The James Hutton Institute

2011 Annual Report 2012

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Message from our Chairman

Ray Perman

It is a pleasure to introduce the first Annual Report of the James Hutton Institute. The intention of the merger, which created the organisation in April 2011, was to bring together a range of scientific expertise to enable us to contribute more effectively to tackling some of the world's most pressing problems, such as food security, environmental sustainability and combating climate change.

A lot has been achieved in our first year. The key appointments in science and business components of our organisational structure have all been made and we have begun work on the five-year research packages that we are undertaking on behalf of the Scottish Government. We launched the Centre of Expertise for Waters and we led the UK team in the international consortium that sequenced the potato genome. The technical aspects of the merger have been completed, but there is much more to do to ensure that we genuinely function as one organisation. We are well advanced on a programme to embed our new culture, structure and approach and to deliver results that will make a meaningful positive impact on people's lives.

We have set ourselves ambitious targets: to deliver the highest quality integrated and innovative science and to be a world leader in research and engagement. It is our responsibility to ensure that the standard of our science is up to the challenge, so we have put in place a series of independent external reviews to help us to achieve and demonstrate our expertise. We also recognise that we cannot do everything ourselves. Although we are now one of the largest research organisations in our field in Europe, to play a leading role globally will demand more skills and resources than we can supply alone. We have always worked with other research institutes and universities inside and outside Scotland, but we have tasked ourselves to widen and deepen those collaborations.

Most of the money that pays for our research comes from public sources, and the largest part of that is sourced from the Scottish Government, with whom we have developed a close and constructive partnership. However, the resources of all public agencies are being squeezed and we have had to make efficiency savings and take cuts to our budget. Those pressures will not go away, so a major focus of our corporate strategy is to build on the good relationships we have with commercial companies, charitable foundations and international agencies – particularly the European Union – to broaden the base of our funding.

The board has an important role to play in ensuring the highest standards of governance and accountability and in helping to set the goals and direction of the Institute. During the first year members have willingly taken on demanding roles on committees. The board has functioned well, but there is always room for improvement, so we are currently reviewing our effectiveness in carrying out our key roles, including supporting and challenging the Executive.

One of our duties will be to continuously review the corporate strategy to ensure that it remains relevant and practical. The world does not stand still.

Chief Executive's Foreword

Professor Iain Gordon

This is the first Annual Report of the James Hutton Institute, launched in April 2011 when it brought together the Macaulay Land Use Research Institute and SCRI (Scottish Crop Research Institute), to combine existing strengths in crops, soils, water and land use and environmental research.

Following our launch, many people asked me why we chose to name the Institute after James Hutton, the "father of geology". James Hutton was indeed a visionary who used his observations of land forms to theorise about how rocks are formed and erode and form again.

His insights led to the theory of deep time. Hutton began to realise that the world is much older than suggested in the Bible. His thinking formed the basis upon which theories such as Darwin's natural selection could develop. However, Hutton was more than a geologist; he was a polymath with his mind ranging across subjects from how rain is formed to how blood circulates around the body.

He was also a practical man. He made his money from the manufacture of sal ammoniac which was used in dyeing, metalworking and as smelling salts. He also farmed land at Slighhouses in Berwickshire where he introduced practices from elsewhere in Europe and experimented with plant and animal husbandry. He recorded his ideas and innovations in The Elements of Agriculture, which is unpublished to this day but which the James Hutton Institute will publish in the future. It is because of his observation and interpretation of the world around him and his use of this understanding when applied to the practices of land management that we are proud to use the name James Hutton for our new Institute.

Land and the ecosystems it supports underpin the provision of food, fuel, clean water and air and many of the cultural experiences that provide for human livelihoods and wellbeing. The provision of these goods and services is supported by ecosystem functions such as climate regulation, nutrient cycling and protection from disease and natural hazards, collectively referred to as ecosystem services. These create a platform on which economic activity occurs, governance regimes are built, resource use is negotiated, land management decisions are framed and lives are lived.

Ecosystem services are now seriously threatened by high levels of consumption and ecosystem degradation which contribute to food and energy insecurity; increased vulnerability to natural disasters such as floods and droughts; reduced availability and quality of water; threats to cultural heritage; poor plant, human and animal health and other, general conflicts. These challenges will be exacerbated further by climate change and population growth.

The nature of the demands and pressures on land are diverse and decisions about its use occur within complex socio-ecological contexts. Delivering innovative solutions necessitates the development and application of high-quality inter-disciplinary research in partnership with people, organisations and governments. This solution building has to be responsive to the requirement for land to meet the current and future needs of our environment and society. The James Hutton Institute is structured to deliver integrated scientific outputs relevant to global challenges, both now and in the future. Delivering our science is premised upon the need to:

- Ensure that our science is of the highest calibre, through the inter-disciplinary science groups. The groups are the foundation of research excellence within the James Hutton Institute. Their function is to maintain and nurture the science and infrastructure necessary to build the inter-disciplinary teams required to deliver the vision. The groups therefore will focus on excellence by promoting science that is credible and leading-edge. They will ensure our research is undertaken in an enabling environment so our scientists are properly resourced, with a good infrastructure and supportive management.
- Integrate our research to address the demands and challenges on land and natural resources to deliver goods and ecosystems services more sustainably, through the research themes. Our themes recognise global dynamics and are purposely responsive and flexible in their planning and delivery. A key aim is to ensure that knowledge generated within the research and other communities flows and reaches the people who can apply it in a timely manner. The themes, therefore, will focus on engagement: innovative research that is relevant, timely, adaptable and business focused. They will be effective by identifying synergies, reducing duplication, and delivering knowledge exchange.
- Offer world-class facilities and services in all aspects of our operations to enable our science to be conducted and delivered. Our Business Enabling Services has two key functions within the James Hutton Institute: to support the science and to provide stewardship of 'corporate health' by ensuring external compliance.

My aim has been to create an Institute that operates as a single organisation across two main sites and a number of research stations and farms. The need is to provide staff with the same operating environment no matter where they are based. This has resulted in a year of change for the staff in the James Hutton Institute as they come to terms with new colleagues, organisational structures, senior management team and redrawn processes and procedures.

Change is never easy, but I have been heartened by the enthusiasm of the staff for the journey that we have embarked upon together. I have been encouraged by the fact that we have been able to continue to generate, and work with partners to apply, great science over this period of change and transition. This is a tribute to the staff of the Institute and the continued enthusiasm of our partners to work with us. In the Annual Report you will see many examples of the excellent science that is creating solutions to the challenges facing the globe. I hope that you enjoy reading it and I look forward to hearing how we can work together in the future.

Our Science

Professor Colin Campbell,
Director of Science Excellence

The James Hutton Institute has over 360 scientific staff working in the area of land use and natural resources. We have an excellent scientific reputation with over 400 peer-reviewed papers published each year. We have developed collaborative partnerships worldwide and numerous interactions with industry, government and the general public. The scientific and societal challenges identified in our science strategy are complex and require the application of a range of skills and disciplines in concert. Innovative approaches within existing disciplines and multi-disciplinary working is required. We also need to recognise that new scientific disciplines are evolving to meet these difficult and complex challenges, e.g., bioinformatics and environmental psychology. Most importantly we require inter- and trans-disciplinary approaches that look at problems in new ways and seek solutions that make a difference. The nature of problems change over time and the skill sets required vary at different stages. Consequently, flexibility to deploy the appropriate skills is needed at different times, and while we apply our science to today's problems we need to keep developing our scientific disciplines to meet the demand of the future.

The James Hutton Institute's science is therefore managed using a matrix structure (Figure 1 and Table 1). Matrix management focuses on integrated project delivery, giving flexibility to apply varied skills to specific projects. It also allows for the co-existence of specialisation, depth of knowledge, professional development and career progression.

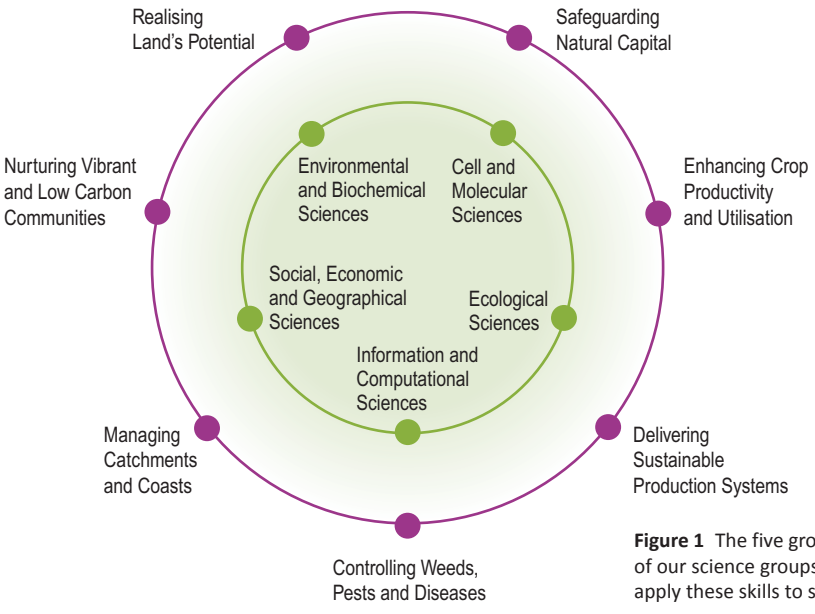


Figure 1 The five groups in green form the core of our science groups and the themes (purple) apply these skills to solve problems.

It aims to share responsibility and encourage the delivery of project-based research and development.

- The science groups are the foundation of the research excellence of the James Hutton Institute. Their function is to maintain and nurture the science and infrastructure necessary to build the inter-disciplinary teams required to deliver the vision. The groups therefore focus on excellence (i.e., promoting science that is credible and leading edge) and is undertaken in an enabling environment (i.e., properly resourced, with good infrastructure and supportive management).
- The research themes integrate our research to address the demands and challenges on land and natural resources. They use the skills and resources from groups in projects applied to the problems and needs of stakeholders. The key aim is to ensure that knowledge generated within the research and other communities flows and reaches the people who can apply it in a timely manner. The themes, therefore, also focus on engagement (i.e., research that is relevant, timely, adaptable and business focused) and effectiveness (i.e., identifying synergies, reducing duplication and delivering knowledge exchange).

The science groups have responsibility for the long-term stewardship of our extensive chemical, physics and biology laboratories and a huge range of cutting-edge analytical equipment. Our facilities for science include over 10,000 m² of glasshouse facilities, ranging from cold houses to sophisticated containment houses, a soft fruit handling laboratory, 28 polytunnel structures, 19 growth rooms, 44 growth cabinets and 18 cold stores. We also have a virtual landscape theatre capable of presenting 3D visualizations to audiences who can interact with the display by voting on options such as where to place wind turbines in the landscape. We have significant national and international scientific resources such as a National Crop Seed Store, Insectaries, Crop Germplasm (Commonwealth Potato Collection, barley and the Ribes, Rubus collection and plant pest and pathogen collections). In addition, we host the National Soils Archive and are a national data centre for soil and land, the Soil Survey of Scotland, and National Mapping of Soil and Land Resources. We continue to invest and enhance these scientific resources and make them more available to the national and international scientific community and more accessible to a variety of stakeholders.

In 2011 we have further invested in scientific facilities to remain at the cutting edge of science and technology. Our imaging facility has recently been enhanced by the investment of more than £500,000 to purchase a Ziess LSM710 confocal laser scanning microscope (CLSM). The microscope is fitted with pulsed diode lasers to enable fluorescence resonance energy transfer (FRET) and is fitted with a fluorescence lifetime imaging (FLIM) detector system. This technology will enable detailed investigation of protein–protein interactions *in vivo* which will greatly enhance our capacity to functionally characterise and examine dynamic interactions between candidate proteins (both plant and pathogen; see Figure 2).

Similarly we have invested in a new state-of-the-art liquid chromatograph mass spectrometer to support our work on metabolomics.

New technologies enabling rapid and cost-effective assessments of organic and inorganic components of soil

Table 1 Indicative primary delivery of science from groups (in green) to themes (in purple).

	Enchancing Crop Productivity and Utilisation	Developing Sustainable Production Systems	Controlling Weeds, Pests and Diseases
Cell and Molecular Sciences	**Crop and pathogen germplasm collections, genetics, genomic skills; metabolomics**	**Germplasm collections**	**Crop, pathogen and pest germplasm collections, genetics, genomic skills**
Environmental and Biochemical Sciences	**Food biochemistry**	**Soil, plant animal nutritional analysis; soil physic; biogeochemistry; hydrology; soil properties**	**Analysing receptor proteins; phytochemicals; pathogen-environment interactions**
Ecological Sciences	**Plant physiology and nutrition**	**Resource use efficiency; integrated pest management (IPM)**	**Epidemiology, plant-insect interactions; IPM; weed ecology**
Social, Economic and Geographical Sciences	**Agri-economics**	**Agri-economics**	**Agri-economics; social dimensions of risk**
Information and Computational Sciences	**Bioinformatic skills; metabolomics**	**Plant-soil systems modelling; spatial analysis**	**Spatial analysis; epidemiology modelling; risk analysis; bioinformatics and network analysis**

and water are also now emerging. We are developing the use of field portable X-ray fluorescence (PXRF) and Fourier transform infrared (FTIR) and near infrared (NIR) spectroscopy for the determination of organic and inorganic components of plants and soil. We are also developing the use of total reflection X-ray fluorescence (TXRF) for the trace element analysis of soils and waters using no more than a drop of solution or suspension so that we can investigate the properties of waters and soils at an appropriate scale (Figure 3).

We are also investing in apparatus and facilities for our informatics and social, economic and geographical sciences by way of computing infrastructure, software and are designing and building a new human psychology lab for our work in environmental psychology.

Innovation is encouraged and nurtured through leadership and developing a culture of curiosity and enthusiasm for discovery and problem solving. We encourage the sharing of ideas through line management leadership, by debating current science at every opportunity but also

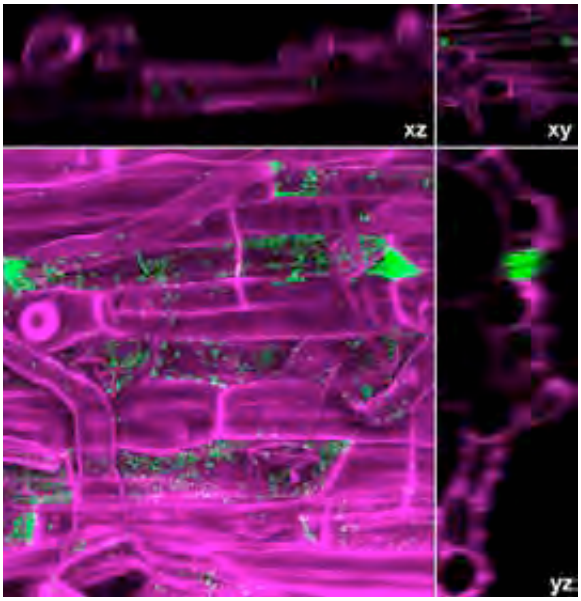


Figure 2 *Escherichia coli* O157:H7 bacteria (green) growing on the surface of a spinach root and within epidermal cells and their associated root hairs. The orthogonal projections (xz and yz) show the depth of penetration of the bacteria into the root.

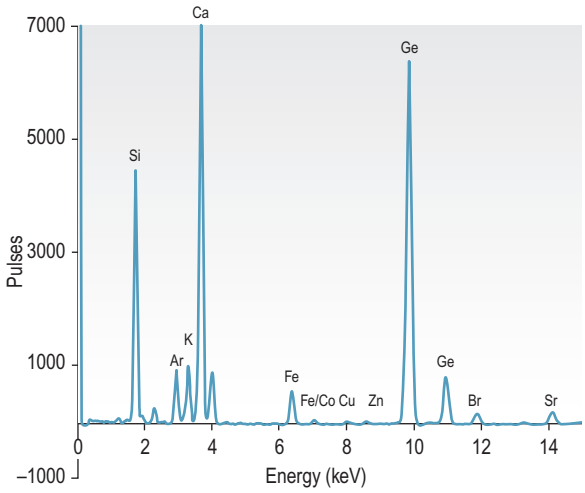


Figure 3 TXRF is a multi-element, micro technique with remarkable sensitivity in the picogram range. For the analysis of liquids or suspensions the sample is spiked with a suitable internal standard and a small drop dried on an optically flat disk. Unlike conventional XRF, the sample is exposed to a very low-angle beam of X-rays and the induced fluorescence measured. The analysis is complete within a few minutes and sample changing is automated. We are currently using the technique for the analysis of soil pore water as seen in this trace.

Managing Catchments and Coasts	Nurturing Vibrant and Low Carbon Communities	Realising Land's potential	Safeguarding Natural Capital
	Molecular biochemistry of cell wall in relation to biofuels		
Hydrology; biogeochemistry	**Ecosystem level fluxes of greenhouse gas (GHG); isotope tracers**	**Land and soil survey**	**National Soil inventory and archive**
Freshwater ecology; invertebrate ecology; aquatic and riparian vegetation	**Long-term vegetation monitoring**	**Landscape ecology**	**Long-term biodiversity monitoring**
Micro-economic analyses; analysis of institutions and governance	**Micro- and macro-economic analyses; analysis of institutions and governance; analysis of behaviour and related constructs**	**Micro- and macro-economic analyses; analysis of institutions and governance; analysis of behaviour and related constructs**	**Micro-economic analyses e.g. non-market valuation, analysis of institutions and governance; analysis of behaviour and related constructs**
Risk modelling; contaminant transport modelling	**Systems modelling; risk analysis and modelling; economic evaluation; non-market analysis**	**Systems modelling; GIS modelling; spatial analysis; visualisation techniques**	**Modelling ecosystems, GIS; population dynamics**

To	Name	Group	For work on
Band G	Dr Rex Brennan	Cell and Molecular Sciences	*Rubus, Ribes* genetics
	Dr Glenn Bryan	Cell and Molecular Sciences	Potato genetics
	Professor Robin Pakeman	Ecological Sciences	Plant ecology
	Professor Alison Hester	Ecological Sciences	Ecology of upland vegetation
Band F	Dr Rob Brooker	Ecological Sciences	Plant succession
	Dr Roy Neilson	Ecological Sciences	Ecology of nematodes
	Dr Luke Ramsay	Cell and Molecular Sciences	Barley genetics
Band E	Dr Matt Aitkenhead	Information and Computational Sciences	Soil process modelling
	Dr Lisa Avery	Environmental and Biochemical Sciences	Fate and survival of enterics
	Dr Peter Cock	Information and Computational Sciences	Bioinformatics of plant pathogens
	Dr Julian Dawson	Environmental and Biochemical Sciences	Biogeochemistry of waters
	Dr Scott Newey	Ecological Sciences	Wildlife ecology
	Dr Ruth Mitchell	Ecological Sciences	Vegetation and soil patterns
Band D	Malcolm Coull	Information and Computational Sciences	Soil databases, geoinformatics
Band C	Richard Gwatkin	Environmental and Biochemical Sciences	Automated field data logging

Table 2 Promotions in 2011

through informal and formal seminars and presentations within groups and across the Institute. Scientific horizons are monitored through reviewing the scientific literature by all staff, through attendance at conferences, and systematic monitoring of key publications from societies, organisations, government and leading institutions.

The Postgraduate School is another route by which we invest in new research, innovation and talent as well as build capacity in new skills. The Postgraduate School has been developed through seeking and winning externally funded studentships, joint funding using Institute seed corn monies and through CASE awards funded by our commercial subsidiaries (Macaulay Scientific Consulting and Mylnefield Research Services). The school comprised 125 students in 2011 with students registered at 35 different universities in the UK and abroad. Sixteen PhD theses were successfully submitted in 2011/12.

We mentor staff through our line management systems and review career development through training and scientific opportunities to attend conferences in the UK and abroad. Table 2 shows promotions in 2011.

A review of our staff complement indicates that we do not fully meet the demand for socio-economics, informatics, bioinformatics and the system approaches we are advocating. So these are science disciplines and areas where we actively encourage recruitment and expansion using internal resources. Seedcorn investment, studentships, training, mentoring and underpinning capacity are all being used to help science groups develop and invest in new areas. Seedcorn funds have been used to support new projects and ideas in an open competitive call to develop strategic science areas. New projects started in 2011/12 include a co-ordinated Solanaceae research initiative, an eco-genomics initiative, and various smaller projects aimed at increasing capacity in socio-economics and informatics and proof of concept projects developing new innovative approaches for analysing materials and our environment.

Enhancing science excellence

The Institute is named after one of Scotland's most inspirational and important scientists and this drives us to emulate James Hutton's insight and impact. We are building on a tremendous track record of our legacy institutes in providing a wealth of information and understanding. We are now publishing over 300 ISI papers annually and from our legacy institutes to date have over 40 papers published in the two top journals of Science and Nature. However, we are also increasingly producing a wider range of outputs including information systems, tools and databases, national assessments and continue to grow our track record of engagement with industry, policy and the public.

Institute scientists published more than 400 research papers in 2011/12 in over 150 different journals (Web of Science Database, Thomson Reuters). There were several excellent papers across the range of disciplines we cover including papers in Nature and Science.

We encourage and celebrate our scientists to win prizes and recognition. Dr Jorunn Bos started her Royal Society of Edinburgh (RSE) fellowship in October 2010. She is studying molecular plant–aphid interactions focusing on *Myzus persicae* interactions with potato. She has established her laboratory interacting with several other laboratories in the Institute and has won a research grant

from the Royal Society (London) to develop yeast-two hybrid screens to study aphid–plant interactions and secured a BBSRC response mode grant starting April 2012.

The Royal Society of Edinburgh has established a new RSE Young Academy of Scotland. The Young Academy brings together some of the most able and innovative young academics, entrepreneurs, artists and professionals in Scotland. We were delighted that Institute scientist Dr Kirsty Blackstock of the Social, Economic and Geographical Sciences group was elected to this new academy.

Seosamh (Joe) Ó Lochlainn was awarded the 2011 Cocking Prize in Plant Science by the University of Nottingham for his PhD thesis on Natural Genetic Variation in Zinc Accumulation in Brassicaceae. Joe was supervised by Philip White at the James Hutton Institute, Martin Broadley, Rupert Fray and John Hammond at the University of Nottingham and Graham King at Rothamsted Research.

We have also made progress in developing our partnerships for excellence, for example with the many visiting scientists from around the world and the honorary and joint appointments that our staff have at universities. We have for many years had a highly successful partnership with the Division of Plant Sciences of the University of Dundee which celebrates its 10th Anniversary in September 2012 and which will expand with two new joint appointees in 2012. We also have new joint appointments in 2011 with Universities of St Andrews (Professor Lesley Torrance and joint Fellow Dr Jens Tilsner) and Herriot-Watt (Professor Derek Stewart). In 2011 Robert Gordon University have also bestowed Wolfram Meier-Augenstein and Lorna Dawson with honorary chairs.

The five science groups are creating an enabling research environment with due regard to gender and culture. We are signatories to the ATHENA SWAN charter that recognises and celebrates good employment practice for women working in science, technology, engineering and mathematics (STEM). The gender balance and distribution of grades in groups across our science groups varies considerably (Figure 4). The Royal Society of Edinburgh has recently reported its findings from its inquiry into Women in STEM for which we submitted consultation responses and we are now considering their findings and acting on them to improve our policies and procedures in this regard.

The foundation of an institute is a time when far sighted principles, objectives and values need to be set out in a way that guides our efforts and endeavours. We have a truly excellent track record in science from our legacy and we are already seeing early signs of new opportunities and synergies in the new Institute which gives us confidence and belief in going forward. Science is at the core of our Institute and in 2011 we have invested in it further and look forward to further innovations, discoveries and milestones.

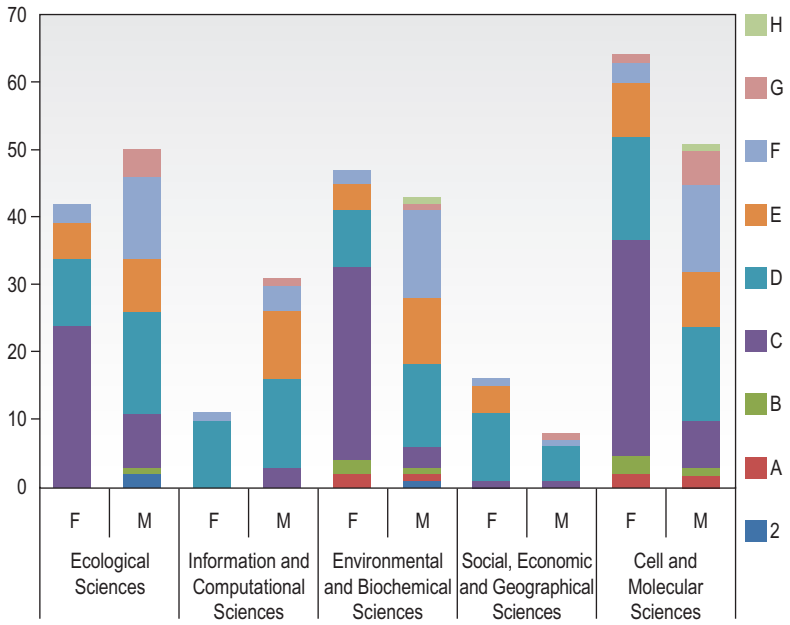


Figure 4 Numbers of staff by gender (F, M) and pay grade in the five science groups of the James Hutton Institute. Pay grades increase in salary from A to H. Bands A–D are predominantly support scientists and Bands E–H are principal investigators/ senior scientists.

Our Research Themes

Professor Bob Ferrier,
Director of Research Impact

By 2050 it is estimated that nine billion people worldwide will require to be fed and also have access to clean water, sanitation and energy. These needs will have to be met in a way that does not compromise vital ecosystem services. The equitable allocation of resources will require an over-arching systems approach which considers food, water and energy supply, resource efficient agriculture and production, green-based industries and human health. These factors will have to be embedded into local or regional frameworks of law, regulation and social behaviour. Without such an approach, 'global security' will remain elusive and it is likely that related stresses, tensions and conflicts will increase worldwide. Therein lies our challenge.

To face these challenges we need science that is robust, focused and timely. We need it to be contextualised against these global challenges and delivered through an inter-disciplinary lens. The seven research themes at the James Hutton Institute provide the context and delivery centres for our collective research efforts. These issues are inherently dynamic in their nature and this is reflected in the way our research themes will evolve. They are forward-looking, analysing opportunities and potential, and developing appropriate synergies and partnerships with public, academic, stakeholder and industry organisations through which they add to their value. Our themes are designed to target research to meet present and emerging policy and societal demands at local, national and international levels.

These themes address the fundamental issues surrounding the natural resource, energy, food, environmental and social issues associated with populations across the globe. They address a multitude of complex issues using an approach spanning natural science, technology, social science, and policy. With a focus on project delivery, they aim to engender a multi-, inter- and trans-disciplinary perspective to problem solving, which benefits from enhanced information sharing and encourages innovation.

