existing research facilities including:

- **RV Prince Madog** - a 35 m multi-purpose research vessel very well equipped with both wet and dry laboratories and an array of other oceanographic equipment, including a CTD profiler, ship-mounted 300 kHz Acoustic Doppler Current Profiling system, hydroacoustic positioning reference system and scientific echosounder. Its research capacity was strengthened in 2011 with a £310k Reson 7125 dual frequency (200 kHz and 400 kHz) SeaBat Multi-beam system for seafloor mapping. The Prince Madog can sail for 10 days between ports, and has berths for 9 scientists and a crew of 8, making it ideal for shelf sea marine research.
- **Isolation compartments** - over 250 units enable production of novel plant genetic stock in pollen-proof environments.
- **Venlo facility** - 26 compartments offering control of temperature and day length.
- **Parasitology** – a fully commissioned (2008) small animal Biological Service Unit (BSU) that includes rodent housing facilities, invertebrate aquaculture rooms and a laboratory to perform Home Office regulated protocols.
- **Gut microbiology** – an extensive set of gut-simulating fermenters, access to surgically modified animals and an extensive collection of pure cultures of bacteria, protozoa and archaea.
- **Metabolomics/proteomics** – state-of-the-art high resolution mass spectrometry techniques (FT-MS, GC-tof-MS, LC-MS) combined with a validated tool box for data mining to provide a centralized advanced data analysis service for BEAA and BBSRC researchers.
- **Controlled environments unit** – offering control of day length, temperature and humidity.
- **Research farms** – 4 modern units and over 1,000 ha of land with a wide range of topographic and climatic conditions. These provide suitable facilities for field trials including a wide range of grass, arable and biorenewable crops, silvopasture and forest. Modern livestock facilities for dairy, beef, sheep and pigs include intake monitoring and methane emissions.
- **Biochar, anaerobic digester and pelletiser facilities** – these recently commissioned facilities provide the Biorenewables and Environmental Change team with large-scale test beds for the evaluation of a wide range of sustainable energy and soil carbon sources.
- **BioComposites Centre** – a closely integrated set of facilities optimised for plant-based biorefining, bioproducts, analysis and testing that is unique in the UK. Most notable are: lab and pilot-scale equipment for supercritical CO_2 extraction; Andritz Sprout-Bauer 12" pressurized refiner; 50-litre chemistry processing unit with a 20-litre rotary evaporator and chromatographic purification; 400 MHz & 500 MHz NMR spectroscopic facilities; quadruple mass spectrometers and FTIR spectrophotometers, X-ray diffraction and surface analysis; ICP-AES and graphite furnace flame AA spectroscopy; half-fringe photoelastometer with image processing to determine stress distributions, single fibre rheology and dynamic vapour sorption analyser.

e. Collaboration and contribution to the discipline or research base

BEAA has a strong track record of collaboration and engagement with industry. Our collaborations with other research organisations and the commercial sector are diverse both nationally and internationally as reflected in our grant portfolio and publications. Selected examples of working partnerships are shown below:

Bioenergy. We collaborate with Rothamsted Research on energy crops including in the BBSRC Bioenergy Centre (BSBEC), a BBSRC responsive-mode grant on flowering time, EPSRC Supergen-Bioenergy and NERC Carbo-BioCrop. Within BSBEC, we also collaborate with Imperial College, and the universities of Cambridge, Dundee and Nottingham. In Supergen-Bioenergy and subsequently, BEAA collaborates with chemical engineers at Aston and Leeds Universities. Novel applications for plant products have been investigated and protected with Plant Bioscience Ltd. BEAA runs a breeding programme with Ceres Inc. and through a BBSRC UK-US partnership award has built collaborations with institutions in the US including: The Noble Foundation, Texas A & M University, University of Georgia (Athens), National Renewable Energy Laboratory, Idaho National Lab and the Energy Biosciences Institute. With a new BBSRC UK-Brazil partnering award, links are being built on nitrogen fixation in grasses and the comparative genomics and biology of miscanthus and sugarcane. BEAA is a partner in an ERA-net and three EU FP7 projects on energy crops involving partners across Europe and in China, Turkey, Ukraine and Russia.

Bioinformatics. We collaborate with The Genome Analysis Centre (TGAC) and the Wellcome Trust Sanger Institute on sequencing and bioinformatics projects. In addition BEAA and the John Innes Centre have identified bioinformatics as a major area of opportunity for future collaboration via a tripartite relationship with TGAC.

Public-good plant breeding. BEAA has long-term strategic partnerships with plant breeding companies (Germinal Holdings Ltd, Semundo and Ceres Inc.) on the development and commercialisation of plant varieties, and with CGIAR and many partner universities and NGOs in south Asia and Africa. Plant breeders on the Defra Oat-Link project work with the Roslin Institute. AU has also recently formed a new technical alliance with Wherry & Sons Ltd, the UK based specialist producers of pulses for food use around the world, to develop a new pulse breeding program as part of our new Innovation and Diffusion Campus. Plant breeders of miscanthus at BEAA and of willow at Rothamsted Research regularly meet and interact to ensure coordination between these two areas.

Greenhouse gases. BEAA has developed a partnership with colleagues at Rothamsted Research, Agri-Food and Biosciences Institute, and Nottingham, Reading and the Scottish Rural Universities to establish the Agricultural Greenhouse Gas Inventory Research Platform coordinating both the nitrous oxide and methane emission programs. We have also formed a strategic partnership with colleagues in New Zealand, Australia, Europe and the Americas via the Global Research Alliance to form the International Rumen Microbial Genomics Network.