Safeguarding Natural Capital

Global challenge – environmental security, climate change

- Understanding the relationships between natural capital, ecosystem functions and services required for human health and wellbeing
- Defining 'critical natural capital' to prioritise and measure progress
- Designing novel and effective valuation methods (economic and social) for ecosystem goods and services for effective application within different policy and governance systems

Enhancing Crop Productivity and Utilisation

Global challenge – food security

- Improving yield and yield stability
- Enhancing product differentiation through improved quality, nutritional value and health benefits from crop-based foods
- Utilising translational genomics, genetics, natural product chemistry to capture value from functional diversity

Delivering Sustainable Production Systems

Global challenges – food security, environmental security, rural development, climate change

- Producing higher yielding and lower input crops for specific environments
- Assessing farming impacts on soil and ecosystem health
- Discovering options to reduce wastage in the global farm supply chain

Controlling Weeds, Pests and Diseases

Global challenges – food security, climate change, environmental security

- Understanding the role of pests/pathogen effectors in suppressing host resistance
- Exploiting sequence data from genomic technologies for plant protection
- Assessing pest/pathogen epidemiology and population biology, tracking disease agents and identifying/monitoring new isolates

Managing Catchments and Coasts

Global challenges – water security, climate change, energy security, environmental security

- Developing and utilising tools to manage catchments across multiple scales and potentially conflicting demands for services
- Providing advice and direction for catchment decisions in relation to food, energy and ecological security
- Understanding the role of governance in catchment and coastal planning

Realising Land's Potential

Global challenges – rural development, energy security, environmental security

- Evaluating options for the sustainable use and management of rural and urban land for long-term human wellbeing
- Understanding the multi-functional uses of land, in particular energy and resource provision
- Developing socio-ecological methods for future-proofing land use decisions

Nurturing Vibrant and Low Carbon Communities

Global challenges – climate change, rural development, energy security

- Quantifying carbon stock changes and greenhouse gas emissions from land use change
- Enhancing the understanding of factors influencing mitigation and adaptation decisions and evaluating governance, institutions and policy incentives needed to ensure their uptake
- Understanding changed behaviours and attitudes to achieving a low carbon future

Most global and environmental problems start and end with people and those same people must be part of the solution and involved from the start. That is the only way to translate research into changed attitudes and behaviours and outputs into outcomes. Many of our research initiatives and programmes implement a collaborative approach to create a mutual understanding of the issue being addressed. This provides an opportunity for researchers to understand societal pressures, resource management issues, policy demands and consequences, and the perspectives of industry. This so-called 'co-construction' ensures that outputs of the research effort are targeted towards impact and the delivery of positive outcomes with the users of that research. The integration of social and economic sciences with natural sciences has ensured that coupled socio-technological options can be evaluated and promoted.

A good example of this is the development of control methodologies for diffuse pollution at farm and catchment scales. Understanding the potential benefit of a suite of possible management options is only one part of the equation. Ensuring that this knowledge is implemented on-the-ground involves dialogue with land-based industries, awareness raising and capacity building resulting in altered perceptions and behaviours.

Our vision for the Institute's research themes is to consolidate and enhance the inter-disciplinary nature of our science delivery. Inter-disciplinary science is not delivered overnight though – it takes time: time for people to feel comfortable in moving from their current knowledge domains, time to learn a unifying language and time to reflect on how their contribution delivers more when integrated into a wider perspective. Many of the themes already embrace this approach and we have established a specific initiative on enhancing opportunities for greater inter-disciplinary working within the James Hutton Institute research delivery as part of our Seedcorn funding initiative.

Research organisations are all facing a world of tighter financial constraints and therefore a vibrant business development ethos is critical to the sustainability of the James Hutton Institute. The thematic structure also aims to increase the efficiency of our income generation strategies, mentoring and empowering staff to exploit opportunities when and where they arise.

In order to achieve our thematic vision, we believe we need to continue to forge alliances with a greater number of national and international organisations. Collaboration should be viewed as a fundamental part of the science process both within and outwith individual organisations and will be encouraged at corporate, theme and individual level. We also consider the benefits of partnerships that provide leverage and giving access to different funding sources and provide a route to industry. There is no doubt that our commercial subsidiaries – Mylnefield Research Services Ltd and Macaulay Scientific Consulting Ltd – provide an important vehicle for this engagement with the private sector. The themes aim to enhance scientific effort and delivery through such collaboration, in particular with the Scottish Government-supported centres of expertise for waters, climate change and animal disease outbreaks. They also seek to work with other networks of excellence and strategic partnerships, such as the EU Technology Platforms, Joint Programming Initiatives, European Innovation Platforms, ERANET activities and international initiatives such as IGBP, Diversitas, and UNESCO.

I commend their work to you and hope you will enjoy reading about their activities in more detail in the chapters that follow.

Safeguarding Natural Capital

Professor Alison Hester, Theme Leader

Protecting the air, water, soil, land and the living organisms which underpin the life support systems of our planet

Defining natural capital

Natural capital is widely defined as the 'stock of natural ecosystems that yields flows of valuable ecosystem goods or services into the future', i.e., the physical, chemical and biological resources of the globe: air, water, soil, land and the biodiversity (including humans) that is supported by those elements.

Safeguarding Natural Capital is one of the biggest challenges facing us today and into the future. Activity tends to be focused in two main ways: the first focuses on protecting natural capital and minimising 'detrimental' effects of humans; the second, which is becoming more prevalent, focuses on protecting natural capital for the services it provides for human health and wellbeing. We need robust, underpinning information to progress understanding and guide decision making.

For example, the major global issues: food, water, energy, carbon – are all fundamentally dependant on natural capital (Figure 5). Global population increases and climate change will further increase pressures on natural capital and the services it provides, and it is critical to incorporate strong predictive analyses of the likely implications of these changes to increase understanding and inform decision making.

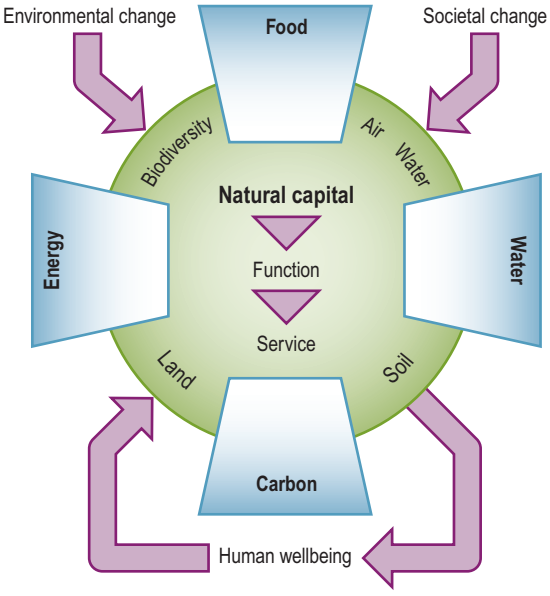


Figure 5 Natural capital, through the functions and services that it provides, is critical for human wellbeing. It underpins all major global needs, such as food, water, carbon and energy.

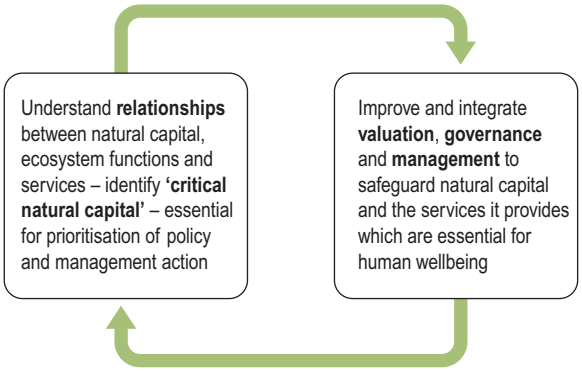


Figure 6 Two main areas of critical global importance for the safeguarding of natural capital, where inadequate scientific understanding is hampering progress.

Our research focus

Research within this theme aims to provide robust, underpinning, evidence-based solutions to progress understanding and guide decision making in the following critically important areas (Figure 6) where inadequate scientific understanding is hampering the safeguarding of natural capital across the globe. These broad areas require linked, iterative research at multiple levels – one of our Institute's strengths – from systems modelling through to more focused, in-depth research to target specific gaps.

Safeguarding Natural Capital underpins and interlinks with all the other research themes, and we integrate our research to address demands on land and natural resources to prioritise action and deliver ecosystem goods and services more sustainably. Much attention is currently focused on the ecosystem approach, originating from the Convention on Biological Diversity as an integrated approach to ecosystem management (CBD), moving away from the 'traditional' focus on species and area protection towards integrated land use planning and ecosystem protection which recognises people and society as integral components of ecosystems, their management and conservation. There is still much debate about the meaning and practical value of this concept in terms of management approaches and management outcomes; our research sets this in context with other approaches and contributes to this wider debate.

Using the two main focus areas, illustrated in Figure 6, the following pages give a flavour of the range of research we do directly within the Safeguarding Natural Capital theme, with a small selection of recent research highlights in more detail.

Relationships between natural capital, ecosystem functions and services

Natural capital provides ecosystem functions, such as energy transfer, nutrient cycling, gas regulation, climate regulation, and the water cycles. Ecosystem services are often defined as those ecosystem functions which are of particular value to humans, although this is a highly theoretical concept, as 'value' is not always clear or definable. Ecosystem services provided by natural capital are generally divided into four categories: supporting (e.g., soil formation, primary production), provisioning (e.g., food, fibre), regulating (e.g., water purification, decomposition), cultural (e.g., recreation).

Soils are the foundation of 'supporting services' that feed through to other services, for example enabling ecosystems to produce food and fibre, supply water, regulate climate, mitigate natural hazards and maintain landscapes and habitats for us to enjoy for recreation or for the survival of wildlife. These multi-functional characteristics make all soils intrinsically valuable to human society. Soil's most widely recognised function is supporting plant growth, whether for crops, trees or native habitats. However, sitting as it does at the interface between the atmosphere, biosphere and underlying rocks, soil is being increasingly recognised for other environmental and ecosystem benefits, including climate regulation (greenhouse gas emissions and carbon storage) and water flow regulation (flood control), and as the largest terrestrial reservoir of biodiversity.

Our soils research aims to improve soil quality to maintain and enhance the supply of ecosystem goods and services benefits through alternate land use systems, innovations in management and restoration of degraded soils.
Our current soil-focused research includes:

- Modelling the contributions of soils to ecosystem services from pedon to landscape-scales
- Understanding the role of soil biodiversity in maintaining and restoring soil capital
- Developing new approaches in measuring and monitoring the soil resource, e.g., developing informative indicators of soil quality and developing management options to safeguard the capital of soils and to enhance and restore the functioning of soils
- Characterising and quantifying the contribution of soils to economic, environmental and social benefits derived from different land uses and from complex landscapes
- Establishing the trade-offs in multiple benefits when soils are managed for different purposes; and understanding the risks to multiple benefits from the impacts of climate change and other pressures on soils
- Examining the implications of policy and incentive mechanisms on the protection and restoration of the soil resource.

Significant losses in **biodiversity** have been documented in the UK and around the world over the last 50 years.

These changes have largely been due to human activities, for example, changes in land use, changes in farming methods, pollution and climate change. Changes in the way humans use the earth's resources will influence what species occur, where they occur, their abundance and how they function in terms of providing ecosystem services. Our biodiversity research aims to improve our understanding of how drivers of change such as land use, pollution and climate change impact on biodiversity and ecosystem services. This knowledge is essential to advise policy makers, land managers, conservationists and other stakeholders on methods to help safeguard our natural capital and to improve the resilience of species and habitats to environmental change.

Our current biodiversity-focused research includes:

- Understanding the role of biodiversity in delivering ecosystem services
- Developing methods to predict the delivery of ecosystem services from biodiversity
- Assessing the impact of government policies on biodiversity
- Assessing the impact of human induced drivers of change on biodiversity
- Developing methods to restore damaged ecosystems and habitats
- Assessing the impact of introduced or non-native biodiversity on native biodiversity and the production of ecosystem services
- Assessing the impacts of re-introducing extinct native species.

Landscapes and regions are where many natural processes and human activities interact and potentially conflict in different ways. Managing landscapes must satisfy multiple purposes, and has to account for multiple time and spatial scales. Landscapes are open systems and therefore the exchange of nutrients, matter and individuals need to be understood in their spatial and temporal contexts. To understand the relationships between ecosystem function and structure, and how these lead to the services provided to society, we adopt a multi-scale perspective, ranging from field to continent, depending on the particular case. This often implies studying and managing landscapes across management units and property boundaries. We integrate multiple disciplines in the natural and social sciences to study socio-ecological systems, giving the human and natural component equal importance to understand the past and future trajectories of change, to examine trade-offs and policy options. Landscapes are dynamic and complex. The nature of their change is inherently uncertain and so can be the outcome of policy interventions. We facilitate approaches to management that involve policy makers, land managers, communities and civil society and permit experimentation, participation and collective learning by all parties involved in this process

Our current landscape/regional level natural capital research includes:

- Quantifying the spatial distribution of natural capital, land functions and ecosystem services
- Understanding the natural and land use factors that influence the distribution of species and habitats at the field, catchment, national, and continental level
- Modelling the direct and indirect effects of climate change on biodiversity and ecosystem services
- Developing satellite-based indicators of the effects of climate and other changes
- Examining and testing models for multi-functional land use options under different scenarios.

Valuation and governance of natural capital

Natural capital and the services which it provides are critical to life on earth, yet the value of these services is rarely quantified, which often leads to their neglect or under-representation in global or local decision making and policy development, in comparison to services and capital which are readily quantifiable, such as manufactured capital. Looking at natural capital and the services which it provides inherently requires looking at the relationships between humans and their natural environment: the concept of 'capital' implies that components of the natural environment are valued and seen as assets. So how are such values played out in practice, e.g., in land management and policy making? In today's societal context where natural capital has to fulfil multiple, often incompatible functions at once, how can we ensure sustainable governance that safeguards our natural resources? These questions form the basis of the research within this theme.

Key components of our research include:

- Understanding how people value their natural environment, to improve and integrate monetary and non-monetary valuation approaches to ensure appropriate representation of natural capital and related ecosystem services in decision making
- Examining the role and potential of different governance approaches to safeguard and promote sustainable use of our global natural capital.

Our research addresses a wide range of natural capital that can be regarded as providing provisioning, regulating, supporting and cultural ecosystem services. We have a team of researchers with expertise in valuation and

governance, embedded in UK and European networks, and active not only in Scotland but also internationally. Valuation and governance are both highly controversial areas, with much disagreement and still much lack of understanding – this provides an exciting opportunity to make a major contribution in both of these critically important areas.

Designing an integrated framework to support the ecosystem approach

The ecosystem approach, and associated ecosystem services assessments, are being incorporated into a wide range of policy objectives and are now being tested on-the-ground for practical management purposes. Within Scotland, for example, the ecosystem approach is being viewed as a broad objective across a range of policies including climate change, National Planning Framework, Scottish Biodiversity Strategy and the Land Use Strategy. As a consequence, there is much interest in developing, testing and applying a framework that can assist with integrated decision making.

A range of frameworks are already in use in various topic areas related to understanding ecosystem services and environmental management, but none are considered to be entirely appropriate for guiding the application of the ecosystem approach. The Scottish Government (RESAS) funded Ecosystem Services Theme (EST) team have therefore developed an integrated framework (Figure 7) to aid decision making in ecosystem service assessment, research, management and monitoring. This was done by reviewing the properties and purposes of many other frameworks, and distilling from them a set of key components that could be incorporated into a single framework aiming to meet the multiple purposes relating to research and practice for the ecosystem approach.

The integrated framework aims to be relevant to decision making consistent with the ecosystem approach at a range of scales, from national-scale policy decisions to local-scale (catchment or sub-catchment) land management decisions. In this way it will help us to systematically work through the issues of applying an ecosystem approach, and to work together where necessary to identify and address gaps in knowledge.

The integrated framework has been presented to stakeholders in the Ecosystem Assessment Working Group www.hutton.ac.uk/eawg and we will continue to develop it with further feedback and testing. We will make the framework available on the James Hutton Institute website and there the latest modifications will always be available. We would also welcome discussion on any attempts to use this framework to assist in applying the ecosystem approach to land management decision making, or that consider how it aligns with other frameworks and processes.

For more information or to discuss using the framework, please contact ecosystemservices@hutton.ac.uk

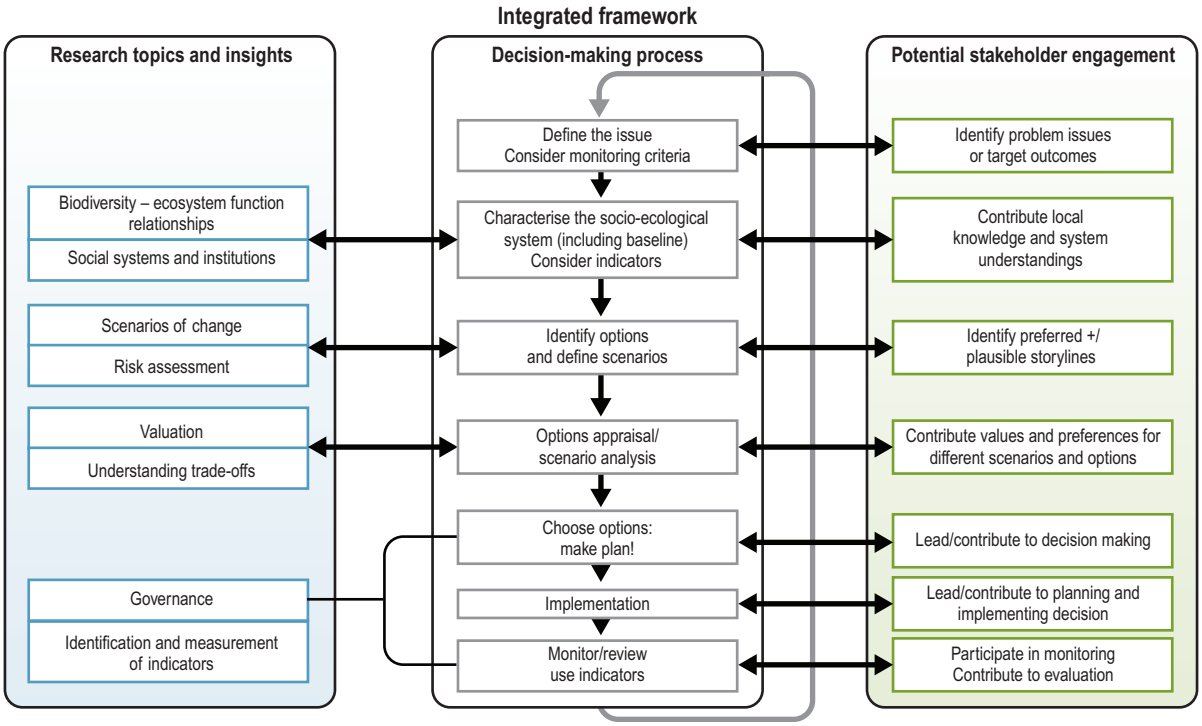


Figure 7 Development of an integrated framework to support the ecosystem approach.

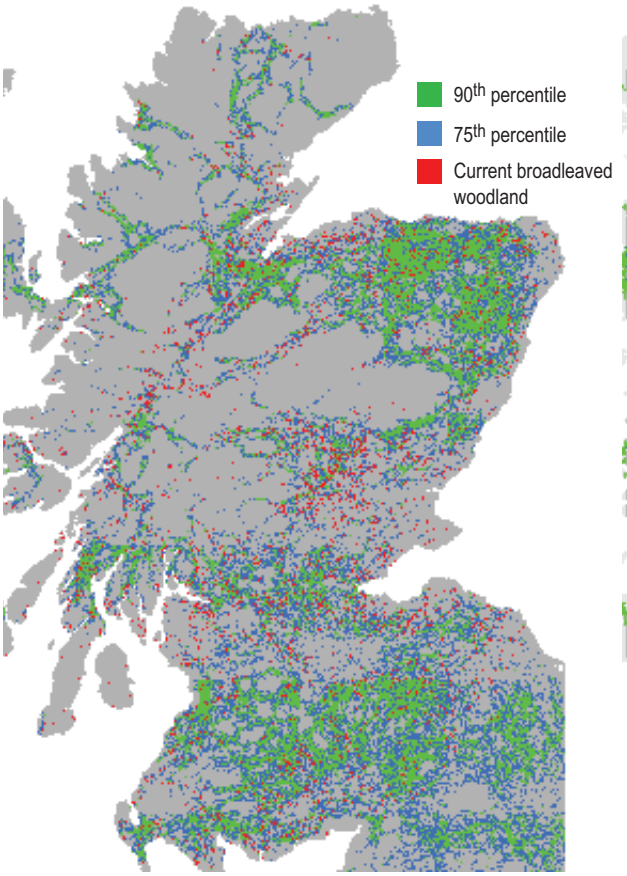
Modelling ecosystem service provision in a changing world

Mapping and modelling the spatial distribution of different ecosystem services is critical for the design and 'future-proofing' of multi-functional landscapes to ensure the delivery of such ecosystem services under predicted environmental and other changes. This allows design of land use strategies and incentives, for example, to encourage particular land use activity in specific parts of the landscape.

Ecosystem service provision from a specific element of natural capital can take a range of forms, for example, woodlands within the landscape provide services such as timber, biodiversity, habitat networks for woodland species to move around between different areas, recreation, shelter for livestock, etc. The 'optimal' location for provision of any one of these services can be mapped and these maps combined to identify which patterns of woodland within an area might deliver the 'most desirable' combination of ecosystem services.

Mapping/modelling of ecosystem services is increasingly being used as a strategic land management tool yet there are many uncertainties which need to be considered to assess the value of such an approach and the potential errors associated with its use for different purposes, for example, the relative value of the habitats and land uses being created versus those being replaced. Additionally, in the case of a habitat that takes many years to develop, such as woodland, a critical issue is the consideration of future changes that might impact on the service provision of a particular landscape. If we take their role as networks allowing the movement of woodland species, for example, the left-hand side diagram in Figure 8 indicates potential pathways that would allow movements of woodland species between different woodland habitat patches (using circuit theory). The 90th percentile indicates the areas in which there is the highest potential for movement within the landscape. The right-hand side diagram shows the areas that would be most impacted by a predicted improvement

Landscape permeability to forest species
Present-day connectivity potential



Potential loss due to agricultural intensification
2050s projection – Climate and Land Use Change

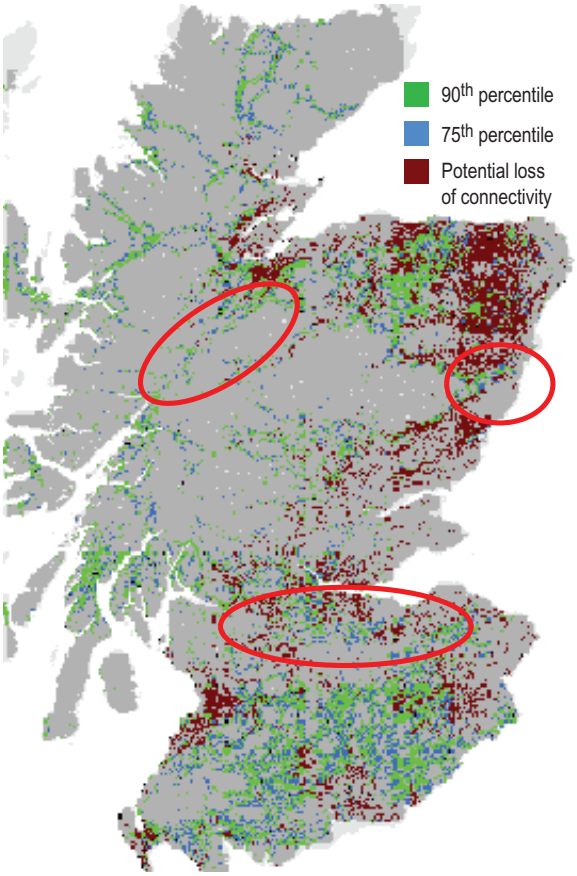


Figure 8 Designing habitat networks under changing environmental conditions: predicted increases in the area of prime agricultural land under future climate and land use scenarios could conflict with the creation of woodland networks, making species movements (e.g. in response to temperature increases) much more difficult.

in land capability for agriculture under future climatic conditions (2050), assuming that farmers do take advantage of the predicted improvements and use the land for agriculture – the brown area indicates the areas which are predicted to become much less permeable to forest species movements under such predicted land use changes. As can be seen, the disruption to north-south movements, for example, could lead to some species being unable to shift their range northwards under changing climatic conditions.

This research is an important component for identifying areas of woodland expansion to meet the 25% targets set by the Scottish Government. It indicates the potential for this approach to improve targeted land use policy in general. This approach can also be used to target economic incentivisation; linked research examining attitudes of land managers to landscape scale incentives in relation to habitat networks is also on-going in the Institute.

Valuation and policy instruments for protecting ecosystem services

Payment for Ecosystem Services (PES) is a policy instrument to promote the sustainable management of natural capital that is growing in popularity. It represents a reward mechanism for ecosystem managers to maintain or improve provision of services valued by beneficiaries. Implementation of a PES system requires the ability to:

- Quantify stocks and flows of 'benefits' from 'nature'
- Understand how these are influenced by other systems/processes
- Understand how land management affects these processes, the stocks and flows of 'benefits' and the identification of beneficiaries
- Understand land managers' and beneficiaries' motives/barriers
- Integrate and incorporate this information to improve governance and decision making, through to implementation.

PES schemes are considered to have a number of benefits over other policy instruments for conservation, such as the widely used 'command and control' types of measures, e.g., they are generally more flexible and more easily applied, and they allow better targeting of specific areas/ecosystems for their service provision. However, there are also concerns about their efficacy and possible negative effects on people's perception of nature. Existing comprehensive reviews of this policy instrument are mostly theoretical and/or qualitative.

Learning from experiences to date is a powerful way to guide the development of PES schemes and their implementation elsewhere, e.g., through increasing our understanding of key features of different PES mechanisms, and identifying information needs for policy design and implementation in different systems. Latin America has more than 20 years' experience of implementing PES, especially for water services; Martin-Ortega et al. (2012) have made a comprehensive and quantitative compilation of Payments for Water Services (PWS) cases in Latin America and used this to design a new, evidence-based conceptual model to aid wider

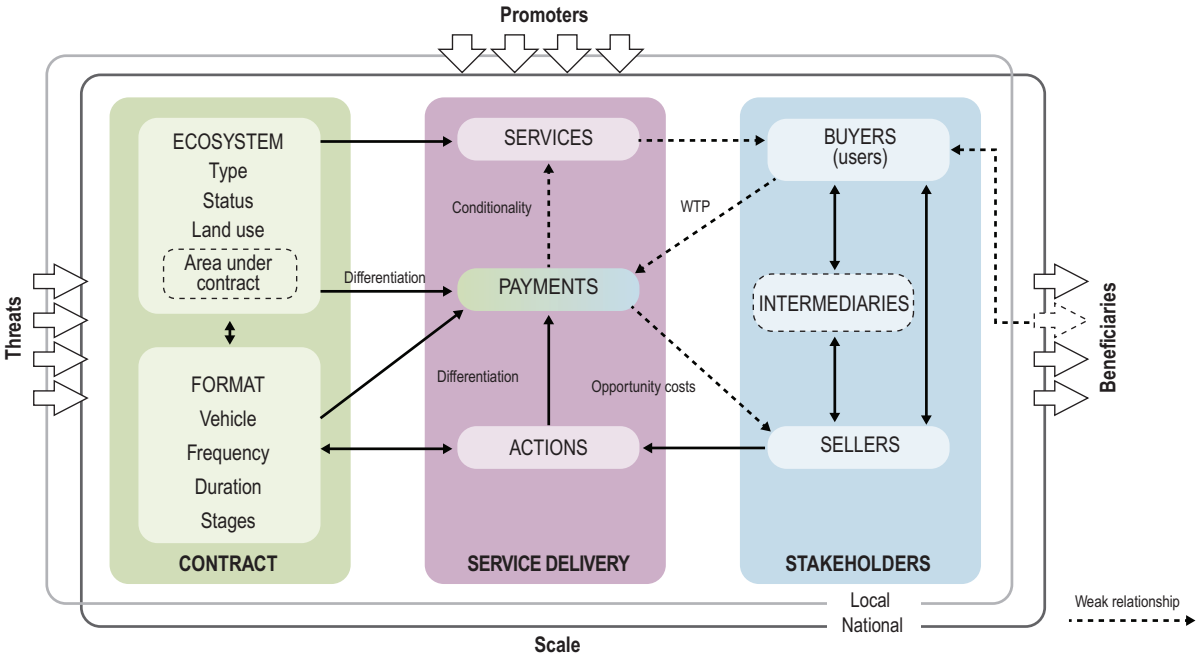


Figure 9 Evidence-based conceptual model of water PES schemes, based on the Latin American experience.

application of PES/PWS across the globe (Figure 9).

Some key issues illustrated in Figure 9 are as follows.

On the left-hand side, threats to ecosystem services are often poorly understood (in Latin America the main threat to water services is from deforestation). The green box indicates the 'contract', i.e., the definition of the ecosystem to be protected and the choice of format (payment amount, duration etc.) for the PES scheme. Notable points here are that the geographical area of any PES contract is often not reported, therefore it is hard to analyse how different payments compare (e.g., value per area). Service delivery (the pink box), requires definition of the actual service to be paid for (generally a poorly defined bundle of services, not just the target service, as many services are intimately interlinked), the payment and required actions to be taken. Payments were found to be based almost wholly on inputs (actions), not outputs (actual service delivery), which gives an undesirable disconnect from the desired outcome. It is generally easier to administer payment for a specific action than to wait for a desired outcome (or not), so this is not easy to solve. The blue box represents the stakeholders – the 'buyers' (e.g., water companies) and the sellers (e.g., farmers) of the ecosystem service, together with the intermediaries (e.g., Non-governmental organizations). It was also notable that the beneficiaries (right-hand side of diagram) often were much wider than just the 'buyers'; for example some PES schemes contributed to global carbon sequestration, not just improvement of local water services.

The findings of this research highlight the following important points

- PES is not a silver bullet but a tool that needs to be tailored to different situations where ecosystems need better management.
- The tailoring process needs a clear understanding of each of the components highlighted by the conceptual model.
- There are three crucial elements to this process which are critical to understand, as indicated by the conceptual model:
  - Action-service conditionality (i.e., we need to understand whether/how action X leads to service Y)
  - Good definition of the ecosystem services (what are people really paying for?)
  - The level of payment which accords with the sellers' opportunity cost and the buyers' willingness to pay.

The next steps will be statistical analysis of the factors influencing the key components of the PES, to better understand their impacts at each stage of the process.

Enhancing Crop Productivity and Utilisation

Professor Derek Stewart, Theme Leader

Unlocking the genetic potential that naturally exists within the plant kingdom to produce humankind's next generation of crops

In global terms, we are currently going through a remarkable period of change with multiple, diverse factors impacting on our way of life.

- Financial stringency and austerity
- A global population set to be more than nine billion by 2050 (approximately 30% increase)
- An age demographic shift in the developed world; e.g., by 2025 18% of the population in Europe is expected to be over 65 years of age
- Climate change and the requirement for sustainable water and nutrient use.

Primary crop development, production and subsequent utilisation are either impacted upon or affected by these factors. Consequently, we need to produce more food and more efficiently. Furthermore the food must reach the consumer in a high-quality state that delivers optimum nutritive value and health benefits. All of these are targets of the theme's research portfolio.

In addition, it is well reported that research is a prerequisite to sustainable economic stability and growth. Indeed the research of the Enhancing Crop Productivity and Utilisation theme chimes with the recent EU's growth strategy for the coming decade of facilitating the delivery of smart, sustainable and inclusive growth. The international level research required to deliver on all these fronts encompasses fundamental-through-to-strategic and has involved collaboration with many world leading groups as well as significant industrial collaboration.

Potato continues to be a key global food crop and is now recognised as the third most important. A milestone was achieved for potato in 2011 with the publication of the potato genome by 26 research institutes that came together from around the globe to form the Potato Genome Sequencing Consortium, led in the United Kingdom by the James Hutton Institute's Glenn Bryan. A more detailed description of this landmark event is outlined below.

Potato is also a key crop in the research funded by the Scottish Government's Rural and Environment Science and Analytical Services Division (RESAS) and part of this deals with the effects of abiotic stress on tuber development. Tuberisation in potato is particularly sensitive to elevated temperature with major effects both on yield and tuber size distribution observed in warmer seasons and it is predicted to be an increasing problem as our climate changes. Preliminary research has identified some of the effects of elevated temperature on the transcriptome and metabolome of potato. Clear effects on the tuber signalling network have

also been identified while the impact of elevated temperatures on photosynthesis, carbon partitioning and respiration has been determined. Considerable progress has been made in developing smart screens that will enable populations of potato to be screened for alleles that may confer tolerance to different aspects of abiotic stress thereby ensuring that we have to tools to ensure that the potato industry has a secure future.

Aligned with this, routes to reducing waste in the potato industry by controlling sprouting are being sought. As part of the Defra Arable LINK project 'Reducing energy usage and wastage by improving ethylene control of potato sprouting', significant progress has been made using a quantitative trait loci (QTL) approach which has identified several candidate genes that are currently being assessed. This has been possible via exploitation of the nascent potato genome and recently developed genomic tools available for potato such as high density SNP genotyping capacity facilitating QTL analysis in tetraploids (being developed by Biomathematics and Statistics Scotland (BioSS)) and potato microarrays based on all the transcripts identified in the potato genome.

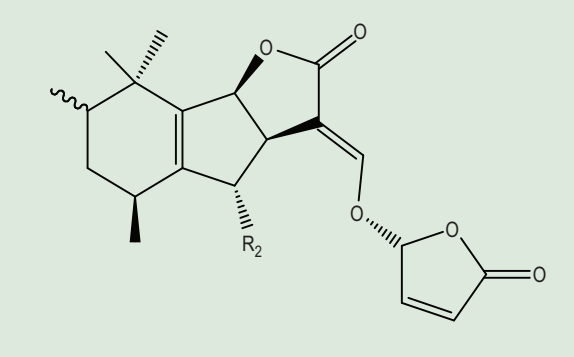


Figure 10 A generic strigolactone; a new group of plant hormones implicated in, amongst other activities, the suppression of lateral shoot branching. R1 – H, CH3; R2 - H, OH, OCOCH3; R3 - H, OH, OCOCH3; R4 - H, O, OH.

Figure 11 Phenotype of *StCCD8*-RNAi (line 1) potato tubers. (a), (b) Formation of new tubers directly from mother tubers. (c) Control Desiree mature tubers. (d) *StCCD8*-RNAi mature tubers showing outgrowth of lateral buds (present in fully underground tubers) and premature shoot emergence from the apical buds, encountered in light exposed tubers.

Tuber development is a key process and the ability to control and exploit this could impact significantly on all aspects of the crop: economy, yield, quality, etc. As part of EU FP7 METAPRO (http://isoprenoid.com) there has been a major breakthrough regarding elucidation of the role of strigolactones in the potato tuber life-cycle and, by silencing the gene responsible for strigolactone biosynthesis (Figure 10), one group have observed dramatic effects on tuber development. These include a loss of apical dominance with consequential impacts on sprouting, tuber formation and dormancy.

The ubiquity of potato as a food crop means that it is an excellent vehicle for the delivery and enhancement of nutrition and health benefits. This is being exploited, again via EU FP7 METAPRO (www.hutton.ac.uk/metapro), with regard to increasing total and specific carotenoid content. On going research is centred around manipulation of genes in the carotenoid biosynthetic pathway, specifically crtW (β-carotene 4,4'-oxygenase) and crtZ (β-carotene hydroxylase). An alternative approach being pursued is that of inhibiting carotenoid catabolism (breakdown). RNAi-driven down-regulation of the plastoglobule-targeted enzyme encoded by the carotenoid cleavage dioxygenase gene CCD4 produced a fivefold increase in total carotenoids and a tenfold specific increase in lutein, a carotenoid required to reduce the risk of incidence of age-related macular degeneration, the most common cause of vision loss in those aged over 50 years of age.

Nutrient use efficiency (NUE) is a hot topic at the moment with the push to grow more with less (inputs) a major research focus in most crops. As part of EU FP7 NUE Crops, nitrogen and phosphorus use efficiency has been studied in winter barley (as a wheat model) and potato, respectively.

An association genetics approach has been taken for barley and applied to pan European trials of 150 two and six-rowed European winter barley varieties grown at three levels of nitrogen supply (0, 120 and 180kg/ha) over several seasons (Figure 12). A broad range of agronomic and phenotypic assessments are being determined to assess differential varietal responses to nitrogen supply and hence determine the prospects for combining improved resource use efficiency with high yield. This is now being extended to wheat to test the transferability and utilisation of genomic information from barley to wheat on the genomic regions and candidate genes that influence nitrogen use efficiency in these closely related cereals.

For potato the target within NUE Crops is P-fertiliser use efficiency (PUE) since potato receives a disproportionately

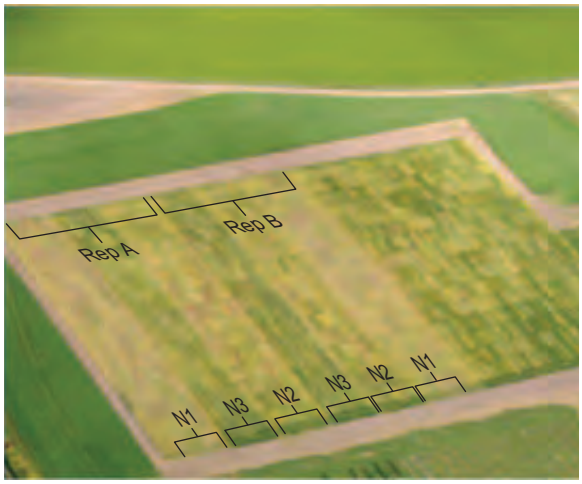


Figure 12 Aerial view of an Institute trial of winter barley varieties grown under contrasting nitrogen regimes with N1, N2 and N3 representing 0, 120 and 180 kg/ha applied respectively.

large amount of P-fertiliser compared to other field crops. Considerable genetic variation was observed in PUE among potato genotypes and, by exploiting a genetic mapping population, preliminary observations suggest that PUE is largely determined by P uptake efficiency and that this, in turn, is related to early season vigour and the development of an extensive root system.

Barley, like potato, is the subject of intense genome analysis. However, the barley genome is much larger (approximately seven times the size of the potato genome) such that one chromosome is the size of all 12 potato chromosomes put together. It is also complicated by highly repetitive DNA sequences that make the determination of a linear and complete DNA sequence very difficult indeed, and probably not possible using the approaches currently used to sequence the genomes of most organisms. To overcome this difficulty, and under the auspices of EU FP7 Triticeae Genome project (www.triticeaegenome.eu), our scientists used a combination of next generation survey sequencing of individual flow sorted barley chromosome arms, hybridising the same chromosome arm DNAs to microarrays that contain the majority of barley genes, and then using conservation of synteny between grass genomes to develop a 'virtual barley genome' that contained more than 85% of all barley genes in a putative linear order. This work, published in the journal The Plant Cell, is enabling gene discovery throughout the international grass research community.

Recognition of this scientific excellence in cereals is reflected in the continuing accrual of competitive, high visibility research projects. David Marshall leads the development of databasing, visualization and analysis tools within the Seeds of Discovery Initiative led by the International Maize and Wheat Improvement Centre (CIMMYT). The project aims to use Genotyping-by-Sequencing (GBS) technology to characterise 25,000 maize landraces with a view to identifying the genetic potential for contributing to global breeding programmes.

Furthermore, the year end was accompanied by the announcement of a major BBSRC barley project led by Robbie Waugh, and in collaboration with The Genome Analysis Centre in Norwich and the European Bioinformatics Institute, to co-ordinate international efforts to transform genomic information into a platform to understand barley genetic traits at a higher resolution and, ultimately, to isolate (and exploit) the genes responsible.

Soft fruit remains central to a noteworthy proportion of our translatory research and one within which the research goes beyond product and into the domain of human health. In comparison to potato and barley, soft fruit is a smaller crop but still economically significant. For example, in the UK berries represent 19% of all fruit sold with approximately a third of consumers purchasing raspberries with an estimated retail value of £125.7 million. Consequently a significant level of effort has been put into developing modern molecular technologies and genomic resources to maintain and expand the James Hutton Institute's international reputation and success with these crops.

The focus of this effort has been on melding these molecular genomics advances with the hugely successful breeding programmes. Targets for this approach have been the key economic traits of fruit quality, pest and disease resistance and more recently health beneficial compounds. Indeed, linkage maps with markers along all seven chromosomes have been developed in raspberry and the chromosomal locations responsible for a number of important traits have been identified. Aligned with this, research into the impact of the environment on the phenotype has shown that, for colour (anthocyanins) at least, high heritability is evident meaning that this trait is amenable to improvement via the use of markers and breeding.

A combined genetic, chemoanalytical and sensory approach has suggested that the level of sugars in the raspberry fruit is more important in determining taste than the type and amount of acids and that three or four volatile agents were key contributors to taste perception. Fruit softness, a trait important for both the fresh fruit (mouth feel) and industrial (processing) markets and a contributor in both markets to fruit spoilage and waste, was also studied as part of a Defra Horticulture LINK grant (Figure 13). Using the Glen Moy x Latham mapping population quantitative trait loci mapping analysis assigned fruit firmness to the Rubus linkage map, and

Figure 13 Laboratory-based analysis of fruit firmness.

QTLs were located on linkage groups LG1, LG3 and LG5. Aligned 454 next generation studies also identified 16 fruit firmness genes which were found to map across all seven Rubus linkage groups. Several candidate genes, including those implicated in cell wall metabolism, and regulation of turgor pressure are significantly associated with the traits of breeder's firmness score and fruit mass.

Success in the soft fruit arena has been built upon by expansion into the newer areas of blueberry and fresh market fruit. For blueberry this is in the early stages with the development of a mapping population developed from two key US blueberry cultivars segregating for a number of important phenotypic traits. The mapping population is being assessed for a portfolio of quality and phenotypic traits, as are a range of currently available cultivars over different seasons, with further data available from the same mapping population planted across the US as part of the USDA Speciality Crop Research Initiative. Once the linkage map has been developed QTL mapping of data from the key traits assessed will be undertaken.

A focused approach to the fresh fruit market in Europe is being addressed via the new FP7 collaborative project EUBerry (http://www.euberry.univpm.it/), which is a consortium of 14 partners from across Europe (Figure 14). As part of this our Institute aims to further develop molecular breeding strategies for both Rubus and Ribes and to use these strategies to identify superior germplasm across the genetic base held by the various partners. In raspberry, an association mapping approach has led to the development of a number of small mapping populations, to identify markers linked to physical fruit quality traits. The utility of these markers will be examined on germplasm from other partner organisations. In Ribes, existing markers for gall mite resistance have been used to identify resistant germplasm from partners in Poland, and newly-developed SNP markers will be deployed for the further evaluation of diverse germplasm for fruit quality and developmental traits. Furthermore, the James Hutton Institute will oversee and lead the research into fruit quality determination including the impact of pre- and post-harvest processes and the validation of human health benefits.

The relevance of fruit consumption continues to be validated with the ellagitannin components recently demonstrated to effectively inhibit α-amylase activity, a human digestive enzyme crucial to starch digestion and glycaemic control. These components were able to replace (or reduce the dose required for) inhibition of amylase by pharmaceutical agents. Furthermore it was also shown that berry polyphenols exhibited anti-genotoxic activity in radiation protection assays in cancer cell lines while the protective effect of raspberry polyphenols towards colon cancer has also been demonstrated. The sources of these health beneficial effects are being elucidated, characterised and validated as traits for targeting in the associated breeding programmes.

Decoding the potato genome

The year 2011 was a momentous year for anyone interested in potato and the future of breeding one

Figure 14 The EUBerry Consortium at the inaugural meeting, Brussels, September 2011.

of the world's most important vegetable crops. In July, an international team of scientists – the UK team being led by researchers at the James Hutton Institute – published their work on the sequencing of the genome of the potato in the journal Nature. This highly significant advance was the culmination of several years of work by the Potato Genome Sequencing Consortium (PGSC) representing 14 different countries. The PGSC came into being towards the end of 2004, although it took a few years for the various countries to obtain the required funding.

Initially the target genotype for sequencing was a heterozygous diploid known as 'RH' with each partner country sequencing one or more of the 12 potato chromosomes. However, uneven and slow progress was made with the different chromosomes, and the high degree of heterozygosity in RH were major barriers to progress. In 2008 a new strategy was adopted – to sequence a fully homozygous genotype 'DM'. DM is unusual in being a 'doubled monoploid' *Solanum tuberosum* Group Phureja clone. Richard Veilleux in the USA had previously generated several haploid potato clones by anther culture and some of these had been doubled to yield homozygous diploids. The homozygous nature of DM made the task of sequencing and assembling the genome much easier.

A further development in 2008 was the sharp drop in the cost of use of 'NextGen' sequencing technologies. It was decided to use a range of different sequencing technology platforms to decipher the DM genome. This activity was led by partners in China at the Beijing Genomics Institute (BGI) who did most of the 'Illumina' (short read) sequencing, with the '454' (long read) sequencing being carried out in Europe and co-ordinated by the James Hutton Institute team.

The sequence data were assembled at BGI, who also led the 'annotation' process, by which approximately 39,000 genes, the coding regions of the genome, were identified. Our team has been responsible for leading the linking of the genome sequence assembly to the genetic and physical maps of potato. This is a hugely important aspect of the genome analysis as it allows the placing of the genome 'scaffolds' into their chromosomal locations.

We have been able to genetically anchor approximately 90% of the potato genome to its corresponding location, and this has also led to the development of a new genetic map as well as several thousand new genetic markers for use in potato genetics and breeding. This is an important step in using the genome sequence in potato improvement and allows scientists and breeders to compare the genome sequence with the locations of important 'traits' in the genome. This is a major advance in identifying the actual genes which play causative roles in important traits, such as tuber shape, tuber dormancy, disease resistance and earliness –all of which are extremely important to the potato industry.

Delivering Sustainable Production Systems

Dr Paul Hallett, Theme Leader

Achieving higher yielding and lower input crop production and livestock systems

Our agricultural science has already delivered production systems and crop varieties that need fewer resources and protect the environment. The monumental challenge we now face as scientists is to push the boundaries even further – countering the impacts of rising input costs, diminishing natural resources, climate change and a growing global population.

The inaugural year of the James Hutton Institute demonstrated that bringing together the lowland arable and the upland grazing expertise of the legacy organisations could better address contemporary issues facing the sustainable intensification of farming. The first publication under the James Hutton Institute banner involving both sites identified links between compounds pumped into soil by crop roots and accelerated rates of carbon turnover. The first cross-site research award was realised because economists in Aberdeen worked with soil scientists at both sites to perform a cost–benefit analysis of mitigating soil compaction. One of our flagship field experiments, the Centre for Sustainable Cropping, provided a focal point to develop new research activities with scientists from the Managing Catchments and Coasts theme investigating interactions between in-field farm management and off-site impacts to water quality. In addition our experimental farms and research stations at Balruddery (arable), Glensaugh (upland grazing) and Hartwood (lowland mixed) provide platforms to take our laboratory-based science into the field to develop and demonstrate practical solutions for modern farming.

Within an agricultural production system a myriad of processes underlie productivity, environmental impact, resource consumption and long-term sustainability. We have amongst the greatest breadth of expertise internationally to study a range of these processes, how they interact and how they are influenced by farming practices. Our work tackles the following broad topics:

- Environmental impact of farming systems
- Enhancing farmland biodiversity to decrease inputs
- Assessing the efficiency of grazing systems
- Increasing the capacity of crops to capture resources and tolerate stresses
- Improving soil conditions for plant growth
- Health implications of contaminants in the agricultural supply chain
- Economics and social impacts of sustainable practices.

New projects that commenced in 2011 linked our researchers with leading groups internationally. A notable example is PURE (pesticide use-and-risk reduction in European farming systems with integrated pest management), the largest EU FP7 project in agriculture ever funded. In PURE we are leading research on the role of ecological engineering in integrated pest and disease management. Much of our research taps into the hidden half of plants, the roots in soil. Defra-BBSRC-LINK funding is identifying wheat root ideotypes that perform well in reduced input agricultural systems. Favourable root systems will be able to penetrate compacted soils and form better associations with beneficial soil organisms such as arbuscular mycorrhizae fungi. Research bursaries from the Nuffield Foundation, Rank Prize Fund and British Mycological Society allowed several undergraduates to investigate how plants interact with the environment, providing positive benefits to our science and the training of the next generation of scientists.

Some of our externally funded research addresses immediate practical issues that could decrease the environmental footprint of UK farming. With ADAS and a range of industrial partners, a Defra LINK and Scottish Government-funded project is examining new technologies to minimise the run-off of nutrients along tramlines. Our on going specialist diagnostic service, which identifies soil nematode species in farmers' fields, received funding to develop a new approach using state-of-the-art molecular biology tools. Quality indicators to assess the sustainability of soils, farmland biodiversity and resource use are under development, with an intention to link with the food industry to enable a roll-out to assess their producers' farming practices. Rapid, in-field methods to assess properties of soils, such as the use of infrared spectroscopy or the use of artificial intelligence linked to the National Soils Inventory of Scotland, are new technologies under development.

A new research programme funded by the Scottish Government also commenced in 2011. A directed work package on sustainable agriculture in the 2006–2011 programme was replaced by several new work packages that tackle a broader range of farming systems and adopt a variety of approaches to assess sustainability. Interactions of agricultural production systems on wider ecosystems, such as the influence on biodiversity, erosion and water movement, or greenhouse gas emissions are being studied. There is dedicated research focusing on the more sensitive farming regions of Scotland, such as the Machair in the Outer Hebrides.

Livestock production, particularly greenhouse gas emissions and the sustainability of grazing systems, is an active research area that we want to strengthen in coming years. Our expertise in dietary intake, digestibility and plant species composition will be applied to delivering more efficient systems. We are also examining the transmission of pollutants, particularly endocrine disrupting compounds (EDCs), to livestock and their impact on health, welfare and reproduction. One route for EDCs into the environment is through the application of waste to land. A long-standing sewage sludge trial at our Hartwood Research Station is one of several field resources used for this research. Sewage sludge is applied to land to provide nutrients to crops and has secondary benefits to soil quality. Bulky organic fertilisers, such as composts and anaerobic digestates, are other nutrient sources that we are investigating to off-set reliance on mined and manufactured fertilisers in agriculture. Beneficial impacts of these amendments to soil structure and increased carbon storage are being studied along with the risks of heavy metals and other pollutants being transmitted through the food chain or adversely impacting soil biological communities.

One of the greatest challenges agriculture faces in Scotland and globally is the supply of nutrients and their uptake by crops. A dedicated team investigates how roots capture nutrients from soil, including compounds that are either locked up on soil minerals or are transformed by soil microbes into plant accessible forms. The James Institute has brought together soil chemistry and plant science expertise, so we have a great capability to understand how enzymes and other compounds produced by roots influence nutrient flows. There are a range of outcomes envisaged for this research including crop varieties that inhibit nitrogen leaching or capture large reserves of phosphorus that are in soils but not in an accessible form.

As this research demonstrates, nutrient use efficiency in agricultural systems extends beyond crops to the wider environment. To provide an in-depth and holistic understanding, we study the proliferation of roots in soil, losses of nutrients before they can be captured by crops and the functional role of soil microbes and other organisms in nutrient cycling. Water use efficiency and the tolerance of crops to stresses from waterlogging, drought and root growth in strong soils are also addressed by examining both the plant and the environment. Good soil management is essential for a sustainable agricultural system since it should decrease environmental stresses experienced by crops and livestock, improve the storage, capture and delivery of water and nutrients, and decrease the environmental impact of farming.

Alongside a management of soil is the optimisation of crop rotations and wider farming systems to decrease required inputs and their losses. Our agroecologists specialise in the impact of agricultural systems on farmland biodiversity and the wider implications to crop productivity. Beneficial

plant assemblages and the trophic interactions between above- and below-ground organisms are key areas of study. Moreover, we are learning from nature to assess plant traits and agricultural systems that could improve the sustainability of production. The properties of natural seed coatings that capture water and impact soils, for instance, could help develop new technologies to improve crop establishment.

In this short article it has only been possible to present a snapshot of our research capability. By bridging crop, livestock, environmental and social sciences, we have the ability at one Institute to have a major impact on future agricultural production systems. The research extends far beyond the borders of Scotland with projects underway across Europe and the globe. We are active partners in numerous international advisory boards and steering groups such as the International Atomic Energy Agency and Food and Agricultural Organization for research on crop nutrition, International Council on Plant Nutrition, European Food Safety Authority (Environmental Risk Assessment Guidelines), and the World Trade Organisation (GM dispute). To help build specific disciplines necessary to deliver sustainable production systems our scientists take an active role in scientific societies. The James Hutton Institute staff includes the current President of the British Society of Soil Science, Helaina Black and several council members, the Secretary General (Elect) of the International Soil Tillage Research Organisation, Blair McKenzie, and many others with important roles. We also actively host international scientific conferences including in 2011 'Agricultural Ecology Research: its role in delivering sustainable farm systems' and in 2012 'Roots to the Future'.

The roots of agricultural sustainability

As the James Hutton Institute is hosting over 300 scientists at the 'Roots to the Future' conference in June 2012, this focus section is dedicated to our strong programme of research on plant roots. Buried in soil, out of sight and difficult to measure, plant roots have been the subject of much less research than stems and leaves. For plant productivity, roots are the conduits that capture water and other resources from soil. Roots also fuel microbial activity that is vital to cycles of nutrient movement and transformations in soil, hold plants up, physically stabilise soils and input considerable volumes of fresh organic matter. Near their surface roots harbour one of the most diverse and abundant biological communities on earth. Great scope therefore exists to improve root systems and their interaction with soil to increase yield and improve the sustainability of farming. Their understanding is vital to the next green revolution in agriculture.

Our approaches, which are at the cutting edge of root phenomics and metabolomics, allow for hitherto enigmatic questions about plant root behaviour to be answered.

- Advanced analytical and modelling techniques to measure the behaviour of chemicals vital to plant productivity
- Isotopic techniques to trace exchanges of compounds between roots, soil and biological communities
- Rapid molecular biology methods that target specific processes such as nitrogen cycling
- Visualization approaches of roots in situ including microscopy, X-Ray, computed tomography (CT) imaging, rhizotrons and gel based systems. We are also developing sensors to rapidly measure root properties non-destructively in the field and a novel 'invisible' soil to enable use of advanced imaging techniques
- Screening approaches to assess the responses of roots to stresses such as compaction, waterlogging or drought
- Field screening of cultivar performance under different physical constraints, soil management practices or the presence of biopores
- A number of approaches to quantify the physical stabilisation of soil by root reinforcement and exudates
- Advanced numerical models of root growth, resource capture and competition between plants
- A wide range of crop varieties and mutants with different root structures, such as branching patterns, the presence of root hairs, aerenchyma formation and lignin composition.

Excavating plant roots in the field is a laborious process, but it is essential for quantifying how they interact with soil (Figure 15). We complement open field research examining the behaviour of different crop

Figure 15 Excavating potato roots in the field to compare traits of different cultivars.

lines with studies in polytunnels and glasshouses where experimental treatments can be controlled better. This research has unravelled relationships between root properties and drought tolerance between potato varieties (Figure 16), leading the way to select crop traits that are highly significant for sustainable agriculture.

To enable visualization of root-soil interactions a number of tools have been developed. X-Ray CT imaging allows us to measure contact between roots and soil, and the response of root growth to soil compaction (Figure 17). Although the resolution of X-Ray CT has improved significantly in recent years, capture rates are slow and a detailed characterisation of root properties is not possible. Confocal microscopy has provided new insight into the production of border cells and cell growth. Other optical imaging approaches used in combination with a transparent media that simulates the structure of soil allows for the rapid, non-destructive capture of root growth in three dimensions (Figure 18).

We use these data to understand root traits that improve plant productivity, resource use efficiency and the tolerance to stresses. They populate models of root growth and resource acquisition to unravel complicated processes that will eventually guide future plant breeding and agronomic practices.

The interaction between roots and the wider soil environment also receives considerable study. Easily degradable compounds exuded by roots, for instance, have been shown using isotopic techniques to enhance the microbial breakdown of less degradable forms of carbon that are in soil. A positive outcome of this research is that it helps explain nutrient release from soil to plant roots, but a negative outcome could be an off-setting of carbon sequestration by plants in soil, particularly in relation to deep-rooting. Root exudates also contain enzymes and other compounds that can improve phosphorus capture and decrease nitrogen leaching following nitrification. Our work in this area will help develop crops much less dependent on fertilisers.