To develop our international strategy, we have recently appointed a Director of International Development and are building strategic alliances with institutes around the world alongside partnership building with selected CGIAR centres, national programmes and universities (e.g. in China, Brazil, India and sub-Saharan Africa). Our focus is around forage systems and livestock, agroforestry and soils, built on the deployment of novel genetic resources and participatory varietal selection, and includes both a focus on postgraduate training and expansion of our capability in public good plant breeding into these countries.

Contribution to the Discipline and Research Base

One of the key objectives of BEAA is to support research within the discipline as a whole, nationally and internationally. Members of BEAA in all categories of age and seniority are encouraged to do this, and all staff returned have made a contribution, as evidenced in the representative sample below of activities during the assessment period.

Research Advisory Panels etc.

NERC peer-review College - ***Thomas*** (2008-11), ***Shaw*** (2008-11), ***Consuegra Del Olmo*** **(**2009-present), ***Carvalho*** (2012-present), NERC-ESRC-DfID panel ***Healey*** (2008, 2012).

BBSRC - ***Draper*** BBSRC Committee B (2011-2012), TDRF Board (2011- to date), ***Scott*** committee B (2008-present), ***Kingston-Smith*** (2008-2011), ***Yadav*** (2008-present) BBSRC “pool”

members, ***Doonan*** advisory panel on Plant Phenomics (2011).

DEFRA - ***Shaw*** Marine Fisheries Science Advisory Group (2008-11), ***Haresign*** Defra LINK Sustainable Livestock Production Research Committee (2008-2011), ***Dennis*** Expert Panel on 'Evidence to define the sustainability of a healthy diet' (2010-2011).

Other UK - *Scollan* Member Welsh Government Land Use Climate Change Committee (2009-11), Member Climate Change Commission in Wales sub-group on Land Use (2012), ***Dennis*** Secretary UK Biodiversity Science Committee (sponsored by Royal Society, 2012-present), ***Powell*** Member John Innes Council, and Member Plant Genomics Advisory Committee of ESRC Genomics, Policy and Research Forum, Member Governing Body of James Hutton Institute, invited Member Secretary of State for Wales' Business Advisory Group.

International - ***Hoffmann*** American Society for Parasitologists Ashton Cuckler New Investigator Award Committee (2010-2011), ***Newbold*** International Advisor to New Zealand Greenhouse Gas Research Centre (2009-present), ***Shingfield*** Member Livestock Research Group and Global Network on Feed and Nutrition in Relation to Greenhouse Gas Emissions (2012-present), ***Powell*** Chairman Program Advisory Committee for Generation Challenge Program of Consultative Group International Agricultural Research (CGIAR), Member International Science Advisory Committee of Fondazione Edmund Mach – Istituto Agrario di San Michelle All'adige Italy, Chair Science Advisory Board of Plant KBBE, a transnational program (France, Germany, Spain, Portugal and Canada) designed to implement a Knowledge-Based Bio-Economy in Europe, Member International Science Advisory Board of Teagasc, the Irish agriculture and food development authority.

Industry - *Haresign* Chair Technical Advisory Committee Red Tractor Pig Assurance (2008-2012), ***Newbold*** Member Scientific Panel of European Probiotics Association (2010-present), ***Kaiser*** UK Minister's appointee to board of Seafish Industry Authority (Seafish) (2007-pesent), UK Minister's independent appointee to Joint Nature Conservation Committee (2012-present), Marine Conservation Zones Science Advisory Panel (2010-2011), Member European Science Foundation Marine Board Working Group "Valuing Marine Ecosystems" (VALMARE) (2013-present), Members Meat Promotion Wales - Hybu Cig Cymru Research Committee ***Haresign*** (2008-present), ***Newbold*** (2008-present), ***Scollan*** (2011-present), ***Williams*** (2013-present).

Editorial positions and roles in learned societies - Over one third of submitted staff (32) have acted as Editors of international journals during 2008-13, including: ***Hoffmann*** Editor-in-Chief Parasitology International (2006-present), ***Newbold*** Editor-in-Chief Proceedings of the Nutrition Society (until 2009), ***Carvalho*** Editor Proceedings of the Royal Society B (2011-present), **Kaiser** Editor ICES Journal of Marine Science (2012-present), ***Fernandez-Fuentes, Consuegra and Hayward*** Academic Editors PloS One, ***Kingston-Smith*** Member Board of Editors, Annals of Applied Biology (2000- present). We also play major roles in learned societies with examples including: ***Newbold and Scollan*** President British Society of Animal Science (2008-2009, 2010-2011), ***Marshall*** Council Member, Association for the Study of Animal Behaviour (2013-present), ***Nash, Shingfield and Rose*** Council Member British Society of Animal Science, ***Whitworth*** Council Society of General Microbiology (2013-present), ***Donnison*** Member Annals of Botany Company (2012-present).

Honours and prizes - *Johnson, Newbold and Powell* Fellow Learned Society of Wales, ***Scollan and Haresign*** Fellow Council of Awards of the Royal Agricultural Society**, *Consuegra, Malhotra, Newbold and Witcombe*** Fellow Society of Biology, ***Johnson*** Royal Society Brian Mercer Award, ***Shaw*** Honorary Senior Research Associate, Rhodes University, South Africa.