The ultimate goal of the James Hutton Institute's research on Delivering Sustainable Production Systems is to decrease inputs, increase outputs and produce a smaller environmental footprint from farming. Our research ranging from practical, on-farm solutions to a detailed understanding of how plants and animals interact with their environment, has a good foundation to achieve this.

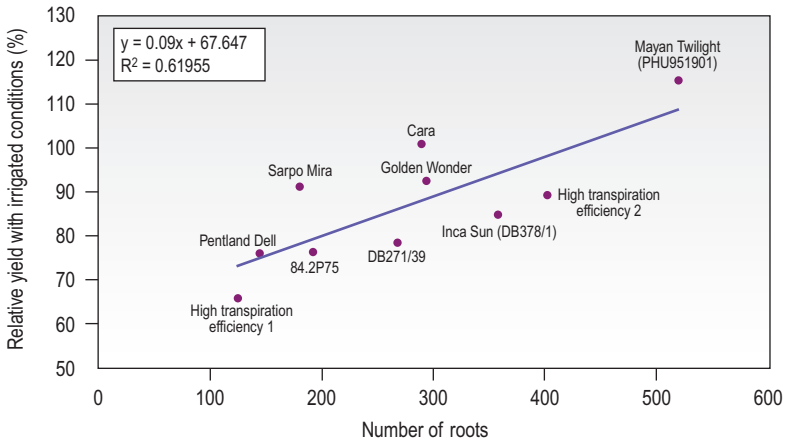


Figure 16 Quantification of direct links between the root properties of different potato varieties and drought tolerance.

Figure 17 A seedling growing in compacted soil. X-ray CT imaging in collaboration with the University of Abertay, Dundee.

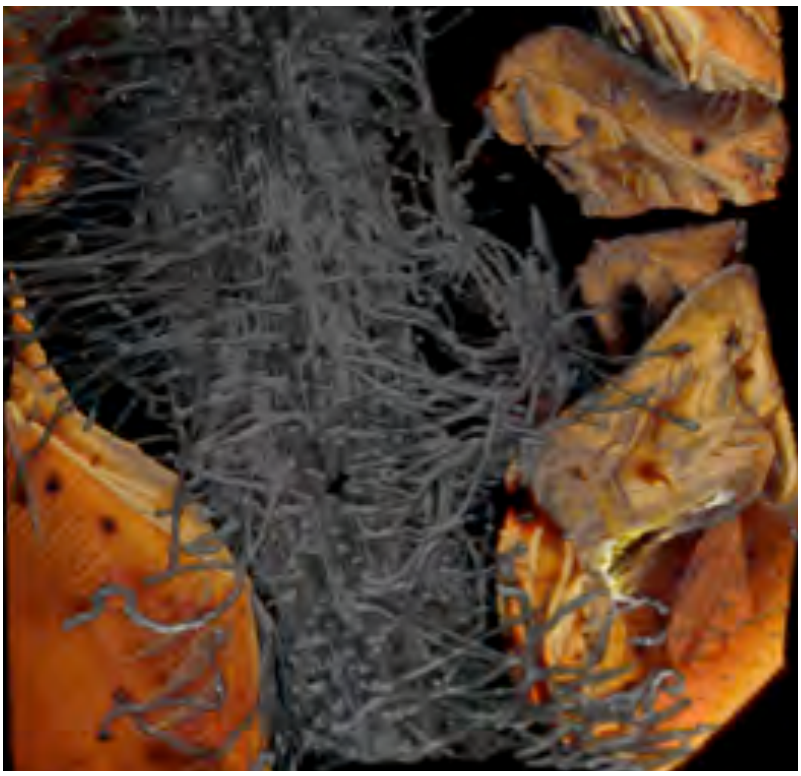


Figure 18 A lettuce root with abundant root hairs growing through ‘invisible soil’.

Controlling Weeds, Pests and Diseases

Professor Ian Toth, Theme Leader

Balancing food security and pesticide reduction

One billion people are undernourished worldwide. To meet projected global food requirements in 2050 the Food and Agriculture Organisation (FAO) of the United Nations estimates that food production will need to increase by 70% overall and by 100% in developing countries. A major constraint on achieving food production is crop loss due to pests and diseases, which accounts for as much as 40% of crop losses globally.

Within the EU, a desire for sustainable agriculture with reduced chemical inputs has led to the implementation of directives designed to increase the stringency of conditions for approval of chemicals for agriculture, limiting the current choice of effective pesticides. In many cases, no effective replacements for withdrawn pesticides are available and resistance against some pathogens is still lacking in many commercial crops. Current breeding strategies for improved crops, and the development of other integrated management practices, are often too slow to compensate for the withdrawal of pesticides.

Climate change and expanding global trade add further to these problems by increasing the risk of introducing new pests and diseases, which may destroy native plant species as well as crops, and/or exacerbating existing problems. Such factors may also affect the spread and survival of human and animal pathogens in the environment.

Therefore there is a pressing obligation on the scientific community to find new, durable and sustainable means to combat crop diseases, as well as limiting the spread of human and animal pathogens. Our major goals at the Institute are to increase food security and quality, and improve human health through sustainable crop production both within Scotland and globally, minimising pesticide inputs, improving disease resistance and other control measures, while minimising the spread of harmful pathogens to animals and humans – key aspects of our science strategy.

Within the theme Weeds, Pests and Diseases we have multi-disciplinary teams whose aims are to ensure the production of sustainable, safe and healthy food by (a) reducing the incidence of crop pests and diseases through sustainable crop production methods; and (b) reducing the spread of human and animal pathogens through the environment and the subsequent infection of their hosts. In addition, we are exploiting knowledge about the way that viruses infect plants to develop 'plant bioreactors' for production of pharmaceuticals and diagnostic tools for animal and human health.

We work on a range of crops: mainly potato, cereals and soft fruit, but also tomato, pepper, onion, broccoli, lettuce, spinach, trees, and heathland/woodland plants. We investigate economically important plant pests and pathogens, including but not exclusively: *Phytophthora infestans;* potato cyst nematodes (PCN); *Pectobacterium* and *Dickeya;* the aphid *Myzus persicae* (and other aphid species); fungi and viruses (mainly potato viruses Y and mop-top) on potato; *Rhynchosporium* on barley; *Pseudomonas* and *Burkholderia* on vegetables; aphids, *Phytophthora* and viruses of berry fruits; all of which are major problems globally. We investigate the role of plants (including fresh produce), soil, water and organic waste in the spread of human and animal pathogens, including the zoonotic pathogens *E. coli* and *Salmonella* species, as well as the role of wildlife/livestock in the distribution and spread of ticks and tick-borne diseases and methods for their control.

We undertake a wide range of research activities within the theme, in a pipeline from strategic science to more applied science and knowledge exchange with a wide variety of stakeholders including Scottish, UK and European policy groups, farming industry, commercial, public, science. The main areas of our science are described below.

Genomics: Within the theme, a key driver for our research is gene discovery and the exploitation of sequence data to elucidate gene function, which feeds through to practical solutions for disease control. This exploitation is only possible with the help of highly skilled computational biologists, who work closely with laboratory scientists.

Pest and pathogen populations: We study the movement of pests/pathogens in the environment and the diseases they cause (epidemiology), and the dynamics and evolution of pest/pathogen populations. The latter is partly achieved through molecular analyses (genotyping) allowing disease agents to be tracked and new strains, e.g., with increased virulence or pesticide resistance, to be identified and monitored. Quantitative diagnostic assays are designed and used for research, statutory and/or commercial testing purposes, particularly where new threats to crop production or human health are identified.

Understanding the movement and survival of human and animal pathogens in the environment is crucial if we are to reduce their impact and so a team has been set up to investigate this area of research in a Centre for Human and Animal Pathogens in the Environment.

Plant–pathogen interactions: One of our main collective strengths is the study of pest/pathogen–host interactions, researching proteins (effectors) that are produced by pests/pathogens to facilitate feeding-site formation and/or the suppression of host resistance (see the 'Dundee Effector Consortium' below). Through our understanding of the interaction between viruses and plants, we have also developed methods for using plants as bioreactors in the production of animal vaccines and proteins for animal disease diagnostics.

Resistance: Host and non-host resistance to pests and pathogens is a major part of our integrated pest and disease management (IPDM) strategy. An integrated approach is being used to identify new sources of durable host resistance, e.g., in the Commonwealth Potato Collection (CPC) and other germplasm such as soft fruit, based on the use of effectors and the development and use of molecular markers and the recently published potato genome sequence. In addition, we are investigating the use of elicitors, which promote natural defences in the plant, for direct application to crop plants. To ensure integration of effort and tools with research in other areas of potato biology as well as that of other solanaceous crops (e.g., pepper and tomato), we have formed a group dedicated to pooling resources in a Centre for Research on Potato and other Solanaceous plants.

Climate change: The climate plays a major part in how and when pests and pathogens interact with plants, soil and other ecological niches. We are, therefore, undertaking a range of activities to examine the possible long-term consequences of climate change on factors such as pest/pathogen populations, disease development, the long-term durability of disease resistance, as well as keeping a watching brief on new potential threats that might arise as a consequence of a changing climate.

Integrated pest and disease control: Integrated pest and disease management systems (including the regulation of pests by their natural enemies).

Dundee Effector Consortium

Plants face a constant barrage of microorganisms – bacteria, viruses, oomycetes and fungi (Figure 20), as well as pests above and below ground, that aim to strip them of their energy and resources. They possess a sophisticated immune system, with cell-surface receptors that are able to detect conserved molecules from pathogens and pests and trigger an array of effective defence measures. Pathogens

and pests deploy effector molecules to suppress these defences and, presumably, to manipulate host metabolism for nutritional benefit. A second layer of the plant immune system is composed of resistance proteins. These act as 'immune receptors' to specifically detect the presence of effectors, rapidly activating further defences. As a key area of science within the theme, we have formed a unique consortium of scientists at the James Hutton Institute and the University of Dundee to study the functions and evolution of effectors from diverse pathosystems, their targets within host plants, and the roles those targets play in plant immunity. A key aim is to exploit our knowledge of effector function and diversity to seek resistance genes that provide durable disease resistance. For more information visit: www.hutton.ac.uk/crps

Centre for Human and Animal Pathogens in the Environment

The Centre for Human and Animal Pathogens in the Environment (HAP-E) provides a hub for research into the transmission and survival of human and animal pathogens within the environment, by developing a strong scientific network aimed at being prepared and equipped for future public health challenges. HAP-E links with associated scientists from other Scottish Main Research Providers (MRPs), as well as collaborators in the UK and internationally.

Research within HAP-E covers a broad range of topics including modes of pathogen transmission; interactions of pathogens with organic matrices or plant hosts; and detection methods and risk analysis. Transmission of pathogens via ticks is the focus of research on insect vector-borne diseases, including Lyme disease (caused by Borrelia species). The research includes risk analysis on the vector communities and the impacts of climate change on those communities. Alternative transmission pathways are being investigated for other pathogens. Research into the survival and transport of *Escherichia coli* O157: H7 and Mycobacterium avium paratuberculosis aims to identify factors affecting bacterial adsorption onto environmental matrices (such as clay colloids and stream biofilms). It has led to international projects that address the impact of biogas digesters, which treat organic wastes, on changes in pathogen transmission. Enteric pathogens in the environment are also able to interact with alternative hosts such as plants where they can proliferate, and work in the centre focuses on aspects that enable E. coli O157:H7 and Salmonella enterica to colonise such hosts. The work extends to investigate plant defence responses that occur during bacterial–plant interactions, which may play an important part in survival and spread of these pathogens. Novel detection methods for multiple pathogens are also being developed to help track these pathogens and to help in risk assessment and outbreak control.

For more information visit: www.hutton.ac.uk/hape

Figure 19 The Dundee Effector Consortium studies the functions and evolution of effectors from diverse pathosystems.

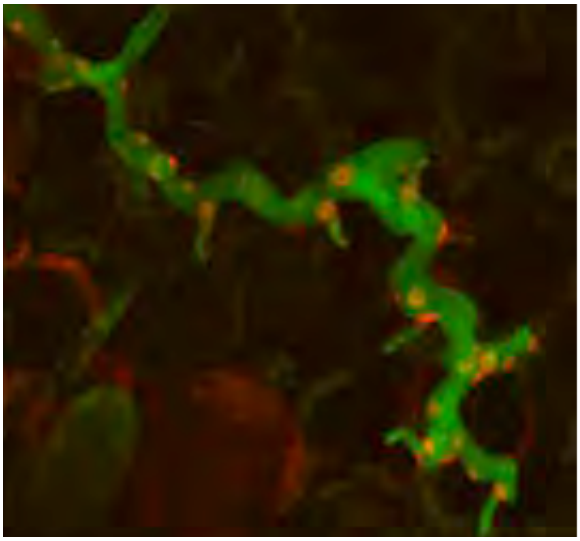


Figure 20 Effector protein AVR3a (labelled in red) localising at the site of haustoria on the hyphae of *Phytophthora infestans* (green).

Figure 21 Potato plant (*Solanum tuberosum*).

Knowledge exchange

Scientists within the theme produce a number of scientific outputs linking their science to our stakeholders including industry, governments and the wellbeing of people in Scotland and elsewhere. Below are some of our outputs and achievements in 2011.

- Major showcasing events for our research took place at events including Potatoes in Practice, Cereals in Practice, Fruit for the Future, Linking Environment and Farming (LEAF), Open Farm Sunday, Royal Highland Show, Crop Protection in Northern Britain, Crop Protection in Southern Britain, Dundee Flower and Food Festival and other science festivals. Some of our scientists visited the House of Lords and presented our work on climate change and plant disease.
- Major new grants were obtained to consolidate our funding from the Scottish Government and increase the reach of our science outcomes. This funding was from organisations including the Technology Strategy Board, BBSRC, Leverhulme, EU, Horticultural Development Company (HDC), Australian Research Council, Potato Council and industry. Many of these grants are in collaboration with Mylnefield Research Services Ltd which plays an important role in linking our research to industry.
- A number of grower and media publications have been produced together with stakeholder reports and publications. These include numerous reports on the completion of the potato genome and others such as the investigation into environmental factors and Johne's disease (caused by *Mycobacterium avium paratuberculosis*).
- Links to policy through presentations on our work to the CAMERAS (A Coordinated Agenda for Marine, Environment and Rural Affairs Science) group; information on the effects of climate change on pests and pathogens to the Scottish Government through the climateXchange centre of expertise, advice to the Food Standards Agency (FSA) on human pathogens on fresh produce. Some of our members joined the Cooperative of Zoonoses Expertise and Experience (CoZEE) as a main route to key research providers and stakeholders in this area.
- Members of the theme in 2011 were invited to participate in working groups and committees, including the European Food Safety Association (EFSA) to advise on pest and disease legislation in the EU; the Technology Strategy Board Biosciences Plant Sector Group and the review committee for the BBSRC/Hort, both of which ensure close liaison between science and industry through their funding; the UKSOL committee to represent the science community at the UK Plant Science Federation; and an EU study group on Lyme borreliosis research and awareness.

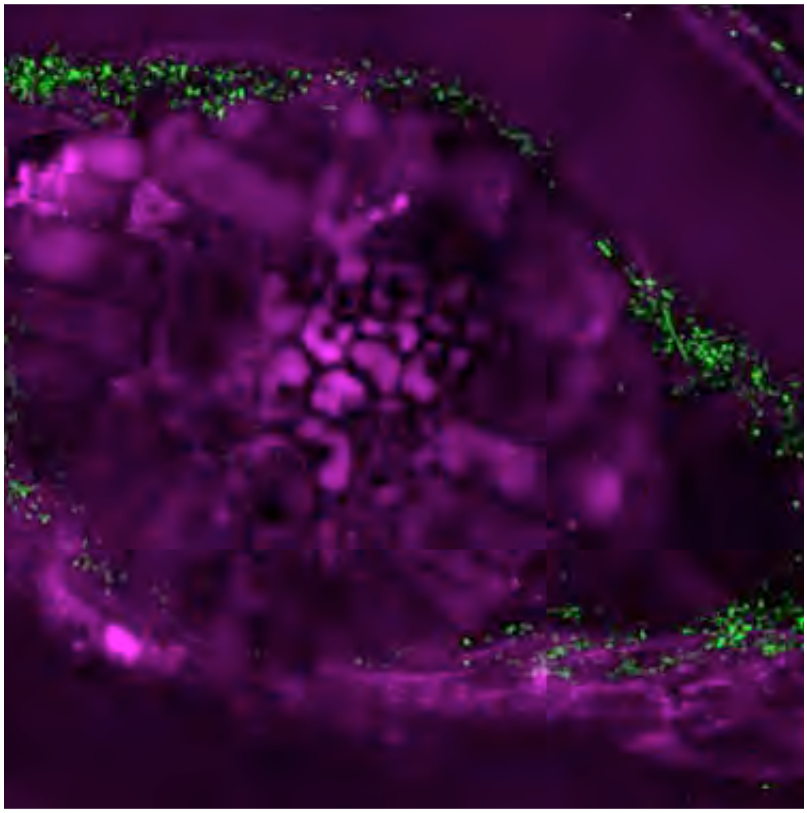


Figure 22 Human pathogenic *E. coli* colonising the roots of spinach plants.

Managing Catchments and Coasts

Dr Marc Stutter, Theme Leader

Providing the solutions when conflicting demands for water resources arise

The Managing Catchments and Coasts theme aims to deliver integrated water resources management using the ethos of 'thinking globally, acting locally'. The theme aims to support innovative scientific research underpinned by robust and extensive environmental information. From this we develop data interpretation tools, modelling approaches and visualization techniques that aid understanding and co-operation across a range of community and water management sectors, shaping effective policy at local, national and EU levels.

Effective catchment management requires an integrated approach to balancing the needs of many interests across scales from the headwaters to the estuarine and coastal environments.

The Managing Catchments and Coasts theme integrates expertise in soil, biogeochemical, hydrological, ecological sciences and socio-economics to manage the potentially conflicting demands for water across multiple spatial scales.

The impacts of land management on groundwater, surface and transitional waters influence a range of ecosystem services such as aquatic biodiversity, nutrient attenuation, safe provision of drinking waters and culture. In maintaining the necessary quantity and quality, water becomes a limiting factor in the provision of a range of other land-based services. Therefore, waters are at the interface of complicated interacting policies for the delivery of flood management, food production, urban development, forestry expansion, soil carbon management and renewable energy. Water provides an integrated signal of catchment pressures and transports contaminants, or flood peaks and their impacts downstream, often across regulatory borders. This necessitates multi-scale governance and co-ordination of management activities.

Our research is driven by a need for effective solutions to manage the complex interplay of pressures centred on the availability and security of water resources. In addition we aim to better link the natural and managed water cycles and take a holistic approach to water and its management. We seek to identify opportunities for multiple benefits for land, water and people that are cost effective and resilient to the future changes in climate, land use and policy. This is achieved by scientists working in partnership with regulators, policy makers, industry and communities.

This really is an exciting time for the science and management of our fundamental, shared asset of water. Momentum is building through 2012 by way of a series of flagship EU events, the World Water Forum, the EU Green Week focus on water, the 'Blueprint' for revised and coherent water policy and the EU Innovation Partnerships on Water and Sustainable Agriculture. These events demonstrate recognition of the importance of water for the environment, society and business at the highest level, and are set against the national profiling objectives of Scottish Government's HydroNation agenda. Understanding how to manage water resources in a sustainable and adaptive way is vital in our rapidly changing world. In the following sections we describe how our research activities are helping to establish this essential knowledge base.

Future scenarios in evaluating water resources and catchment impacts

The Managing Catchments and Coasts theme is working towards understanding the consequences of future strategies for managing freshwaters in the face of environmental change. Managing freshwater systems is challenging, even without planning for the effects of changes in climate, land use, air pollution and human driven resource demand. An evidence base of the effectiveness of different measures (such as the design of buffer strips; Figure 23) for mitigating diffuse pollution is underway which will be used to inform the analysis of various land management options that could be adopted to improve water quality in catchments.

Figure 23 Buffer strip in the Tarland sub-catchment, River Dee, Aberdeenshire.

Figure 24 illustrates the results from a scenario of climate and land use change simulations to predict stream water nitrate concentrations in the Tarland Burn of the River Dee, north east Scotland. A weather generator was used to create multiple possible representations of both historic and future climate taking into account the uncertainty in prediction of future climate. Baseline simulations (Figure 24A) were applied using a 30 year meteorological time-series representative of the period from 1961–1990, and with land use based on a typical 1980s cropping pattern. Simulations were then generated for the 2050s period, initially assuming no changes in land use or management (Figure 24B). A future land use change scenario based on ensuring food security was developed. This centred on the premise that any land that was capable of supporting arable agriculture was used for cropping. The results of this scenario applied to the 2050s period (Figure 24C) demonstrate that future land use changes could lead in some areas to more significant impacts on water quality than those resulting from climate change (note different scale on y axis). This work is contributing to an EU Framework 7 project REFRESH and our continuing activities as part of the River Dee Catchment Partnership.

Assessing the effectiveness of rural land use management and policies

Incorporated within Scottish Government policies' concerning water is the necessity to meet Water Framework Directive (WFD) and public health regulations to protect and restore water quality while protecting the social and economic interests of those who depend on it. It prescribes the use of economic principles, such as derogation from Good Ecological Status (GES) on grounds of disproportionate costs of mitigation. The Draft River Basin Management Plan (2010) requires implementation of programmes of measures to achieve these balanced targets. Urban sources of pollution are controlled by the national Controlled Activities Regulations (CAR, 2008) and diffuse pollution is regulated by General Binding Rules, whereby activities posing a risk, such as cultivation of land and storage of manures need to follow rules to protect the water environment.

Assessing the cost-effectiveness of diffuse pollution mitigation at local and national scales

We have completed analyses of the cost-effectiveness and proportionality of pollution mitigation measures for P pollution of standing waters at local and national levels. The assumed mitigation target was achievement

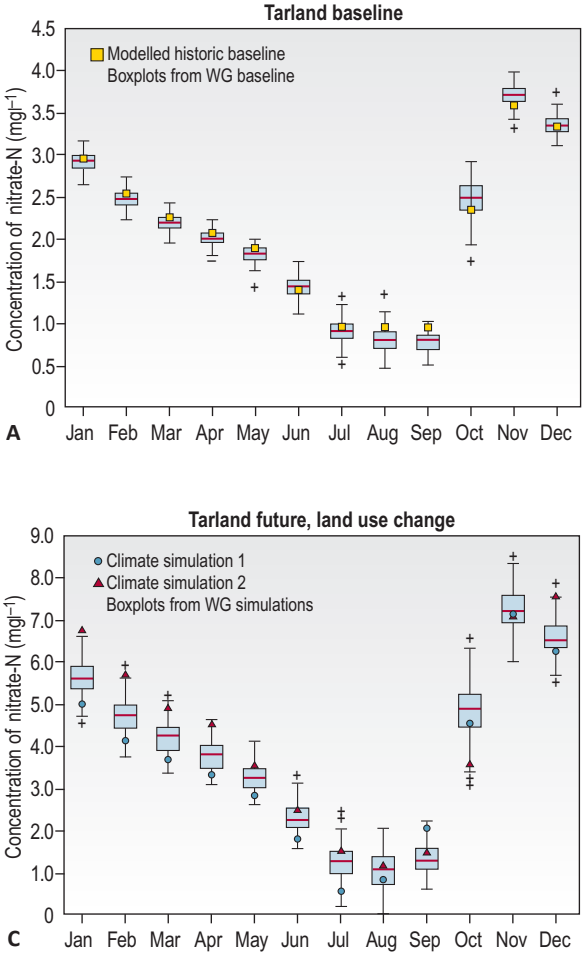


Figure 24 Predicted streamwater nitrate simulations for Tarland Burn, Aberdeenshire, accounting for future climate and land change scenarios: (A) baseline model results using historic meteorological data and 100 weather generator (WG) simulations; (B) results for 2050 response under scenario of no land use change using two possible extremes of future climate and 100 WG simulations; (C) results for 2050 response including land use change scenario using the same climate simulations as in (B).

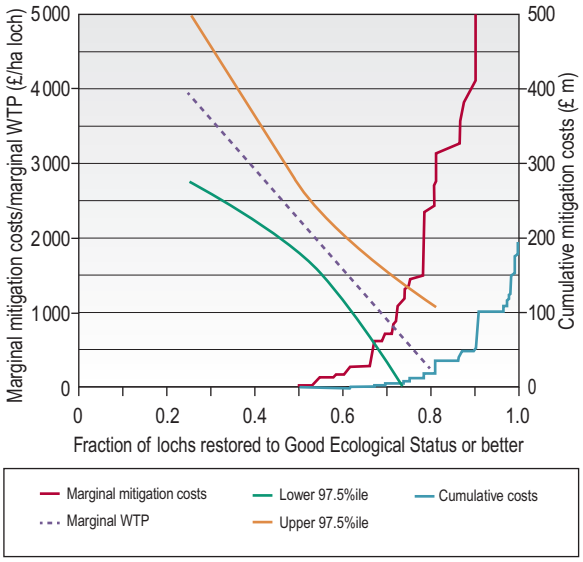


Figure 25 Marginal costs and benefits of achieving loch P mitigation: estimates at national scale. Any costs to the right of the point where the marginal cost curve cuts the marginal benefit curve, are not proportionate.

of WFD standards for P status. In the national level work, mitigation cost-effectiveness was assessed using combined mitigation cost curves for managed grassland, rough grazing, arable land, sewage and septic tank sources. These provided sufficient mitigation (92% of national P load) for GES to be achieved on 62% of the national loch surface area at an annualised cost of £2.09m/year. Where potential mitigation of external sources was insufficient to achieve WFD standards, we assumed achieving GES could be done by removal of P directly from lochs (a "mop-up" cost of £200/kg P/year , leading to a total cost of £189m/year. Lochs were ranked by mitigation costs per loch area to give a national-scale marginal mitigation cost curve. A published choice experiment valuation of WFD targets for Scottish lochs was used to estimate marginal benefits at national scale and combined with the marginal cost curve. This gave proportionate costs of £5.7m/year leading to GES in 72% of loch area (Figure 25).

Operationalising the ecosystem services approach for water management

We have explored the opportunities and risks associated with the use of the ecosystem services (ES) approach in a WFD context. This approach enables multiple benefits and costs to be assessed more thoroughly than is possible with a single pollutant approach. Since the release of the Millennium Ecosystem Assessment (MEA), the ES approach has been increasingly endorsed by the scientific community and is finding its way into the policy arena, to the point that it can soon become the dominant paradigm for approaching resource management and conservation. The MEA defined ES as "the benefits people obtain from ecosystems". An analysis of opportunities and risks associated with the use of the ecosystem service approach in the WFD (Table 3).

Opportunities	Risks and Potential Limitations
Values recognition	
Opportunity to incorporate the benefits that people derive from ecosystems. This often gets ignored in the decision making	Anthropogenic focus: is this enough for sustainability? What about existence values?
Helps recognition of the many values of nature within all societal decision making contexts and affecting all stakeholders	
Increasing knowledge	
It helps a better understanding of ecosystem functions, roles and interactions	Is the link between good status and services delivered completely clear? Can we have a good status but a ecosystem not functioning properly?
It enables analysis of unintended consequences and benefits of actions	
It can enable analysis of trade-offs in situations with competing demands	Can the ES approach catch the global perspective when understanding water problems?
Enabling dialogue	
Powerful communication tool, pragmatic and helpful for management	Risks associated with the 'loss in translation' from science to policy. Are all components being transmitted?
Helps linking policy-science integration	
It helps developing a common language	
It helps inter-disciplinary science, because it is understood by hard and soft scientists	There are risks associated with getting the wrong number into policy. Valuation problems.
It leads to multi-lateral decision making, because all the stakeholders are invited around the table	
Changing visions	
It forces us into a more systemic intervention in the context of the WFD (i.e. beyond the water body basis initially introduced by the WFD). Also, it is more holistic that the WFD because it considers semi-aquatic and terrestrial components (while the WFD only addressed them if they are protected areas)	ES might be used to "sell" business as usual work as if it was actually new
It can help reconciling perverse pressures and effects	
It can support categorisation, selection of measures, acceptable tools and also justify exemptions	
Using the concept of ES is goal oriented, more practical, it supports bottom-up approaches, its system oriented, asking for tailored made solutions, requires flexibility	Is the ES serving for creating new demands instead of clarifying existing needs?
ES can help formulate research questions, forcing you to think out of the 'water box'	
It can help overcoming the rigidity of WFD's current approach to full cost recovery	
Policies integration	
It is useful at the policy strategic level	Lack of consistency across EU policies (e.g., WFD discussions seems to embrace ES, while Common Agricultural Policy's (CAP) does not)
ES can support understanding links between water and other policies (e.g., spatial policy, agriculture)	
Source: Own elaboration on the basis of the discussions at the 2nd *Water Science Meets Policy Event* held in Brussels in 29–30, September 2011. http://www.onema.fr/IMG/EV/images/2ndSPIevent.pdf. All speakers are to be credited for this information, but special mention should be made to Edward Interviews for his ideas regarding the risks (Interviews, 2011). The discussion on the potential of ES for the implementation of the full cost recovery principle was brought up by Antonio Massarutto, and the expression 'thinking out of the water box' is from Colin Byrne.	

Table 3 Opportunities and risks associated with the use of the ecosystem service approach in the WFD.

Development of innovative methods for controlling diffuse pollution

A novel and practical approach to controlling soil erosion using 'filter fences' has been developed in collaboration with farmers in the Lunan catchment. These leaky barriers comprise a woven fabric pinned to a line of fence posts and supported by wire, installed temporarily on the toe of the slope in fields after erodible crops. On one steeply sloping field, more than 70 tonnes of soil containing more than 40 kg P was trapped, and ongoing trials are seeking to optimise the design to catch fine soil/sediment while allowing run-off water to drain (see Figure 26). The concept has been discussed at a farmer focus meeting in the catchment and has attracted the interest of NFUS and local MSPs.

Hydraulic modelling for assessing flood risk

The risk of flooding in Scotland is predicted to rise in

Figure 26 Part of a filter fence in an arable field after potatoes, showing capture of soil from an erosion rill spreading the sediment out along the contour, with fine sediment being captured in the corner of the plot by finer mesh fabric.

the future with the impact of climate change. Modelling techniques are able to help in predicting where flooding might occur, how severe it might be, and the impact that different mitigation measures might have on flood risk in different situations. A hydraulic model of Tarland Burn was developed using the computer software called ISIS. Flood Estimation Handbook (FEH) techniques are used to determine catchment characteristics such as topography, slope, land use, soil and sub-surface moisture conditions required for the model. The results from the model can be viewed in a graphical form (Figure 27). This shows water

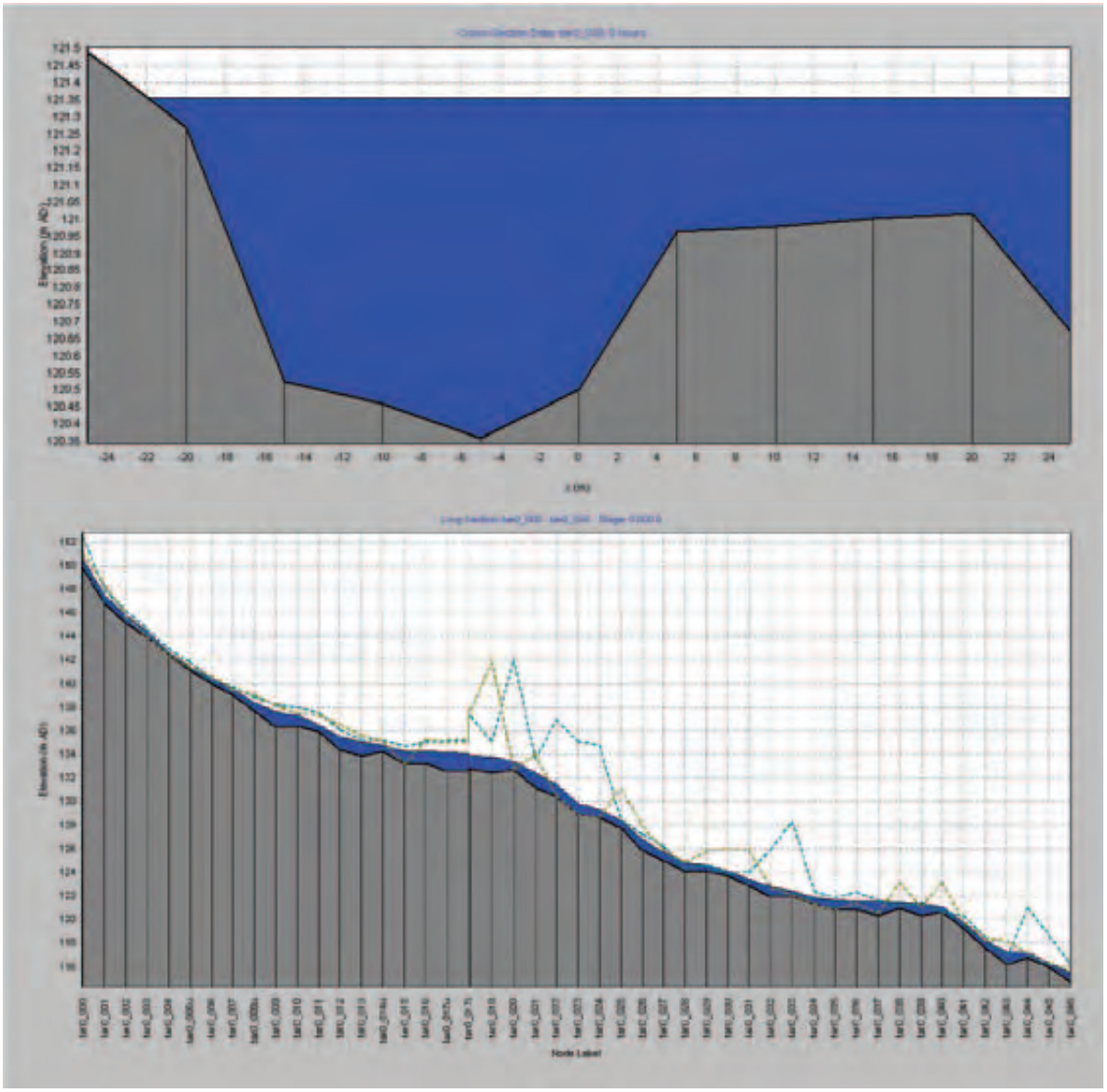


Figure 27 Water flow profiles from ISIS model (1 in 100 year event).

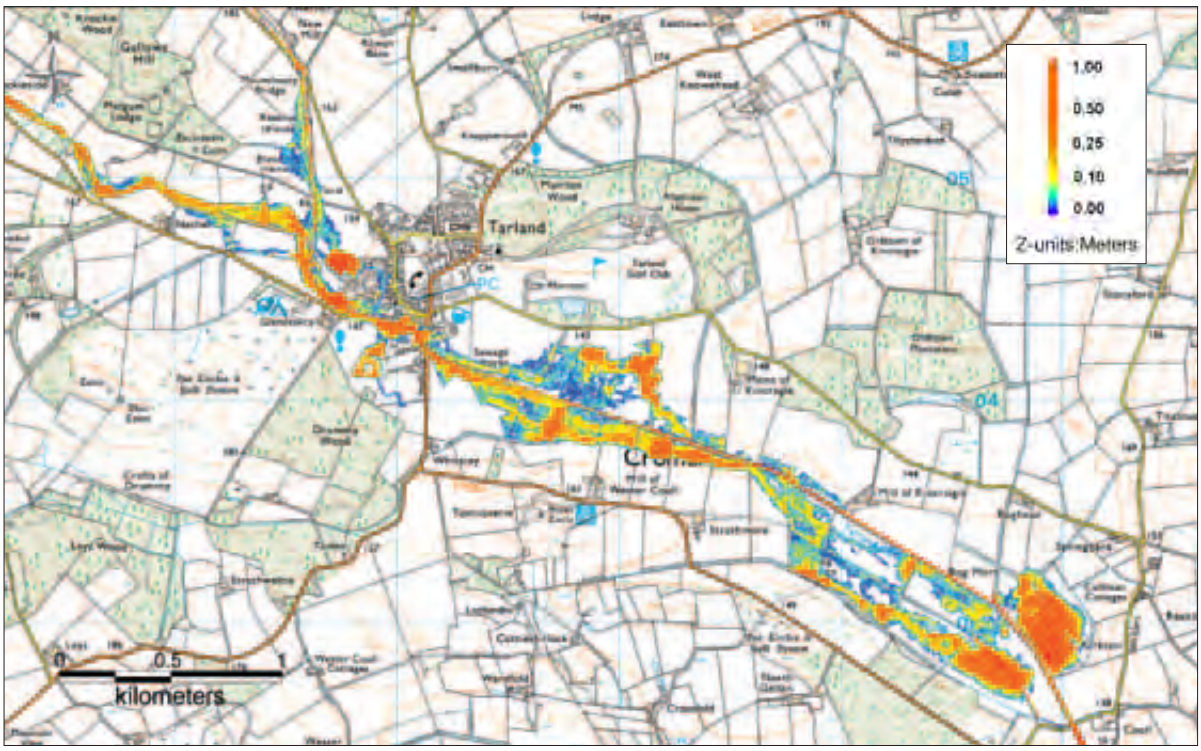


Figure 28 Flood extent map (1 in 100 year) showing depth of flooding in Tarland. Ordnance Survey data used by permission.

levels in a longitudinal direction along the watercourse as well as lateral direction at any point of interest. The figure indicates that extreme rainfall events such as 1 in 100 year event will result in overtopping of river banks thereby increasing the risk of flooding in many locations including the residential areas of Tarland village and Aboyne.

In order to better understand the process of flooding, a two-dimensional hydraulic model was developed using Tuflow. The model provides information on how the flood wave advances within the floodplain, providing useful data and information such as depth of flooding, extent of inundation, residence time, rate of increase and duration of flood and most importantly the direction of flow paths as the flood water travels. This information can be overlayed onto base maps or aerial photographs (Figure 28), so that they can be easily read by farmer and members of the at risk community. This allows local communities and land managers to find out whether their farm/property/community is likely to be flooded in a specific situation. The results from both models indicated that significant areas including part of the Tarland village are likely to be flooded from extreme rainfalls such as 1 in 100 year event. Work is continuing on improving the model by incorporating more detailed information to better represent land use and incorporating survey data on in-channel structures such as bridges and culverts. The impact of land use change and natural flood management measures such as storage ponds, buffer strips etc. on mitigating flood risks will be assessed in the next phase of the research.

Achieving multiple benefits using riparian buffer strips in agricultural landscapes

Catchment riparian areas are considered key zones in which to target mitigation measures aiming at interrupting the movement of pollutants from agricultural land to surface waters. Hence, unfertilised buffer strips have become a widely studied and implemented ‘edge of field’ mitigation measure assumed to provide an effective physical barrier against nitrogen, phosphorus and sediment transfer across them (Figure 29). The James Hutton Institute has led an initiative to look at wider aspects of managing buffers to achieve a number of multiple diffuse pollution mitigation, stream and riparian habitat and social functions (Table 4). A workshop was held in 2010 in Ballater, UK to highlight research on riparian buffer strips under the EU COST Action 869 knowledge exchange programme. Following this workshop the James Hutton Institute has contributed to six out of 13 papers for a special collection of the Journal of Environmental Quality, and acted as editor with colleagues at the Danish National Environmental Research Institute and at Alterra Institute in the Netherlands.

To ease the legislative process buffer strips are often narrow mandatory strips uniformly against all streams




Figure 29 Four photographs of riparian management in north east Scotland. Clockwise from top left: Cattle access for watering to the stream; consequences of a narrow ineffective riparian field margin; a fenced buffer, planted with trees with a public access footpath; a fenced buffer with cattle crossing point.

Aspects of multiple benefits associated with riparian restoration	Research?	Guidance?	Policy or funding?
Diffuse pollution control	✔	✔	✔
Biodiversity	✔	✔	✔
Shading and temperature regulation	✔	✘	✘
Water storage and flood control	✔	✔	✔
Carbon sequestration	✘	✘	✘
Cultural services	✘	✘	✘

Table 4 The range of ecosystem services that well-managed riparian areas can provide. Ticks are given where the state of research knowledge, guidance to practitioners, policy and funding is sufficiently developed.

and rivers, across different riparian soil water conditions, between bordering land uses of differing pollution burdens and without prescribed buffer management. It would be easy to criticise such regulations for not providing the opportunity for riparian ecosystems to maximise their provision of a wider range of ecosystem goods and services. However, the scientific basis on which to judge the best course of action in designing and placing buffers to benefit their multi-functionality has slowly increased over the last five years. Our collection of papers evaluates a range of studies of riparian buffer management and assessment from across Europe.

The themes addressed are:

- Evidence of catchment- to national-scale effectiveness
- Ecological functioning linking terrestrial and aquatic habitats
- Modelling tools for assessment of effectiveness and costs
- Process understanding enabling management and manipulation to enhance pollutant retention in buffers.

The combined understanding leads us to consider four principal challenges for buffer strip research and policy.

- How can we bring efficient placement and design of buffers in landscapes to minimise diffuse pollution delivery?
- What are the key aspects and aims in the ongoing management of riparian buffers?
- How can we maximise benefits for riparian habitat restoration through buffer design?
- What are the most important aspects of multiple benefits to different stakeholders and how should we go about observing progress to achieving desired goals?

Marine litter issues, impacts and action: contributing to a marine litter strategy for Scotland

Increasingly, policy makers and the public are experiencing the problem of litter in our seas and on our beaches (Figure 30). Marine litter has a substantial impact on Scotland's society, economy and marine environment. In 2010, a total of 53,162 items of litter were collected on a sample of Scottish beaches (along a length of 22.3 km), an average of 2380 items per km. The majority consists of plastics and is highly persistent in the marine environment, with the lifetime of plastics estimated between 100-1000 years. Globally, as well as for Scotland, studies estimate that the greatest proportion is from land-based sources (Figure 31).

As part of a Scottish Government-funded study, contributing to a marine litter strategy for Scotland, the James Hutton Institute and Scottish Association for Marine Science examined the impacts of marine litter. Environmental, social and economic impacts were documented that threatened marine resources and the future success of policies, such as the Marine Strategy Framework Directive that focus on delivering a clean and healthy marine environment.

The approximate cost of marine litter in Scotland, estimated at £16.8 million per annum, was recognised

Figure 30 Beach litter, Cairnbulg Aberdeenshire.

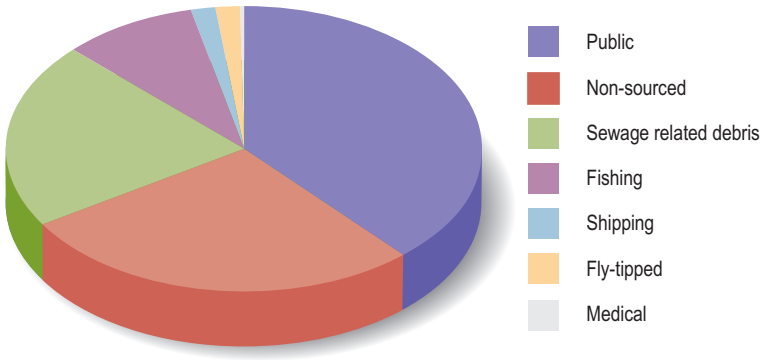


Figure 31 Beach litter origins (MSC, 2010).

as a gross underestimate due to a lack of data on impacts in many sectors such as recreation or tourism. The research provides concrete policy options towards becoming a society that embraces the concept of 'waste as resource' across five strategic directions:

- Improving public awareness of and behaviour changes around, marine litter
- Reducing terrestrial and maritime sources of litter entering the marine environment
- Contributing to a low carbon economy by treating 'waste as a resource' and seizing the economic and environmental opportunities
- Improving monitoring at a Scottish scale
- Increasing engagement at the UK, EU and international scales.

The study highlighted that a mix of regulatory tools exists across Scotland, but these should be co-ordinated into a Scottish marine litter strategy. This strategy, and resulting policy, should take an innovative systems approach across terrestrial and marine sectors, using a variety of institutional, social, technological and regional tools to bring about the required changes in human behaviour. The vision for the proposed strategy is: 'By 2020 marine litter in Scotland is significantly reduced and does not pose a risk to the environment or communities. This is achieved within a Scotland where people and businesses act responsibility and reuse, recycle, and recover waste resources'.

Realising Land's Potential

Professor David Miller, Theme Leader

Researching the means to maintain a land that can support multiple uses in a sustainable way

Forces of change such as globalisation and climate are interacting with altered demands for food, fuel and fibre, and coinciding with national shifts in demographic and social patterns (e.g., expectations for homes, leisure and work patterns, quality of life expectations, access to land for recreation). Accelerated changes in land use increase the risks of degrading and depleting ecosystem services through unexpected and unintended environmental consequences that can undermine efforts to promote a sustainable, wealthier and fairer society. Thus, there is increased demand, and opportunity to use ecosystem services within land use decision making to better understand intrinsic trade-offs involved in delivery of multiple functions and services, based upon the long-term implications for human wellbeing.

Realising Land's Potential aims to develop the scientific evidence base for sustainable use and management of land. It seeks to understand the mechanisms supporting the multi-functional use of rural and urban land (e.g., agriculture, forestry, renewable energy, recreation, urbanisation) at different scales, and to provide methods of enabling improved future-proofing of land use decisions through understanding the role of energy in social and ecological systems – international and local. We are using integrated inter-disciplinary methods and approaches, including the assessment and communication of risks associated with land use futures, quantitative and qualitative studies of agents of change (i.e., people, such as land managers and developers), modelling of biophysical resources of land now and under scenarios of change, the measurement monitoring and analysis of change, and effective means of knowledge exchange.

Our scientific challenges include understanding and communicating the biophysical and socio-economic trade-offs between green energy production and other land uses, assessing service flows between areas and across scales, and linking land potential with risk. The ultimate outcomes from realising the potential of the land are protection of ESS, increased wellbeing, sustainable and resilient supply chains, all in support of sustainable economic growth.

We plan our research to be relevant to international, European and Scottish policy areas. Examples include the environmental governance and resource efficiency priority area of UNEP, and its Energy Programme, the EU Sustainable Development Strategy; and the EU's Europe 2020 strategy, the European Common Agricultural Policy and associated rural development policies. For the Scottish Government, an important challenge is reconciling global, national and local influences on rural and urban Scotland, ensuring economic growth, social justice, and protection of the natural and cultural heritage. The Scottish Land Use Strategy responds to this challenge with a vision of recognising understanding and valuing 'the importance of our land resources, and where our plans and decisions about land use deliver improved and enduring benefits, enhancing the wellbeing of our nation'. Delivery requires linking public policies such as the 2020 Routemap for Renewable Energy, Scottish Adaptation Framework, Food and Drink, National Planning Framework 2, Scottish Rural Development Programme, Scottish Soils Framework and Building a Sustainable Future.

The theme places considerable importance on developing close relationships with stakeholders by:

- Running consultative groups drawn from across the public and private sectors on land use, and renewable energy
- Playing an active role in stakeholder institutions, such as the Land Use Strategy Action Plan, the Scottish Agri-renewables Strategy Consultative Group, the Woodland Expansion Advisory Group, discussions on the National Ecosystem Assessment 2, and contributing to the Scottish Government deliberations on the CAP post-2013 in Scotland and Europe.

Together, these interactions with both the public and private sector enable us to gain new insights into debates of societal interest.

Figure 32 Accessing digital map data online (left screen) and using it in a GIS (right screen).

Natural resource datasets and databases

Protecting and improving the health of soil is a major way to increase food security and fibre production: to protect water supplies, to mitigate climate change and make our ecosystems more resilient to environmental change. Recognising the importance of soils to many aspects of Scotland's economic and environmental health the Scottish Government produced the Scottish Soil Framework in 2009, which identifies threats to the resource and encourages sustainable soil management.

To support delivery of the Soil Framework, we are drawing on the unique resources of our physical archive of soil samples (Figure 33), collected since 1930 from across Scotland and overseas, and the national mapping of Scotland's soils. All our maps of soils and peatlands, 900 in total, have been digitised, at scales of 1:500 (peat deposits) to 1:250,000 (Scotland-wide soil data). These data are being made available via the internet (http://sifss.hutton.ac.uk/, Figure 32) for anyone to obtain information about the soils in their area of Scotland. Queries can be made by identifying locations on maps, or using postcodes or geographic co-ordinates. Outputs include maps, graphical summaries and scaled diagrams of soil characteristics. Dissemination of soils information is also being developed for Scottish Government, to produce a website compatible with the Scottish Environment website (www.environment.scotland.gov.uk), the principal portal for environmental information for Scotland.

Exploiting databases: example – soil forensic science

Benefits have accrued to a range of stakeholders from the underlying science and methods developed from funding by RESAS, and the maintenance of the Institute's soil and vegetation databases. One example is advice to the police and investigating authorities. This includes guidance on identifying areas to search for scenes of crime, testing the authenticity of artefacts in cases of potential fraud and our staff being called as expert witnesses to the criminal courts in cases of serious crime. Cutting-edge approaches have been developed in the use of soil, vegetation and geological material for use in criminal investigations across the British Isles. Their uptake illustrates how innovative tools can be developed in one area of science and deployed to great effect in another.

Land use change, monitoring and systems

Our research focuses on studies with Scotland-wide scope, developing and applying the concepts of resilience and adaptive capacity to the systems of land management. The most significant external driver influencing such

Figure 33 National Soils Archive.

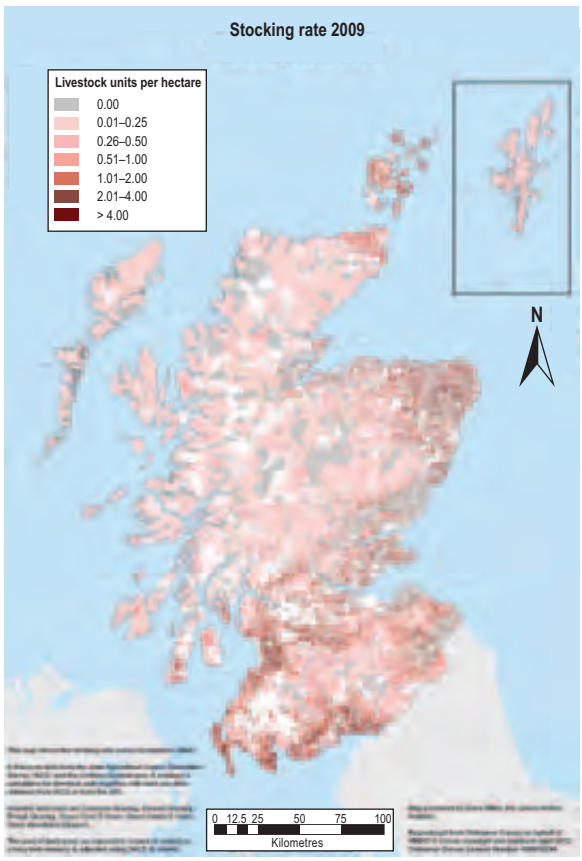


Figure 34 Geographic distribution of stocking rate across Scotland for 2009 (White areas indicate those areas for which there are no map data from the IACS or Crofters Commission sources, and those in dark grey are due to issues of limited information).

systems in Scotland is that of the £560 million from the European CAP. We have developed a unique agricultural land use database, which links the Scottish June Agricultural Census and December Survey, together with mapping from the Integrated Administration and Control System (IACS), with other data from Ordnance Survey and Forestry Commission. This has enabled us to model the potential consequences of CAP post-2013 on land systems, and future land uses under climate change. Such analyses are developed jointly with RESAS and policy staff through CAP Stakeholders Technical Working Groups and informal meetings, and provide inputs to modelling of work on land use scenarios and futures.

This database has been used to derive maps showing the distribution of livestock, which is a key input to many Scottish Government rural policy objectives. Following the Pack Inquiry, to advise Scottish Government on how to support agricultural and rural development, the Land Use Strategy, and more recently the work of the Woodland Expansion Advisory Group, the question of 'How much livestock is where?' is a current issue.

Figure 34 shows the output of our mapping of stocking rates across Scotland which, for the first time, illustrates the geographic distribution of stocking rates for Scotland in livestock units per hectare. Our calculation was at a holding level using our agricultural land use databases together with mapping from the Crofters' Commission, taking account of livestock types (cattle, sheep and deer) and numbers, forage area, seasonal rentals, multiple users of land parcels and common grazings.

The output shows the highest concentrations of highly stocked units to be in the areas associated with dairy cattle, such as the lowland areas of south west Scotland, in particular the lowlands of Ayrshire, Galloway and Dumfries, and Orkney. Although there are also units with high stocking levels in north east and south central Scotland the overall density and geographic clustering is lower.

Current work is considering the potential implications of these findings with respect to pressures on waters and soils, and the potential for displacement of more livestock if changes in land use, such as woodland expansion, arise in south west Scotland compared to north east Scotland, or land management adapts to climate change.

Scenarios and land use futures

Environmental, economic and social issues associated with agriculture are often fundamental for rural prosperity and sustainability, with consequent implications for any debate

about future land use. A key to supporting the planning of change is to understand the capability of the land for uses such as agriculture for the future as well as today, and the ecosystem service supply and land uses they can support. We are creating a series of new models of land capability for different ecosystem services at different scales and trade-offs in values between combinations of ecosystem services. This work uses spatial frameworks for ecosystems, multi-functional rural and urban land use, and landscape capacity for change, and targets aims of the Scottish Land Use Strategy.

Evaluation of multiple benefits from land ('multi-functional land use') was investigated through the development of land use change scenarios. These combine different coherent options of land uses and land management, and consider consequences of climate change, present and future. To facilitate creation of scenarios, the LandSFACTS toolkit was developed to support scenarios from field to national scale, for snapshots in time to multiple years. These land use change scenarios have been used to evaluate consequences for water quality in the Dee catchment (north east Scotland) (Figure 34), and assessing risks to the environment, economy and society, and resulting priorities of climate change adaptation, through the Centre of Expertise on Climate Change (CXC). Assessments of changes in water supply/demand budgets are enabling studies of interactions between land use, climate change and water resources, through the Centre of Expertise for Waters (CREW). Our new typology of different land managers then enables us to better understand different motivations and preferences towards multi-functional land use and characterisation of the choices identified by the scenarios.

Another set of techniques being developed to investigate land use change is through the use of remote-sensing data, linked to the array of new satellite and airborne data sources. High-resolution applications are being developed to map vegetation change, micro-climate and land use patterns. The links between land use and land cover have been investigated through a project for Scottish Natural Heritage to map the distribution of priority habitats in the uplands. The distribution of many of these habitats in Scotland has been poorly recorded outside of protected sites. This project mapped the most likely areas using other data such as soils, geology, geomorphology, climate, land use and topography, providing inputs to the mapping of ecosystem services being undertaken in the Safeguarding Natural Capital theme.

The European Landscape Convention has led to integrated views of landscapes in which visual, cultural and social qualities are included with ecological functions. Indicators which synthesise information relating to landscape functions and their interactions, such as pressures of socio-economic change systems on natural systems, were articulated in terms of ecosystem services in the Millennium Ecosystem Assessment. We are developing a framework to link landscape concepts with those of ecosystem services, as part of the testing of Ecosystem Approaches.

We use visualization tools (e.g., the virtual landscape theatre) to interpret scenarios of land use change through public preferences for landscapes, and elicit scenarios of preferred future land uses from audiences familiar and unfamiliar with an area. In the study of the Tarland sub-catchment of the Dee (Figure 35), our findings show significant differences between audiences related to medium-sized windfarms on hills north of the village. Those unfamiliar with the area (Birmingham and some in Edinburgh) argued that renewable energy was a priority and highlighted open hilltops as opportunities for maximising energy return. Those familiar with the area, even if not residents, were conscious of the local significance of prominent hills and previous rejections of windfarm proposals, with audiences in Edinburgh and Ballater (Figure 36) being positive towards small-scale wind turbines associated with farming or communities. However, there was commonality between audiences for increasing amenity woodland adjacent to the village, quality recreation within the village, conservation interests, and recognition of risks to water quality with increased agricultural activity.

A new collaboration was initiated with the Scottish Association for Marine Science (SAMS), focusing on environments above and below sea level. The approach uses the Virtual Landscape Theatre with sea floor data (from SAMS and British Geological Survey), terrain (Ordnance Survey), and protected areas (Scottish Natural Heritage). It enables interpretation of habitats, above and below water, in the context of designations and use (e.g., renewable energy and aquaculture). It was launched at the World Congress on Marine Biodiversity in Aberdeen, to international representatives from public policy, resource management, the private sector, and scientists. We will be exploring its use in modelling multiple uses of seascapes, in collaboration with the Managing Catchments and Coasts theme.

Attitudes and behaviours

Critical though our understanding of biophysical processes is to understanding different options for our land, factors such as governance and how society, and in particular land managers, respond are key to how that change will actually manifest itself on the ground. The research in this area focuses on understanding land-manager attitudes and behaviours, particularly as these relate to environmental

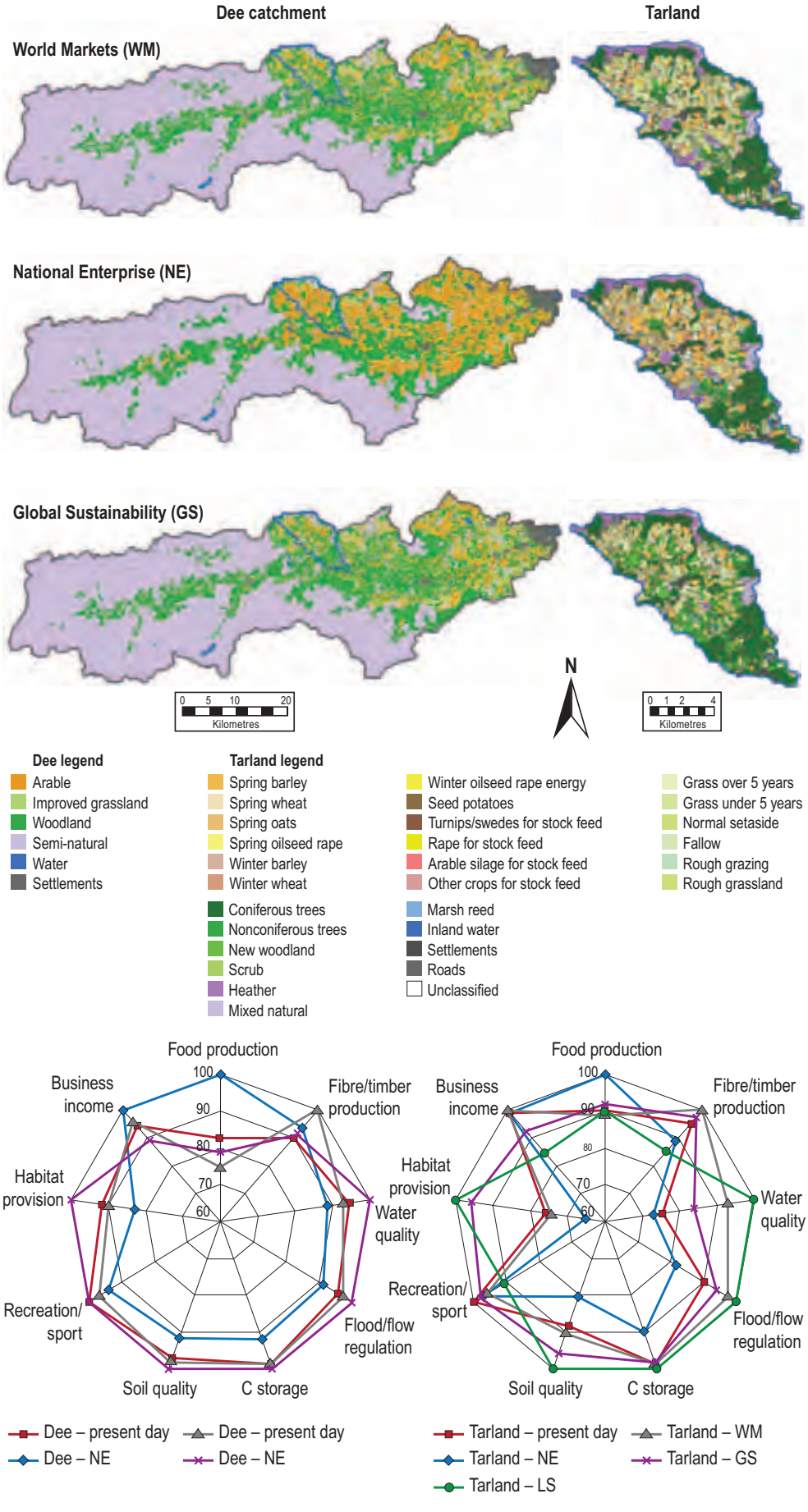


Figure 35 Evaluation of land use scenarios and ecosystem services.

Figure 36 Eliciting public opinions on alternative future land uses in the virtual landscape theatre with audiences from: (A) Edinburgh and (B) Ballater.

assets and climate change. Although farmer environmental attitudes and behaviours have been studied at the Institute for over a decade, the topic of climate change is relatively new to social science. Therefore, our current work started with a scoping study of the existing research.

We found that published research focuses on agricultural land management, and decision making on commercial farms, as opposed to estates, public sector bodies, crofts, or hobby farms, and concentrates on uptake of agri-environmental schemes and organic farming. There is a body of literature on how farmers interact with the environment but it is primarily focused around how they respond to individual policy incentives or decide to convert to organic farming, and not on how they would respond to the combinations of policies and issues that arise from a global phenomenon such as climate change. We also found that there has been very little research on the system-level changes that occur to influence change, i.e., how combinations of policies interact with changing markets, business opportunities and land capability.

The scoping has been followed by a programme of engagement with stakeholders (i.e., NGOs, local authorities, National Farmers Union Scotland, Scottish Land and Estates, the New Entrant Forum, farmers and academics) to identify specific topics on which to focus. These were on-farm renewable energy, formalised farmer collaboration (specifically machinery rings and response to collaborative agri-environmental incentives), soil management and part-time/hobby farming. A spatial context is being provided by analysing geographic relationships between land management and governance, at different scales across Scotland, to test the compatibility between land management objectives (e.g., forestry, biodiversity, rural development, soil management, renewable energy).

Preliminary findings from interviews with key actors revealed that machinery rings are important service providers and included information on renewable energy production, and that 'hobby farming' comprises commercial part-time farms, non-commercial small-holdings, and people with livestock and horses as 'pets' who do not view themselves as farmers. We found that small-scale land holders improve the environmental condition of their land independently of agri-environmental schemes or cross-compliance. Finally, we found that local planning authorities and Scottish Government are the strongest actors influencing uptake of on-farm agri-renewable energy production. This has increased rapidly in the last 10 years, primarily wind energy, but there is also high potential for small-scale hydro on rivers and anaerobic digestion of livestock slurry. Most of the early wind energy developments were organised by non-agricultural businesses, on land they either purchased or long-term leased from farmers. However, the National Farmers Union of Scotland expects uptake of renewable energy production by farmers to increase rapidly, in part reflecting the introduction of 'feed-in tariffs' to support renewable energy production by both private households and commercial businesses. This informs the work being undertaken by the Institute's renewables team.

We are now studying the influences of system-level changes on farmer uptake of renewable energy production (i.e., interactions between energy companies, turbine suppliers, government policies, energy and commodity markets, social norms), and how or if land managers differ from households in terms of their rationales for engaging in renewable energy production. We are reviewing the sources of information and processes land managers use to get involved in renewable energy production, particularly in relation to risk and, using agent-based modelling tools, mapping how land managers of different types interact. Linking with the Institute's environment, risk and health team, our research is studying the roles and responsibilities of different actors specifically for soil conservation.

Renewable energy, supply and demand

The International Energy Agency (World Energy Outlook

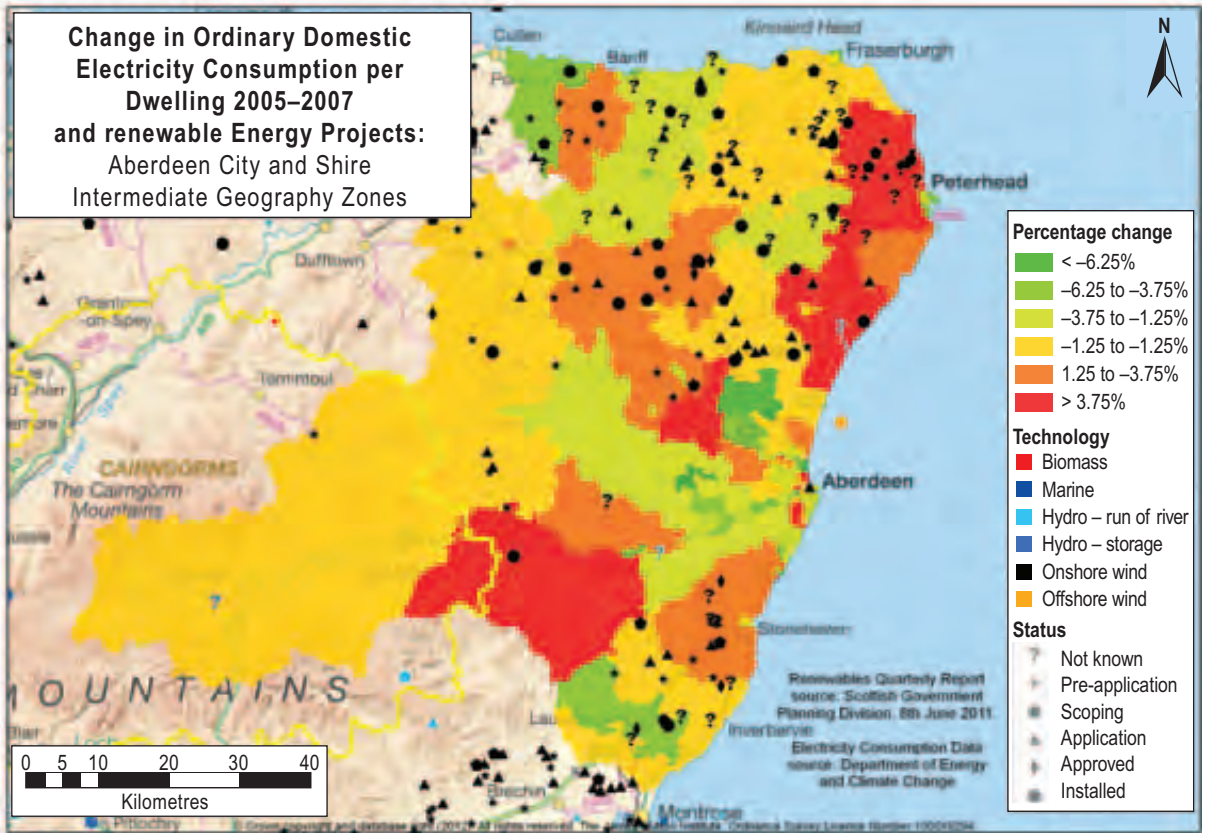


Figure 37 Change in ordinary domestic electricity consumption and renewable energy projects (2011).

by 2035, as the world's population grows by a further 1.7 billion people. In 2011, the Scottish Government published its Routemap for Renewable Energy. This sets demanding targets to be achieved by 2020, of 100% electricity from renewable energy, 11% of renewable heat, 30% overall energy demand, and 500MW from community and locally-owned renewables. The Routemap identifies new strategies for micro-generation and agri-renewables, reflecting the growing significance of small-scale generation and opportunities for local and rural ownership of energy, and the best use of biomass and biofuels to aid delivery of the targets on heat.

Our research seeks to better understand biophysical, economic and social constraints on the provision of renewable energy and to identify means for the delivery of renewables as part of land use mixes and systems. Our principal question is: What are the main trade-offs in land use options with respect to energy provision and use, at different geographic scales? Our work uses land use and climate change scenarios to consider the implications for future capability to meet renewable energy demand in Scotland. This enables options for the provision of renewable energy to be assessed (e.g. biomass production using crop types that are not currently suitable for the Scottish climate) and the role of water use efficiency. The work focuses on biophysical assessments but social, behavioural and economic factors are also critical in determining capability to deliver resources. For example, we are currently studying the geographic distributions of demand for electricity and the provision of energy from renewable sources (Figure 37). This will draw on the social research expertise in the social, Economic and Geographical Sciences group and the systems research skills within the Environmental and Biochemical Sciences group.

A particular challenge for our research is to consider the cumulative impacts not just of one type of development (e.g., wind turbines) but of the combination of means of generating renewable energy, and understanding the potential conflicts and complementarities of wind, micro-hydro and biofuels on each other, and on a suite of ecosystem services.

Urban land use and change

Ultimate outcomes sought from our environment need to be compatible with improved human wellbeing. One of the ten principles of the Scottish Land Use Strategy is that Scotland's landscapes are important to our sense of identity and to our individual and social wellbeing, and increased attention is being paid to managing stress by supporting positive wellbeing. This forms one of the contexts for our research on ecosystem services supported by urban and rural landscapes.

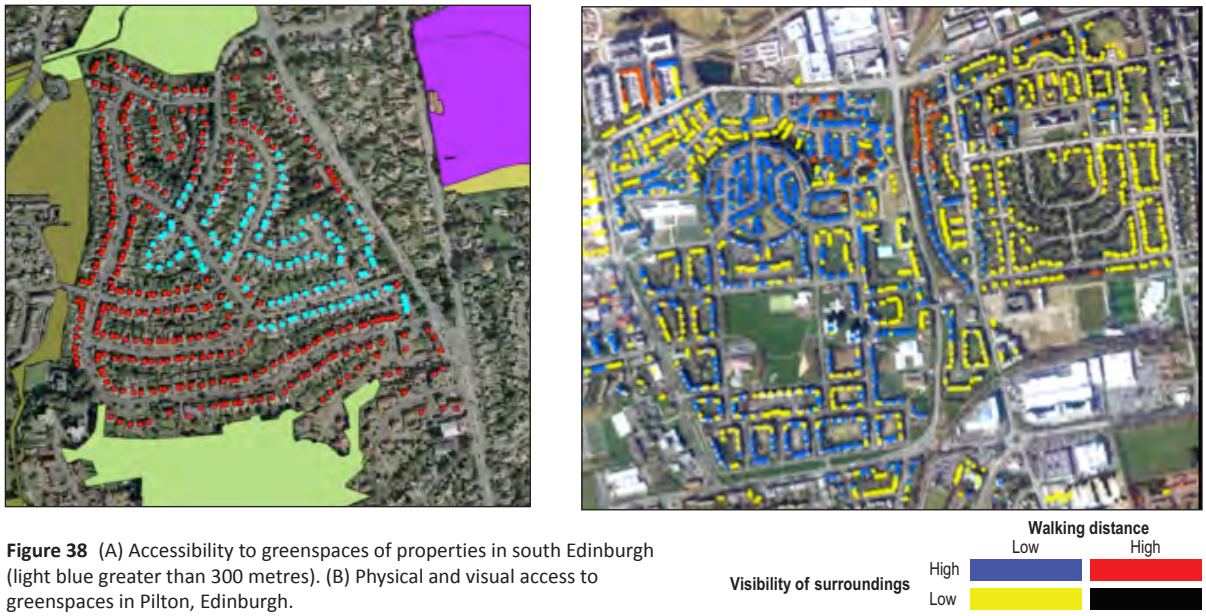


Figure 38 (A) Accessibility to greenspaces of properties in south Edinburgh (light blue greater than 300 metres). (B) Physical and visual access to greenspaces in Pilton, Edinburgh.

The expansion of urban areas increases pressures on a range of ecosystem services, impacting on above and below ground biodiversity, soil sealing, and changes the number, size and configuration of green and open spaces. We are studying accessibility to greenspaces, physical and visual (Figure 38), with analysis to identify potentially spatially significant urban greenspaces which can offer multiple benefits in relation to ecosystem services supply at a city scale (e.g., green networks), site level (e.g., urban gardens), semi-natural sites (e.g., neglected woodlands), and urban water courses (e.g., rivers, ponds).

Research for the Scottish Government on the roles played by greenspaces and human health and wellbeing (the Green Health project) has shown that people's stress levels are directly related to the amount of greenspace in their area – the more greenspace, the less stressed a person is likely to be. We showed that for every 1% increase in 2011) estimates that energy demand will grow by 40% greenspace there was a corresponding steeper decline in stress hormone levels and where there is more greenspace people tend to respond better to disruptive events, either by not getting as stressed in the first place or by coping better. This complements the ethnographic studies on greenspaces in the Nurturing Vibrant and Low Carbon Communities theme.

Knowledge exchange

The theme's aims for knowledge exchange are to use effective communications to increase our profile and impact in research, consultancy and policy arenas, such as those identified in the introduction. Our strategy is to position ourselves as the first choice for advice and partners, and to work with stakeholders to improve the quality of interactions, and the impact of our products. Our significant role in the Centre of Expertise on Climate Change (CXC) and the consultative groups we run, provide key mechanisms in the delivery of this strategy.

For younger audiences, we focus on the provision of materials for teachers to use in class, designed for use as part of the Scottish Curriculum for Excellence and accredited by the Scottish Qualifications Authority. An example is the ongoing maintenance of a suite of factsheets and Powerpoint slide sets on Scotland's soils, soil formation and associated ecosystems. Such products are developed in collaboration with key stakeholders, in this case principal geography teachers, and augmented by workshops for children for gaining direct feedback and staff development.

For public audiences, outputs include awareness-raising events, such as that on forensic science, books and web resources, and the role of soils in the crofting counties of Scotland (Figure 39). Soils of the Crofts was written in partnership with Crofting Connections, school teachers and The Soil Association and endorsed by HRH Prince Charles. This resource has been used in over 200 schools in Scotland, particularly those in remote areas.

We aim to share visions, focus on collaborative projects and foster co-construction of research. To do so, we seek to take advantage of the positive benefits of trans- and inter-disciplinary research to have a greater impact on scientific and other stakeholder communities, thus building on Institute strengths of high level of inter-disciplinary capabilities. In collaboration with other research themes, we will be seeking new opportunities to develop and expand our core areas to deliver research outcomes to different stakeholders on how to optimise systems to provide multiple benefits.

Figure 39 *Soils of the Crofts* (open double page of book).

Nurturing Vibrant and Low Carbon Communities

Dr Robin Matthews, Theme Leader

Preparing rural communities for a low carbon future by helping break the link between economic prosperity and greenhouse gas emissions

With global population predicted to increase to around 9 billion people by 2050, concomitant increases in demand for food, water and energy against a backdrop of climate change, urbanisation, limited land resources, and the need to reduce greenhouse gas emissions, there is growing concern that the planet's limits are being reached and that a move to a more sustainable and equitable way of living is urgently required.

Seventy-five per cent of the global population is projected to be living in urban environments by 2050, but with the need to preserve enough land to provide food and other ecosystem services, rural/urban interactions are likely to become more important. Historically, rural communities throughout the world have experienced relative disadvantage in earnings compared to urban counterparts, a trend which has only recently been reversed in parts of some developed countries.

In developed countries, past dependencies on primary industry have reduced and rural areas are now much more like urban areas in their economic structure, albeit with more small/medium enterprises. In many developing countries, however, stimulating growth in the rural sector is seen as the route to stimulating growth in the whole economy and thereby reducing poverty. In both cases, there are large spatial variations in wellbeing and a range of social, economic, institutional and environmental factors mediate the pursuit of sustainable development. Further, the traditional practice of public support to rural areas primarily through the farm sector is increasingly challenged by the Organisation for Economic Co-operation and Development's (OECD) territorial approach, which builds development strategies around multi-sectoral territorial development.

Alongside these rural socio-economic challenges, mitigation of and adaptation to climate change is becoming increasingly factored into policy making and land use decision making. Addressing poverty and disadvantage through low carbon interventions in developing countries, is central to, for example, the Department for International Development's (DFID) and other aid agencies' missions.

In Scotland, although it contributes only around 0.2% of global greenhouse gas emissions, per capita emissions are relatively high. The country, therefore, has a moral responsibility to reduce its carbon footprint and to demonstrate to the rest of the world that this can be done in a sustainable way. In 2009 the Scottish Government passed the Climate Change (Scotland) Act committing the country to a target for reduction of greenhouse gas emissions of 42% by 2020 and 80% by 2050. The Climate Change Delivery Plan (June 2009) noted the role of rural land use in contributing to emissions and the measures that can be taken within the agriculture, land use and forestry sector to deliver targets, particularly to protect high carbon soils, restore degraded peatlands and to increase forest cover to 25% by 2050. Scotland also has obligations to contribute to the UK's monitoring and reporting of greenhouse gas emissions and to the emission reductions required by Annex 1 countries of the Kyoto Protocol. As part of this, the impact in other parts of the world of Scotland's choices in moving to a low carbon future on greenhouse gas emissions also needs to be evaluated.

Approach

The challenge, both globally and in Scotland, is to move to a more sustainable development path, maintaining or increasing food production and the provision of other ecosystem services, while at the same time reducing net greenhouse gas emissions from human activities and enhancing livelihoods and social equity.

We contribute to addressing this challenge by identifying and improving understanding of the factors that encourage and enable sustainable development in rural areas, including endogenous bottom-up approaches. We examine current policy interactions, conflicts and synergies, and explore alternative future policy scenarios and assess their consequences on the farm, rural and wider economies. We will also contribute to improving the evidence base for monitoring progress towards a net reduction of greenhouse gases in rural areas, recognising the global footprint of rural consumption as well as the emissions and carbon stores associated with the rural land use sector, and by assessing options for increasing use of renewable energy and sequestration of carbon in vegetation and soils. We enhance our understanding of the perceptions, attitudes and behaviours influencing individual decisions and social norms regarding the adoption of these options, evaluate the governance, institutions and policy and incentives needed to ensure their uptake, and assess the implications of these for community vitality.

These issues are complex, often involving social, economic and biophysical perspectives, and therefore require inter-disciplinary socio-ecological systems (SES) approaches to address them rather than a piecemeal approach dominated by either the social, economic or biophysical sciences. For this reason, the Nurturing Vibrant and Low Carbon Communities theme aims to draw on the expertise of researchers from all of the five science groups where appropriate. We are using a range of approaches, from qualitative research to better understand the functioning of formal and informal governance mechanisms in key rural institutions, through to quantitative research, including modelling and scenario analyses, to formalise our understanding of social, economic and biophysical processes and their interactions, and how they influence trajectories to a sustainable future. We take a global perspective by seeking synergies between experience gained in Scottish agricultural, forestry, moorland, grassland and peatland systems and that from similar systems in other parts of the world.

Examining possible changes in soil C stocks following the resampling of the National Soils Inventory of Scotland

The change in soil carbon stock over around 25 years has been measured at 179 sites on a 20 km grid as part of the National Soils Inventory of Scotland (NSIS) resampling. There was no detectable change in total soil carbon stock (to 100 cm depth) overall or within specific vegetation or soil types. The exception was for woodland soils, excluding those on deep peat, which exhibited a significant gain of 1.0 t C ha^{-1} $year^{1}$. Woodland (mainly coniferous plantation) also showed a significant increase in percentage carbon, a significant decrease in bulk density and an increase in the depth of the LFH layer (accumulating pine needles). Recalculating the C stock to 15 cm showed a significant increase in moorland soils in addition to woodland soils, suggesting that had we only sampled to 15 cm, we would have reached a different, possibly misleading, conclusion. Ap horizons (i.e., cultivated top soils) increased in depth from 29 to 32 cm, with a concomitant decrease in %C and a slight increase in bulk density; this we ascribe to deeper, or more efficient, ploughing. In the context of possible soil carbon losses, our data shows that a loss of 0.09% per year is unlikely (P=0.05) and that a loss of 0.18% per year is very unlikely (P=0.01).

Understanding and managing rural conflicts: the case of outdoor access

How to increase the uptake of outdoor access opportunities (and provide associated health and economic benefits) while meeting agricultural and conservation land management objectives, is a key challenge for rural policy, especially given the history of

conflict between recreational and other land uses. Our research addresses the crucial issue of identifying formal and informal governance mechanisms for mediating, resolving and avoiding such conflict. During 2011 we used observational and novel mobile video methods to do the following:

- Identify and assess the frameworks, tools and deliberative (and other) processes involved in the functioning of a Local Access Forum. Provisional findings were presented to the Cairngorms Local Outdoor Access Forum generating subsequent requests to share the findings with other stakeholders, including the Cairngorms National Park Authority Board and the National Access Forum
- Deepen understanding of how conflicts of recreational disturbance of wildlife and livestock arise (and could be prevented), through:
  - demonstrating how knowledge of rights, rules and codified protocols are necessary but insufficient for achieving 'responsible' outdoor access
  - identifying some of the key social, environmental and human-animal interactional factors that shape how (ir)responsible practices occur
  - highlighting the ways in which these factors are insufficiently taken into account when designing management interventions
- Disseminate insights to policy and practitioner audiences through the establishment of a Twitter feed (@outdooraccess) and through Scottish Natural Heritage's Sharing Good Practice event 'Dealing with Dogs!'
- Investigate tensions surrounding newer forms of recreation in environmentally sensitive areas using a case study of mountain biking in the Cairngorms National Park. Initial findings have been used to inform policy and provide direct advice for the revision of Scottish Outdoor Access Code supporting guidance.

Governance and decision-making for community empowerment in rural communities

The question of how rural communities can be empowered, or can empower themselves, is of key importance in this 'age of austerity' and the push to localism and the 'big society'. Researchers from the James Hutton Institute are working with colleagues at SAC to develop methods of understanding, improving and designing effective approaches to utilising local capacity to deliver vibrant rural communities, and to assess approaches to designing a place-tailored approach to rural policy.

A recent literature review of conceptual frameworks and methodologies relating to community vibrancy, empowerment and resilience highlighted the need to:

- Develop the concepts of vibrancy, empowerment, adaptive capacity, social capital, wellbeing, governance, institution decision making and resilience in rural communities
- Understand the key criteria through which interventions to enhance or support the capacity of rural communities are evaluated, including how outcomes can (or cannot) be attributed to specific interventions.

These concepts and methodologies will be evaluated through a series of case studies. The James Hutton Institute is leading a specific case study working with Orkney Housing Association and the Climate Challenge fund to look at the social effects of installing energy monitors in domestic homes.

Meeting the Scottish Government's woodland expansion targets

The James Hutton Institute, in collaboration with Forest Research, has been providing advice to the Woodland Expansion Advisory Group. It was established by the Scottish Government to take forward the initiative within the Land Use Strategy to expand woodland cover in Scotland to 25% by sometime in the second half of this century. A range of biophysical, policy and designation issues have been examined in relation to the opportunities and constraints that they provide for woodland expansion. Almost half of Scotland is seriously constrained because of unacceptable growing conditions for tree growth or because of different policy drivers related to protecting prime agricultural land for food production and peat deposits for carbon storage precluding large scale expansion. Other areas are designated for their open ground habitats and associated wildlife and woodland expansion is likely to be constrained here as well.

The net result is that woodland expansion is likely to focus on a relatively small proportion, approximately a third of the Scotland land mass: 'the squeezed middle'. This currently contains a mix of land uses from arable land to poor rough grazing. Notably much of the improved grassland resource in Scotland is found in this area and any new woodland onto it would have implications for the livestock industry in Scotland. Additionally current research suggests that this type of ground might become more flexible in terms of agricultural production in a warming climate.

This work provides a valuable context for research in a number of our themes and helps focus where there are most opportunities to achieve multiple benefits from land; many areas simply do not have that flexibility. How do we optimise and reward land management activities that maximise carbon sequestration but at the same time provide the range of other services that we expect from land? Our multi-disciplinary approach to research puts us in an excellent position to explore a range of scenarios to examine trade-offs between these services but within the real world context of the biggest anticipated land use change in the country.

Restoring Scotland's peatland

The agriculture, forestry and land use sector has an important role to play in meeting the emissions reductions targets of the Scottish Government, as it acts both as a source of greenhouse gas emissions as well as a carbon store, contributing about 20% of total greenhouse gas emissions but removing about 16%. A major part of this includes land use changes on peatlands. Discussions at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) meetings are currently underway to include accounting for emissions from peatlands in any post-2012 climate change agreement, so that they would be included in the Agriculture, Forestry and Other Land Uses (AFOLU) chapter of national greenhouse gas inventories, and in the creation of internationally accredited carbon credits. Scotland contains about two million hectares of peatlands, 60% of which are degraded due to drainage and use for agriculture and forestry. Restoration of these areas could potentially represent sequestration of considerable amounts of carbon. Consequently, the Scottish Government has identified peatland restoration as a key milestone in its commitment to meet its 2020 and 2050 greenhouse gas emission reduction targets. (Low Carbon Scotland: Meeting the Emissions Reduction Targets 2010–2022. The Report on Proposals and Policies.)

There is, however, a huge amount of uncertainty in current estimates of abatement potential of peatland restoration. This is complicated still further by the predicted increased temperatures and decreased precipitation of future climates, making peatlands vulnerable to increased oxidation of the organic carbon they contain, which could potentially release significant quantities of CO_2 into the atmosphere. Work is continuing within the Nurturing Vibrant and Low Carbon Communities theme to reduce some of this uncertainty. Key points that have emerged from the work so far include the following.

- Net potential abatement benefits from peatland restoration, given our wide span of values for near-natural and damaged sites could range from 0.6 to 8.3 t CO_2e ha^{-1} $year^{1}$.
- Values at the lower end represent restoration C savings of the least damaged sites, which may be achievable within less than a 10 year timeframe after restoration efforts. In addition, early intervention on such less damaged bogs also prevents further progression to a more damaged, and more highly emitting, state. Values near the upper end apply to the restoration benefits of severely damaged sites but these will take longer to stabilise (20– 50 years) and temporarily high methane emissions may limit early carbon savings.
- A precise figure for the area in Scotland that has the potential for some degree of change in management or active restoration is not available but is likely to be in excess of one million hectares of which around 350,000 ha may be in the 'severely damaged' category of previously cutover, eroded, severely drained or afforested peatlands that would require active efforts to restore.

Reducing Emissions from Deforestation and Degradation (REDD)

Deforestation represents an estimated 15-20% of anthropogenic greenhouse gas emissions; greater than that from the whole global transport sector. The 2007 Stern Review concluded that reducing deforestation is a highly cost-effective way to reduce net global emissions relatively quickly, as well as providing co-benefits in terms of soils, water, climate protection, protection of biodiversity and livelihoods, rights of local communities and sustainable forest management. The concept of reducing emissions from deforestation and degradation (REDD), in which non-Annex 1 countries could voluntarily choose to reduce their national emissions from deforestation and gain carbon credits at the end of a commitment period that could be sold on international carbon trading markets or to other governments, thus earning income for the country, has been receiving much attention at UNFCCC meetings. The REDD-ALERT project, led by the James Hutton Institute in partnership with 12 research institutions in Europe, Africa, Asia and Latin America, aims to contribute to the evaluation of mechanisms and the institutions needed at multiple levels for changing stakeholder behaviour to slow tropical deforestation rates and hence reduce greenhouse gas emissions. The project focuses on case study areas in Indonesia, Vietnam, Cameroon and Peru, which represent different stages of forest transition, to document the key drivers of deforestation and land conversion. At each of the field sites, data has been collected on deforestation rates, deforestation drivers, socioeconomic variables, soil and biomass carbon contents and greenhouse gas emission rates from selected land use transitions. An analysis of forestry-related policies at the international level is being made to investigate conflicts and synergies, and potential REDD mechanisms are being identified for influencing deforestation behaviour at the local level. Agent-based modelling is then being used to integrate this social, economic and ecological information to evaluate impacts of climate change, the potential REDD policy levers and possibly shifts in food crop versus bioenergy demand on land use change in tropical forest margins.

There are two major issues that must be addressed: firstly, the way a continuum of tree densities in the landscape is forced into a forest/non-forest dichotomy, with substantial areas of land around the cut-off point of any definition; and secondly, the institutional rather than vegetation-based interpretation of 'forest' that exists in many government agencies that are the source of internationally available data. An example is the FAO and UNFCCC definition of forest, which can include 'forests without trees' (harvested, but with an intention of replant), while 'trees outside forests' (not meeting the shape and size of area, canopy cover, or tree size aspects of the operational forest definition), agroforestry trees, and tree crops tend to be excluded. He says there is 'growing awareness' that the national reporting systems in tropical forest countries need to be improved to cater for 'whole system carbon accounting', and treat the 'forest' issue as a subset of this, depending in the rules that will emerge in international discussions. Work by the REDD-ALERT collaboration has developed a hierarchical land cover classification subdivided into 'forest', 'tree-based systems' and 'open-field agriculture' categories in a stepwise fashion towards locally meaningful entities. The project team are now working on developing new negotiation support tools. One example of such a tool is a carbon calculator for exploring the greenhouse gas emission consequences of different land uses on peatlands.

Mr Michael Gibson (left) Chair of the Macaulay Land Use Research Institute and Mr Peter Berry CMG (right) Chair of SCRI sign legal documents forming the James Hutton Institute with Mr Ray Perman who was appointed Chair of the James Hutton Institute.

Iain Gordon addressing press in Dundee on launch day.

Mr Anthony Aglen, a direct descendant of James Hutton was a guest for our launch reception at the Royal Society of Edinburgh.

Review of the Year

Phil Taylor, Head of Communications

On 30 January 2008, First Minister Alex Salmond announced to the Scottish Parliament that, "Scotland's environmental research capacity will be strengthened and its international competitiveness enhanced by encouraging our environmental and rural research organisations – notably the Macaulay and Scottish Crop Research Institutes – to form a new single Institute."

From that moment, service teams at the two sites began devoting an increasing portion of their time to planning for the new, unified organisation. By the beginning of 2011, detailed planning was underway to achieve business continuity from the very first day of the new James Hutton Institute.

When did the heart of the James Hutton Institute start beating? Was it upon the appointment of our Chairman, Ray Perman, in March 2010? Was it the selection of Professor Iain Gordon as our Chief Executive in July that year? Or was is when Professor Lesley Torrance suggested we name our Institute after the Scottish Enlightenment hero, Dr James Hutton in late August 2010.

Whatever the answer, for the 600-plus staff of the new Institute, many months of hard work resulted in the official launch of the James Hutton Institute on 1 April 2011.

The organisation's logo was created by our in-house graphic design team, adding the strapline Science Connecting Land and People. The equally spaced vertical segments in the logo show structure and foundation. This, together with the horizontal segments, hint at 'unconformity in land' one of the many discoveries made by James Hutton as he studied the land and its potential. The landscape and water are illustrated in the waved lines of the logo. The purple (heather) is to symbolise the Scottish roots of the James Hutton Institute. The design can be interpreted as geological strata, as field plots or as runrig in traditional Scottish farming and crofting.

The public launch of the Institute was held at the Royal Society of Edinburgh on the capital's George Street. Guests attending the reception in the 'Hutton Room' were able to examine the orginal manuscript of Element of Agriculture which was on show for the evening.

The then President of the RSE, Lord Wilson of Tillyorn, reminded the audience that Hutton was a founder member of the Society in the late eighteenth century. The use of the Hutton's name for the Institute was entirely approved by the Society, said Lord Wilson, and he wished the new "very significant" organisation very good fortune.

Another speaker at the launch was Denise Daly Walton, an authority on the life and times of James Hutton. She told the gathering, "I can honestly say for all of us who have worked over the last years to bring James Hutton into common knowledge that this is the ultimate in recognition that he so justly deserves. His name will now be carried with every communication and every service emanating from this new, super-institute onto the global stage."

One of the first stakeholder events to be hosted by the newly formed James Hutton Institute was the second EU REFRESH project meeting held at Craigiebuckler, Aberdeen. It was attended by just under 100 delegates who spent a week developing research plans for measures that might minimise the adverse consequences of climate change on freshwater quantity, quality and biodiversity.

The arrival of summer brought with it some staple events including LEAF (Linking Environment and Farming) Open Farm Sunday which was held on the Dundee site – a LEAF Innovation Centre. The special guest was scientist Dr Heather Reid OBE who gave several of her informal lectures on meteorology. With her experience in the television industry, Heather had earlier agreed to present a video about the plans for the James Hutton Institute which was used at our launch events and throughout the year.

One of the biggest public engagement events in our calendar is the Royal Highland Show (RHS). The corporate display together with Scottish Agricultural College (SAC), in the Scottish Environment and Rural Services (SEARS) marquee and in the Royal Highland Education Trust building, entertained an astonishing 7000 children between Thursday and Sunday. Iain Gordon and his management team engaged with special guests including an official delegation from China's Jilin Province – home to 27 million people. Other VIPs paying us a visit included the Scottish Secretary, Michael Moore, the then Scottish Conservative leader Annabel Goldie and the Holyrood Environment and Climate Change Minister, Stewart Stevenson, who spent time engaging with the James Hutton Institute team.

The Minister was soon back with us visiting the Institute's Glensaugh Research Station in August to find out more about issues affecting moorland areas. The visit was jointly arranged by the James Hutton Institute and the Moorland Forum and aimed to highlight the work being undertaken by the two bodies, as well as the practical measures the research station undertakes with regard to upland hill farm management.

As the first months in the life of the Institute rolled by, we hosted the annual meeting of the Scottish Society for Crop Research (SCCR). SSCR functions through its crop sub-committees for combinable and energy crops, potatoes and soft fruit. You can read of their work elsewhere in this Annual Report and SSCR continues to support vital research work at the Institute.

Long-established and growing industry events held on the Dundee site got a new lease of life under the James Hutton banner: Fruit for the Future and Cereals in Practice attracted good turn outs and incredibly, record rainfall and serious flooding did little to deter a record attendance at Potatoes in Practice. The event is co-hosted with Potato Council at our Balruddery Farm in Angus and drew a large number of visitors, including guests from Norway, France and China as well as farmers and agronomists from England.

The new organisation also managed to show its colours at many other events during 2011, both large and small:

- A Hutton Berry Festival at the Royal Botanic Garden Edinburgh
- Dundee Flower and Food Festival
- The Fourth International Workshop on Barley Leaf Blights attracted 75 delegates from all over the world
- British Potato 2011 in Harrogate in company with Mylnefield Research Services
- Macaulay Scientific Consulting Ltd (MSC) successfully showcased its analytical services at the Offshore Europe Exhibition at the AECC, Aberdeen
- The Science and Parliament event at Holyrood hosted by the Royal Society of Chemistry
- The first ever wood ant symposium organised by the National Wood Ant Steering Group of which the Institute is a partner.

In the autumn, at the request of the Scottish Government, the Institute co-ordinated a day-long workshop on the impact of climate change on agriculture. Once again we were delighted to welcome the Scottish Government Minister for Environment and Climate Change, Stewart Stevenson MSP.

Speakers from the James Hutton Institute included Colin Campbell, Iain Brown, Willie Towers, Adrian Newton and Robin Matthews. Other speakers came from the Scottish Government, SAC, the Rowett Institute of Nutrition and Health and the Moredun Research Institute.

Among the audience were policy officials from the Scottish and UK Governments, scientists and representatives from food and farming bodies including the National Farmers Union Scotland. There were also delegates from the devolved administrations in Wales and Northern Ireland.

Dundee also welcomed a group of senior Ukrainian government officials. Led by the vice-Governor for the Lviv region, Ivan Stefanyshyn and Ivan Bilak, the Head of Sambir District State Administration, the group was on a tour of Scotland organised by Continental Farmers Group, which operates 70,000 acres of arable land in the Ukraine.

The James Hutton Institute continued to make the news headlines. Evelyne Delbos, who works with Macaulay Analytical and the Scanning Electron Microscope in Aberdeen, found herself at the centre of media attention after the renewed volcanic disturbances in Iceland. Evelyne's analysis of samples from the ash plume featured

on the BBC News website and she was interviewed by the Press Association and several other outlets.

There was global media coverage of the mapping of the potato genome. This global collaboration was led in the UK by Dr Glenn Bryan and his team at Invergowrie. Glenn Bryan and Commonwealth Potato Collection assistant curator Gaynor McKenzie talked to the Channel 4 News Science Correspondent Tom Clarke in a news feature broadcast soon after the story broke.

Institute specialists helped BBC Scotland's Beechgrove Garden investigate the science of soils. Presenter Jim McColl joined Jason Owen in the laboratories in Aberdeen where Jason had set up some experiments to show what effect organic matter has on soil drainage.

Winners at the 2011 Postgraduate student competition. Front from the left: Nicola Cooke, Florian Jupe and Hazel Bull. Rear from the left: Howard Davies, Nigel Kerby and John Jones.

Looking back on the first year of the James Hutton Institute, you could be forgiven for seeing a busy – but fairly routine 12 months in the life of a scientific research institute. What makes the story rather more remarkable, perhaps, is that this energetic schedule of activity and engagement with stakeholders from many sectors was maintained during a process of fundamental change for all our staff in Aberdeen and Dundee.

Playing the Colonise game with children at the Royal Highland Show.

Biomathematics and Statistics Scotland

Professor David A. Elston, Director

Improving science and society through an understanding of variation, uncertainty and risk

Biomathematics and Statistics Scotland (BioSS; www.bioss.ac.uk) is one of the Scottish Government's main research providers, delivering research, consultancy and training in statistics, mathematical modelling and bioinformatics. BioSS plays a unique role in the Scottish research community, bridging the gap between research in the mathematically-based and traditionally more qualitative sciences. Although formally part of the James Hutton Institute, BioSS interacts scientifically with all of the MRPs and indeed with other institutions as if it were an independent organisation.

The scientific projects that BioSS staff contribute to cover four broad application areas: *plant science; animal health and welfare; ecology and environmental science; and human health and nutrition.* We also conduct a programme of applied strategic research to address generic issues encountered in these application areas. Our research is managed in three broad themes: *statistical bioinformatics*; *systems and process modelling*; and *statistical methodology.* The additional capacity gained from our research ensures that the methodological approaches adopted in our applied work are constantly advancing.

Analysis of omics data

Understanding the complex molecular interactions taking place within plant cells is an important activity at the James Hutton Institute, enabling researchers to learn about the processes which control economically important traits of crop plants such as flavour. Transcriptomics allows us to study the molecular interactions controlled by plant genes, proteomics allows us to quantify the number and levels of the proteins expressed in an experiment and metabolomics measures the great many different types of smaller molecules called metabolites involved in the growth and development of plant cells. These omics technologies utilise a variety of modern lab equipment such as microarrays, 2D gels and gas chromatography-mass spectrometry (GCMS), providing estimates of the presence and concentrations of features in the cells of plants of different varieties, at different stages of growth or growing in response to different nutritional treatments.

Having determined which features are to be considered as responding to a factor or factors of interest, a second issue is how to present the results from so many analyses. We have developed a cluster analysis approach, whereby the subsets of features that are considered to be responding to the factors of interest are clustered into groups which appear to be responding to the factors in similar ways. Profile plots of feature mean values for the different levels of the factor of interest allow visual examination of similarities and differences both within and between clusters. Future work will investigate the estimation of false discovery rates for complex treatment combinations rather than the single treatment terms (Figure 40).

Predicting the effect of climate change on crop productivity

BioSS has been working with collaborators in the James Hutton Institute and Scottish Agricultural College (SAC) to develop an approach to using data from climate projections as inputs to plant–environment models in order to explore some important aspects of the potential effect of climate change. Simulated weather data were used to drive three different plant–environment models: CropSyst for spring barley, DNDC for grass production, and PALM for short-rotation coppice. This work was done as part of a Scottish Government-funded cross-cutting theme project to take a co-ordinated approach to learning how best to use the capabilities of UKCP09, the UK Government's state-of-the-art resource for providing projections of future climate and associated simulations of weather.

Within this project, we took a stratified random sampling approach to selecting 100 from the 10,000 potential future climates available under the IPCC A1FI (high emissions) scenario for any specified 5 km by 5 km square in Scotland. The stratification, which was on projected spring temperature and summer rainfall, ensured balance with respect to two important determinants of plant growth. For each specified 5 km by 5 km square, we generated 30-year series of simulated daily weather for each selected future climate, and used these weather data as inputs for each model, resulting in 3000 simulated annual yields of spring barley and grass cut for silage. Due to the need for an establishment period and triennial cutting, we only had eight short-rotation coppice yields per future climate.

As expected, the three different crops showed different mean responses to the stratification of climate samples: cut grass yields and coppice yields responded positively to increasing spring temperature, whereas spring barley yields responded negatively to increasing spring temperature. More interestingly, we were able to perform variance components analyses to examine the relative contributions to the variation in the simulated yields made by uncertainty about the future climate and by annual variability in weather. For example, when analysing yields

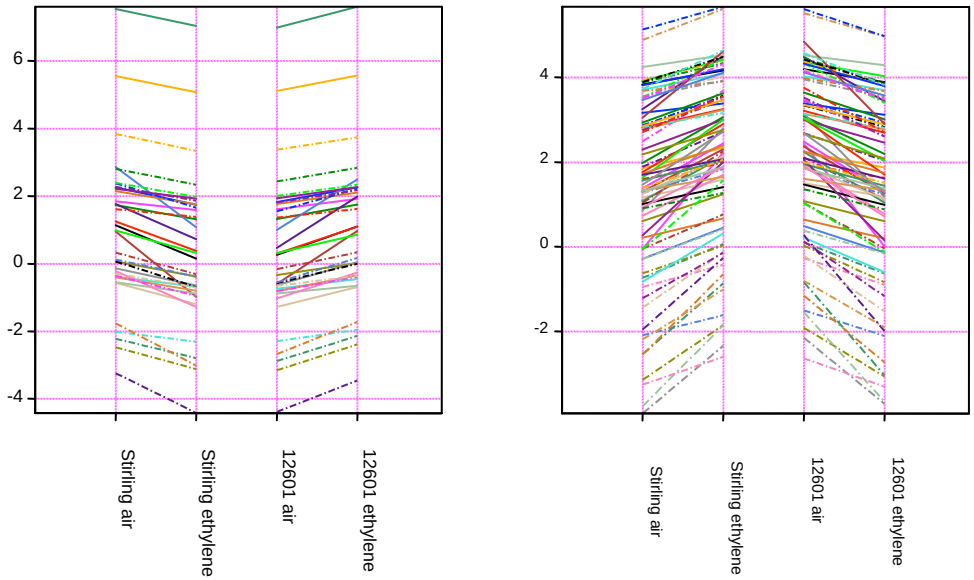


Figure 40 Analysis of omics data. Vertical axis: Standardised expression levels. The data in the figure display standardised mean expression levels of genes in a microarray experiment selected as displaying an interaction between the two factors: treatment (air, ethylene) and genotype (Stirling, 12601). The left-hand panel shows results from the cluster in which ethylene caused a reduction in mean expression level for Stirling but an increase for 12601: the right-hand panel shows results from the cluster in which ethylene caused an increase for Stirling but a decrease for 12601.

produced using simulated weather data from projected climates for the 2080s, we found that the residual variation within 5 km by 5 km squares reduced by 26% for total silage yield and by 62% for spring barley yields when a random effect for climate projection was added to the model: the corresponding ratios of variance components for climate projection to residual were 0.35 and 1.63. Although there are many caveats relating to these results, the broad interpretation is that, relative to inherent variation between years, the particular trajectory followed by our future climate will be less important for silage yields than for spring barley yields. More work along these lines will be carried out in the new Centre of Expertise on Climate Change (ClimateXChange).

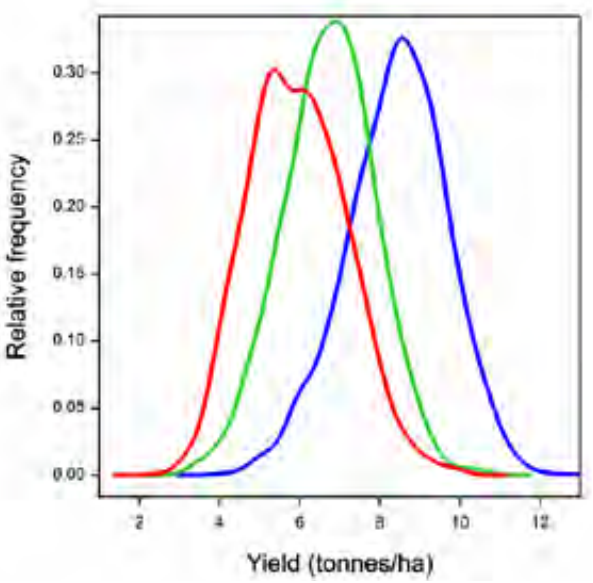


Figure 41 Kernel density estimates of the distributions of spring barley yields for the 5km by 5km square containing Mylnefield near Dundee. Yields were calculated from the Cropsyst model using UKCP09 simulated weather data for each of three time periods: before the onset of climate change (blue); and using projected climates for the 2040s (green) and 2080s (red) under a high greenhouse gas emission scenario.

Mylnefield Research Services Ltd

Nigel Kerby, Managing Director
Jonathan Snape, Commercial Director

Mylnefield Research Services Ltd, is a leading technology company providing products and services to the agricultural, horticultural and environmental sectors realising the potential resources of the James Hutton Institute.

Introduction

Mylnefield Research Services (MRS) Ltd was established in 1989 as a wholly owned subsidiary of Scottish Crop Research Institute and began trading in 1992. It was established to generate commercial income, diversify the funding base and reduce the reliance of SCRI on Government funding. This remit is just as relevant today for the James Hutton Institute as it was in 1992. A significant proportion (determined by the Board of Directors) of profits made by MRS have been transferred to SCRI (and now the James Hutton Institute) and the Mylnefield Trust through Gift Aid. MRS has made a profit every year and carries out its activities without subsidy. On the 1 April 2011 the ownership of MRS transferred from SCRI to James Hutton Institute. Ray Perman was appointed as Chairman and Iain Gordon and Julia Brown joined the Board of Directors.

The mission of MRS is to assist the James Hutton Institute achieve its mission, namely:

To deliver the highest quality integrated and innovative science that contributes knowledge, products and services to meet the multiple demands on land and natural resources.

This is implemented in the following ways:

- Product development: building upon the scientific expertise that we have in cereal, potato and soft fruit crops to develop high-quality, innovative products
- Intellectual property: ensuring the appropriate exploitation of intellectual assets
- Partnership: encouraging commercial partnerships that benefit James Hutton Institute and provide routes to market for its products and services
- Knowledge Transfer/Exchange: focusing our knowledge transfer and exchange activities to maximise exposure and return.

Analytical services

The turnover from Mylnefield Lipid Analysis (MLA) in 2010/2011 was the same as the previous year (£350k). With the assistance of Marilyn Emery Consulting (MEC) Ltd, Claire Traynor and her team were successfully inspected by the Medical and Healthcare products Regulatory Agency (MHRA) and can now undertake analyses to Good Manufacturing Practice (GMP) standards as well as Good Clinical Practice (GCP). MLA is one of only a few specialist laboratories in the world able to offer this service and it has already generated new business from clients in Iceland, Ireland and North America.

Under the leadership of Professor Wolfram Meier-Augenstein, the stable isotope analysis business grew by 2% in 2010/2011 to reach £126k. In addition, MRS is a partner in a new Technology Strategy Board project with Rutherford-Appleton Laboratory and Protium MS, to develop a commercial laser isotope ratiometer for detecting food adulteration.

Associated businesses

MRS has a 47% shareholding in EnPrint Ltd, a company established in 2008 to commercialise the intellectual property generated from a Scottish Enterprise Proof of Concept project to develop laboratory-based molecular analysis service business focused on water quality. In 2011, EnPrint started work on a project co-funded by Scottish Water and the Technology Strategy Board to develop methods for analysing *Cryptosporidium* in drinking water. This project has attracted interest from other UK water companies.

Licensing and royalties

Royalty income declined by 8% compared to the previous year partially due to an 18% decline in the area of Glen Lyon planted in Spain and Glen Ample facing stiff competition in the UK from North American primocane varieties. Potato royalty income showed a modest increase and Lady Balfour – the UK No.1 organic variety, entered the top ten of UK export varieties for the first time.

Income from soft fruit accounted for almost 74% of all royalties with raspberries accounting for 45%, followed by blackberries 9%, blackcurrants 9% and strawberries 10%. 16% of royalty income was derived from potatoes and the remaining 10% from brassicas.

In 2011, one potato variety (Pioneer) was placed on the National List and four other potato varieties (two for the fresh market, two for processing) were entered into National List trials. Two raspberry varieties (Glen Ericht and Glen Cally) and one blackcurrant variety (Big Ben) were granted EU Plant Variety Rights and two raspberry varieties were granted Norwegian Plant Variety Rights. MRS sought Plant Variety Rights for two raspberry varieties in Norway, two blackcurrant varieties in the USA, one blackberry variety in Serbia, one potato variety in the EU and one processing potato variety in South Africa. A total of 13 new propagation licences were granted in 2011, including licences to growers in Uruguay and Serbia for the first time.

MRS now has a portfolio of 45 varieties that are licensed to 103 propagators/growers in 28 countries. In addition, there are currently more than 100 trialling and testing agreements for varieties bred at SCRI by MRS. As a result of the merger between SCRI and Macaulay Land Use Research Institute in April 2011, and the resulting change of ownership of MRS, all of these companies had to be contacted and informed of the change in early 2011.

Contract research

Despite the recession, income from contract research managed to grow by 32%. This strong performance was made possible by several new contracts starting in 2011 including a major new Technology Strategy Board project developing potato breeding tools based on association mapping and genomic sequencing. Other new contracts included a project to isolate genes important for carotenoid production in potatoes, a new contract from the HDC on onions and efficacy testing of crop protection compounds on raspberry and spring barley.

Project management

In 2011, MRS expanded its commitment to manage large multi-partner collaborative research projects, especially those funded by the Technology Strategy Board and LINK. A dedicated project manager (David Somerville) was recruited to strengthen the MRS team and enable us to support more projects. A three day course on scientific project management was developed by MRS and delivered for the first time in November 2011 and will be repeated in future years.

Macaulay Scientific Consulting Ltd

Bill Donald, Commercial Director

Leading the way in environmental consultancy by offering unparalleled experience in soil, waters and land evaluation.

In the first year of the James Hutton Institute, and the period of major change that accompanied it, the Aberdeen-based Macaulay Scientific Consulting (MSC) Ltd maintained business as usual. The enterprise has continued to develop successfully its external income streams, particularly for advanced analytical services, with the objective of achieving the agreed business targets for the 2011/12 financial year.

Organisational background

Macaulay Scientific Consulting Limited is operationally centred at the Aberdeen site and offers a comprehensive range of advanced analytical laboratory services and environmental/land use consultancy services to private and public sector customers.

MSC was formed in April 2008, following rationalisation of the previous, MLURI commercial business vehicles, Macaulay Enterprises Limited (MEL) and Macaulay Research and Consultancy Services (MRCS).

MSC operates as a shell company, with no directly employed staff or owned assets, essentially purchasing all analytical laboratory facilities and staff services from the Institute on an as-required time basis. MSC therefore leverages the benefits of the excellent analytical facilities at the Institute's Aberdeen site and draws on the extensive scientific knowledge and skill sets of its inter-disciplinary scientists for the benefit of its external customers.

Current business/operating environment

The MSC business has shown favourable, year-on-year growth largely due to the successful and focused development of its advanced analytical services despite the essential structural changes in the new Institute implemented during the year and the unfavourable economic climate which affected both private and public sectors. Science consultancy services in the areas of soil forensics and surveys, environmental studies for renewable projects and commercial land development have also contributed to the overall income generation of MSC, although income contribution is slightly down on previous year.

MSC is developing promising new technologies in the analytical services sector to support customer demands and to provide differentiation and uniqueness in its advanced services. For example, we have developed and implemented an advanced software analysis tool to greatly enhance our scanning electron microscopy capability. This provides better analytical data interpretation and presentation for the identification and monitoring of oilfield scales and reservoir produced solids. This is already positively received by our oilfield customers, saving costly interruptions to production operations and reducing equipment down-time.

We have seen an increasing demand for fast-track analytical services throughout the year, particularly from the oil and gas sector and for which we apply premium prices. These new technologies and fast-track services for existing and new customers will play a large part in fuelling growth for our advanced analytical services in the coming years.

Business review and outlook

MMSC has benefited from its strategic positioning in the advanced level of analytical and consultancy services markets as a reliable and experienced supplier, while maintaining diversity and applied relevance in its range of service offerings to industry and public sector organisations. Our customer base has grown rapidly with more than 200 active customers (from private and public sectors). Key sectors served include oil and gas, minerals (mining and processing), other commercial laboratories, other research organisations, food and drink processors, environmental consultancies and agencies, general industry (manufacturing, engineering, construction), governmental organisations, local councils, universities, consultancies (civil engineers/land surveyors), science societies, land owners and developers.

Not surprisingly, the major part of MSC business (33%) came from the North Sea oil and gas sector and opportunities to expand business in this key sector nationally and internationally continue to arise as the industry remains buoyant with a promising outlook. A significant amount of business came from other commercial laboratories (12%) and this supports our positioning strategy and focus on the advanced analytical services market.

The MSC business is projected to show at least 5% overall growth for the financial year ending March 2012, well supported by analytical services income (which is projected to grow by 14% in real terms) with a significant contribution from X-Ray Diffraction Analysis (XRD) work. Income from consultancy projects has been lower than previous years. Total income contribution to the Institute is projected to be in the order of £1.26 million. MSC also continues make a profit for the Institute.

During the year, strong marketing and promotional initiatives were implemented in order to continue to raise the profile of our specialist, advanced analytical and scientific services with direct marketing and sales campaigns mounted for target customers in key sectors. The initiatives also included attendance at industry-specific events such as Offshore Europe and All-Energy/Renewables Exhibitions and Conferences and AECC, Aberdeen and advertising campaigns mounted at Aberdeen Airport at key times during March and September. A significant number of new commercial customers were won and retained during the year which would indicate that our promotional and profile raising campaigns were effective.

Due to increasing demand, we are also planning to extend our clay mineralogy analysis and interpretation service (in a phased manner) beyond XRD analysis to include the physical testing of clays, minerals and associated mineral products.

The outlook for continued MSC income growth is therefore very favourable. This is projected in our operational budget plan for the 2012/13 financial year. Overall income is projected to be £1.532 million, an average increase of ca 8–9% over the forecast for 2011–12 (subject to consultancy income continuing to be channelled through MSC). A continuing significant contribution to the Institute's income and profit delivery is budgeted.

Continuing, stronger and customer-focused marketing and promotion initiatives will be required to deliver planned short term and longer term growth for the MSC business.

To support the growth in the commercial analytical business, there is also a need to review and probably extend the available capacity within the analytical sections of the Institute and this is being addressed. Given the current external business climate, this can only be beneficial to the Institute and its income generation plans.

Division of Plant Sciences, University of Dundee

Professor John W. S. Brown, Head of Division

Our main event in 2011 was the Quinquennial Review of the Division of Plant Sciences by an external review panel of Professors Sir David Baulcombe (University of Cambridge; Chair), Nick Talbot (University of Exeter), Alan Schulman (University of Helsinki) and Simon Turner (University of Manchester). The plant sciences' Principal Investigators (PIs) presented their research achievements and future plans and students and postdocs presented posters. The panel also met Professor Iain Gordon and senior scientists from the James Hutton Institute.

The Quinquennial Review report recognised the scientific excellence of the plant sciences PIs and their research programmes. They particularly praised the partnership with the James Hutton Institute and emphasised the added value to both institutions, rewarded by increasing successes in joint funding and publication outputs. After a positive review, the University of Dundee College of Life Sciences (CLS) and the division are delighted to reaffirm commitment to strengthen this partnership and build a strategy that extends and exploits our interaction for the future.

A major milestone has been establishment of the Dundee Effector Consortium (DEC), composed of research groups from the University and the Institute, which is studying effectors (proteins secreted by pathogens into plants to overcome immunity) from bacterial, fungal, oomycete, aphid and nematode pathogens and pests. This unique combination of systems under one roof allows members to share knowledge and technologies co-ordinate resource acquisition. The consortium has prepared grant and studentship proposals to support primary research and training, and to promote collaboration.

Paul Birch's research investigates the functions and recognition of RXLR effectors from the oomycete pathogen *Phytophthora infestans*, and the defence mechanisms that they manipulate in the host. Highlights in 2011 were the demonstration that the host target of *P. infestans* AVR3a is required for cell death triggered by various pathogens and that AVR3a is able to suppress all of these cell death responses. In addition, recognition of AVR2 by the host R2 protein depends on another host protein, BSL1, a phosphatase in the brassinosteroid signal transduction pathway.

John Brown's lab demonstrated that alternative splicing (AS) occurs more frequently in plants than previously thought – around 62% of intron-containing genes undergo alternative splicing, including genes involved in virtually every aspect of plant development and stress responses. In addition AS can regulate gene expression and features of transcripts which lead to reduced transcript levels were identified. This regulation was found to be important in a range of regulatory genes and, in particular, in the circadian clock which controls and optimises plant growth and metabolism.

Claire Halpin leads the University of Dundee/James Hutton Institute part of the BBSRC Sustainable Bioenergy Centre and had a successful review and site visit in 2011. In collaboration with Robbie Waugh, excellent progress has been made in association mapping in barley to identify QTLs for traits including grain yield, straw biomass, and amount of sugar released from straw by saccharification. The Global Climate and Energy Project (GCEP) programme, with Gordon Simpson, has discovered several novel genes with previously unrecognised roles in lignin biosynthesis.

Edgar Huitema's lab is studying the processes that govern translocation of a class of effector proteins called Crinklers and their role in infection by asking which host proteins are targeted. An interesting observation is that all Crinklers appear to go to the plant nucleus, leading to the intriguing suggestions that key nuclear host proteins and processes may be disrupted by *Phytophthora*. Complementary to these efforts, his group is using *P. capsici* in comparative studies with *P. infestans* to examine what determines host range of these pathogens.

Gordon Simpson's lab, which produced a seminal paper in *Developmental Cell* on the function of FPA as a regulator of RNA 3' end formation, has used direct RNA sequencing to determine, for the first time, signals in plant genes which control polyadenylation. This has led importantly to a reappraisal of current ideas about the degree of non-coding RNA transcription in the genome and the frequency of for example anti-sense transcripts. This has led to a major new grant from BBSRC to investigate the non-coding RNA genome of plants.

Andy Flavell has developed association genetics approaches for exploiting natural barley diversity for breeding, in collaboration with colleagues at the James Hutton Institute. A bottleneck in gene-identification and breeding is the high proportion of barley genes that are trapped in heterochromatic chromosome regions with low recombination. Unlocking these genes will expand the genetic variation in the barley gene pool. A BBSRC grant will begin in 2012 to understand the genes in these areas and the factors involved in this genomic compartmentalisation.

The CLS won the BBSRC Impact with Excellence competition in 2011. Claire Halpin was one of two PIs responsible for driving the CLS entry and many Plant Sciences staff contributed. Staff of the Division at all levels have been active in public engagement, participating in the CLS Doors Open Day (part of the Dundee Science Festival) and other events. Claire Halpin and Gordon Simpson presented their work at the Edinburgh International Science Festival. Finally, several of our students won prizes for research talks at various events.

The Scottish Society for Crop Research

Dr Bill Macfarlane Smith

The Society is the successor to the Scottish Society for Research into Plant Breeding which was established in 1921 to set up and run the Scottish Plant Breeding Station in Edinburgh. Over the years, it has had a strong and very close relationship with first SPBS and then, in 1981, with the newly created Scottish Crop Research Institute (SCRI). However, at that time, the Society relinquished its role in the direct running of the Institute.

Very recently with the creation of the James Hutton Institute, the Society has been reviewing its role, and this will be an ongoing process for the foreseeable future. Giving further emphasis for this need to review, has been the marked increase in communications from farmers and other end-users, over the future of research in Scotland and whether or not there will be a continuation of the past support. In this specific context, the Society sees a need to continue and expand its interface role between scientists and end-users, and to continue to assist in its role with knowledge transfer.

Currently, the Society provides a link between the James Hutton Institute and farmers, processors and other interested bodies.

Currently, the Society provides a link between the James Hutton Institute and farmers, processors and other interested bodies:

- By supporting field events in the summer and meetings during the winter, for the exchange of information
- By financing science-based publications for the benefit of the membership
- Through the formation of crop-based sub-committees which maintain contact with members on specialised topics
- By funding research at the Institute which is either ‘pump-priming’ to initiate new research, or work for minority interests that the large funding bodies would not support
- In helping to fund sabbaticals for scientists who wish to work for periods of up to a year at the James Hutton Institute.

The Society also has a role in raising awareness of items of interest and concern to the agriculture, horticulture and forestry industries. At the moment, this is achieved by funding the Annual SSCR Lecture given by people prominent in the industry, immediately following the Annual General Meeting. The 2011 Annual General Meeting was held on Wednesday 25 May and the Annual Lecture was given by Professor Iain Gordon, recently appointed Chief Executive of the James Hutton Institute.

The Society currently supports research on a range of topics, with funding being made available on an annual basis for work selected by the three crop sub-committees. Reports on the outcome of research funded in the past by SSCR, are provided on the Society's website (http://sscr.co.uk). Funding is also provided for a keynote speaker at the Crop Protection Northern Britain Conference.

Cereals in Practice was held on 5 July 2011 at the Institute's Balruddery Farm, attended by growers, processors, end-users and scientists. This event combined the research and practical demonstrations of the work of James Hutton Institute and Scottish Agricultural College (SAC) scientists, and again included demonstrations of new varieties, new husbandry methods and displays of machinery.

The Fruit for the Future event was held on 14 July 2011, and attracted breeders, growers, end-users and processors. New selections of raspberries, strawberries, blackcurrants, and gooseberries were displayed, with the opportunity provided for the tasting and evaluation of prospective new varieties of raspberry.

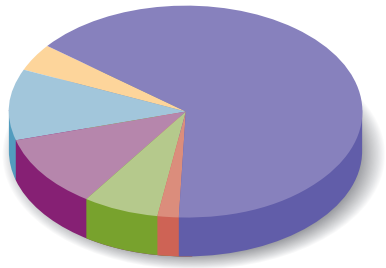
Potatoes in Practice was held on 12 August 2011 at Balruddery Farm. This was attended by growers, breeders, scientists and advisers. Perhaps due to the difficult and continuing economic problems, there was enormous interest in new research, new cultivars and on new methods of crop husbandry. The focus of interest was very much on how growers might control and reduce their input costs. Support was again provided by the Potato

Council, SAC, Masstock Arable (UK) Ltd, the James Hutton Institute and the Society.

The Potato, Combinable Crops and Soft Fruit Crop Sub-Committees held other half day meetings during the year to provide information on current research and to permit continuing interaction between end-users, growers, processors and scientists. These meetings were supported by over 200 people in total.

At its AGM on 25 May, acting Chairman for the day, Mr Ian Ivory, re-iterated the Society's views on the important role it could play in the future, and expressed his thanks to previous Directors and staff of SCRI, SHRI and SPBS, for the tremendous contributions they had made to agriculture, horticulture and forestry, both in Scotland and the wider world. Presentations had been made earlier to the retiring Director of SCRI, Professor Peter Gregory, and to the Society's Honorary Treasurer, Dr Neil Hattersley. Mr Andrew Logan stood down after 41 years' service as a member, on the Society's Committee of Management and as a Trustee and was thanked by Mr Ivory for his sterling contribution.

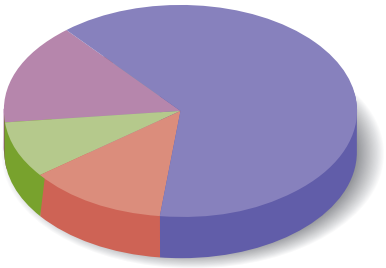
Accounts



Income

- RESAS – revenue
- RESAS – Voluntary Exit
- RESAS – capital
- Research grants and contracts
- Trading income from subsidiaries
- Other income

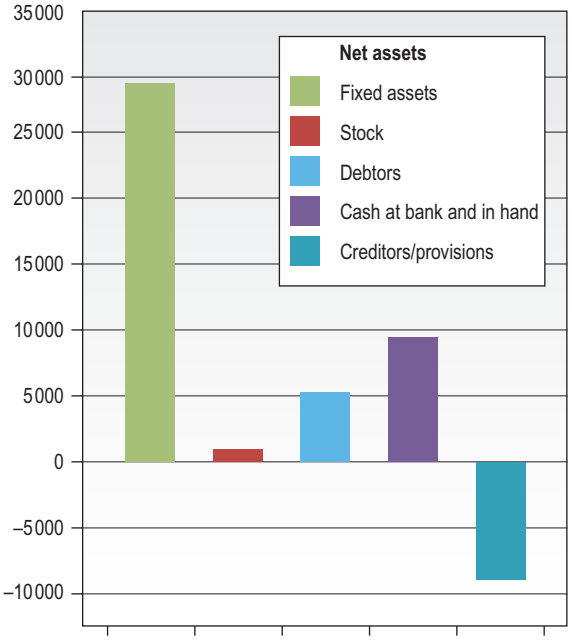
Income 2011–2012		
	£,000	
RESAS - revenue	24,524	63%
RESAS - Voluntary Exit	951	2%
RESAS - transition costs	0	0%
RESAS - capital	3,101	8%
Research grants and contracts	4,299	11%
Trading income from subsidiaries	4,313	11%
Other income	1,643	4%
Total income	**38,831**	

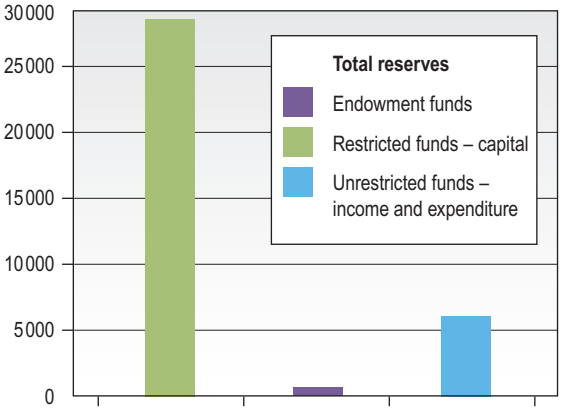


Expenditure

- Staff costs
- Scientific consumables
- Depreciation
- Other costs

Expenditure		
	£,000,	
Staff costs	24,413	63%
Scientific consumables	4,847	13%
Depreciation	3,345	9%
Other costs	5,973	15%
Total expenditure	**38,578**	
Surplus for year	**253**	





Balance sheet 31 March 2012		
	£,000	
Fixed assets	30,073	
Stock	500	
Debtors	5,936	
Cash at bank and in hand	9,742	
Creditors/provisions	**(8,959)**	
Net assets	**37,292**	

Institute Publications
2011–March 2012

Publications that appeared in refereed journals

Aalders, I., Hough, R.L. & Towers, W. 2011. Risk of erosion in peat soils - an investigation using Bayesian belief networks. *Soil Use and Management,* **27**, 538-549. http://dx.doi.org/10.1111/j.1475-2743.2011.00359.x

Adams, T., Ackland, G., Marion, G. & Edwards, C. 2011. Effects of local interaction and dispersal on the dynamics of size-structured populations. *Ecological Modelling,* **222**, 1414-1422. http://dx.doi.org/10.1016/j.ecolmodel.2011.02.006

Addy, S., Soulsby, C., Hartley, A.J. & Tetzlaff, D. 2011. Characterisation of channel reach morphology and associated controls in deglaciated montane catchments in the Cairngorms, Scotland. *Geomorphology,* **132**, 176-186. http://dx.doi.org/10.1016/j.geomorph.2011.05.007

Adriaens, M.E., Jaillard, M., Eijssen, L.M.T., Mayer, C.D. & Evelo, C.T.A. 2012. An evaluation of two-channel ChIP-on-chip and DNA methylation microarray normalization strategies. *BMC Genomics,* **13**, 42. http://dx.doi.org/10.1186/1471-2164-13-42

Aitkenhead, M.J., Aalders, I.H. 2011. Automating land cover mapping of Scotland using expert system and knowledge integration methods. *Remote Sensing of Environment,* **115**, 1285-1295. http://dx.doi.org/10.1016/j.rse.2011.01.012

Aitkenhead, M.J., Albanito, F., Jones, M.B. & Black, H.I.J. 2011. Development and testing of a process-based model (MOSES) for simulating soil processes, functions and ecosystem services. *Ecological Modelling,* **222**, 3795-3810. http://dx.doi.org/10.1016/j.ecolmodel.2011.09.014

Aitkenhead, M.J., Coull, M.C., Towers, W., Hudson, G. & Black, H.I.J. 2012. Predicting soil chemical composition and other soil parameters from field observations using a neural network. *Computers and Electronics in Agriculture,* **82**, 108-116. http://dx.doi.org/10.1016/j.compag.2011.12.013

Aitkenhead, M.J., Owen, M. & Chambers, D.M. 2012. Use of artificial neural networks in measuring characteristics of shielded plutonium for arms control. *Journal of Analytical Atomic Spectrometry,* **27**, 432-439. http://dx.doi.org/10.1039/c2ja10230g

Alcon, F., Martin-Ortega, J., Berbel, J. & de Miguel, M.D. 2012. Environmental benefits of reclaimed water: an economic assessment in the context of the Water Framework Directive. *Water Policy,* **14**, 148-159. http://dx.doi.org/10.2166/wp.2011.001

Andersen, R., Poulin, M., Borcard, D., Laiho, R., Laine, J., Vasander, H. & Tuittila, E.T. 2011. Environmental control and spatial structures in peatland vegetation. *Journal of Vegetation Science,* **22**, 878-890. http://dx.doi.org/10.1111/j.1654-1103.2011.01295.x

Andrews, M., Edwards, G.R., Ridgway, H.J., Cameron, K.C., Di, H.J. & Raven, J.A. 2011. Positive plant microbial interactions in perennial ryegrass dairy pasture systems. *Annals of Applied Biology,* **159**, 79-92. http://dx.doi.org/10.1111/j.1744-7348.2011.00473.x

Andrews, M., James, E.K., Sprent, J.I., Boddey, R.M., Gross, E. & dos Reis, F.B. 2011. Nitrogen fixation in legumes and actinorhizal plants in natural ecosystems: values obtained using N-15 natural abundance. *Plant Ecology & Diversity,* **4**, 131-140. http://dx.doi.org/10.1080/17550874.2011.644343

Andrivon, D., Avendano-Corcoles, J., Cameron, A.M., Carnegie, S.F., Cooke, L.R., Corbiere, R., Detourne, D., Dowley, L.J., Evans, D., Forisekova, K., Griffin, D.G., Hannukkala, A., Lees, A.K., Lebecka, R., Niepold, F., Polgar, Z., Shaw, D.S., Thompson, J., Trognitz, B., van Raaij, H.M.G. & Zimnoch-Guzowska, E. 2011. Stability and variability of virulence of *Phytophthora infestans* assessed in a ring test across European laboratories. *Plant Pathology,* **60**, 556-565. http://dx.doi.org/10.1111/j.1365-3059.2010.02392.x

Anthony, J.P., Fyfe, L., Stewart, D. & McDougall, G.J. 2011. Differential effectiveness of berry polyphenols as anti-giardial agents. *Parasitology,* **138**, 1110-1116. http://dx.doi.org/10.1017/S0031182011000825

Armitage, H.F., Britton, A.J., Van der Wal, R., Pearce, I.S.K., Thompson, D.B.A. & Woodin, S.J. 2012. Nitrogen deposition enhances moss growth, but leads to an overall decline in habitat condition of mountain moss-sedge heath. *Global Change Biology,* **18**, 290-300. http://dx.doi.org/10.1111/j.1365-2486.2011.02493.x

Arts, K., Fischer, A. & Van der Wal, R. 2012. The promise of wilderness between paradise and hell: a cultural-historical exploration of a Dutch national park. *Landscape Research,* **37**, 239-256. http://dx.doi.org/10.1080/01426397.2011.589896

Ascough, P.L., Bird, M.I., Francis, S.M., Thornton, B., Midwood, A.J., Scott, A.C. & Apperley, D. 2011. Variability in oxidative degradation of charcoal: influence of production conditions and environmental exposure. *Geochimica et Cosmochimica Acta,* **75**, 2361-2378. http://dx.doi.org/10.1016/j.gca.2011.02.002

Asensio, A.C., Marino, D., James, E.K., Ariz, I., Arrese-Igor, C., Aparicio-Tejo, P.M., Arredondo-Peter, R. & Moran, J.F. 2011. Expression and localization of a rhizobium-derived cambialistic superoxide dismutase in pea (*Pisum sativum*) nodules subjected to oxidative stress. *Molecular Plant-Microbe Interactions,* **24**, 1247-1257. http://dx.doi.org/10.1094/MPMI-10-10-0253

Ashfaq, M., McGavin, W. & MacFarlane, S.A. 2011. RNA2 of TRV SYM breaks the rules for tobravirus genome structure. *Virus Research,* **160**, 435-438. http://dx.doi.org/10.1016/j.virusres.2011.07.007

Aspinall, S.J. & Aspinall, R.J. 2011. The Fair Isle wren. *British Birds,* **104**, 312-324.

Bakam, I., Pajot, G. & Matthews, R.B. 2011. Estimating carbon price from a closed emission trading scheme in the agricultural sector. *Journal of Land Use Science,* **6**, 1-18. http://dx.doi.org/10.1080/1747423X.2011.563324

Baker, R.H., Buschbaum, S., Matthews, J.B., McKendrick, I.J., Schnieder, T., Strube, C. & Nisbet, A.J. 2011. GTP-Cyclohydrolase and development in *Teladorsagia circumcincta and Dictyocaulus* viviparus (Nematoda: Strongylida). *Experimental Parasitology,* **128**, 309-317. http://dx.doi.org/10.1016/j.exppara.2011.04.001

Balana, B.B., Lago, M., Baggaley, N., Castellazzi, M., Sample, J., Stutter, M., Slee, B. & Vinten, A. 2012. Integrating economic and biophysical data in assessing cost-effectiveness of buffer strip placement. *Journal of Environmental Quality,* **41**, 380-388. http://dx.doi.org/10.2134/jeq2010.0544

Balana, B.B., Muys, B., Haregeweyn, N., Descheemaeker, K., Deckers, J., Poesen, J., Nyssen, J. & Mathijs, E. 2012. Cost-benefit analysis of soil and water conservation measure: The case of exclosures in northern Ethiopia. *Forest Policy and Economics,* **15**, 27-36. http://dx.doi.org/10.1016/j.forpol.2011.09.008

Balana, B.B., Vinten, A. & Slee, B. 2011. A review on cost-effectiveness analysis of agri-environmental measures related to the EU WFD: Key issues, methods, and applications. *Ecological Economics,* **70**, 1021-1031. http://dx.doi.org/10.1016/j.ecolecon.2010.12.020

Balana, B.B., Yatich, T. & Makela, M. 2011. A conjoint analysis of landholder preferences for reward-based land-management contracts in Kapingazi watershed, Eastern Mount Kenya. *Journal of Environmental Management,* **92**, 2634-2646. http://dx.doi.org/10.1016/j.jenvman.2011.06.001

Ballingall, K.T., Nath, M., Holliman, A., Laming, E., Steele, P. & Willoughby, K. 2011. Lack of evidence for an association between MHC diversity and the development of bovine neonatal pancytopenia in Holstein dairy cattle. *Veterinary Immunology and Immunopathology,* **141**, 128-132. http://dx.doi.org/10.1016/j.vetimm.2011.01.017

Barakate, A., Stephens, J., Goldie, A., Hunter, W.N., Marshall, D., Hancock, R.D., Lapierre, C., Morreele, K., Boerjane, W. & Halpin, C. 2011. Syringyl lignin is unaltered by severe sinapyl alcohol dehydrogenase suppression in tobacco. *Plant Cell,* **23**, 4492-4506. http://dx.doi.org/10.1105/tpc.111.089037

Barrett, G., Campbell, C.D., Fitter, A.H. & Hodge, A. 2011. The arbuscular mycorrhizal fungus *Glomus hoi* can capture and transfer nitrogen from organic patches to its associated host plant at low temperature. *Applied Soil Ecology,* **48**, 102-105. http://dx.doi.org/10.1016/j.apsoil.2011.02.002

Baxter, E.M., Jarvis, S., Palarea-Albaladejo, J. & Edwards, S.A. 2012. The weaker sex? The propensity for male-biased piglet mortality. *PLoS One,* **7**, e30318. http://dx.doi.org/10.1371/journal.pone.0030318

Bayer, M., Milne, I., Stephen, G., Shaw, P., Cardle, L., Wright, F. & Marshall, D. 2011. Comparative visualization of genetic and physical maps with Strudel. *Bioinformatics,* **27**, 1307-1308. http://dx.doi.org/10.1093/bioinformatics/btr111

Beale, C.M., Lennon, J.J. 2012. Incorporating uncertainty in predictive species distribution modelling. *Philosophical Transactions of the Royal Society B-Biological Sciences,* **367**, 247-258. http://dx.doi.org/10.1098/rstb.2011.0178

Beattie, J.H., Nicol, F., Gordon, M.J., Reid, M.D., Cantlay, L., Horgan, G.W., Kwun, I.S., Ahn, J.Y. & Ha, T.Y. 2011. Ginger phytochemicals mitigate the obesogenic effects of a high-fat diet in mice: A proteomic and biomarker network analysis. *Molecular Nutrition & Food Research,* **55**, S203-S213. http://dx.doi.org/10.1002/mnfr.201100193

Beesley, L., Moreno-Jimenez, E., Gomez-Eyles, J.L., Harris, E., Robinson, B. & Sizmur, T. 2011. A review of biochars' potential role in the remediation, revegetation and restoration of contaminated soils. *Environmental Pollution,* **159**, 3269-3282. http://dx.doi.org/10.1016/j.envpol.2011.07.023

Belanche, A., Abecia, L., Holtrop, G., Guada, J.A., Castrillo, C., de la Fuente, G. & Balcells, J. 2011. Study of the effect of presence or absence of protozoa on rumen fermentation and microbial protein contribution to the chyme. *Journal of Animal Science,* **89**, 4163-4174. http://dx.doi.org/10.2527/jas.2010-3703

Beleggia, R., Platani, C., Papa, R., Di Chio, A., Barros, E., Mashaba, C., Wirth, J., Fammartino, A., Sautter, C., Conner, S., Rauscher, J., Stewart, D. & Cattivelli, L. 2011. Metabolomics and food processing: from semolina to pasta. *Journal of Agricultural and Food Chemistry,* **59**, 9366-9377. http://dx.doi.org/10.1021/jf2022836

Belenguer, A., Holtrop, G., Duncan, S.H., Anderson, S.E., Calder, A.G., Flint, H.J. & Lobley, G.E. 2011. Rates of production and utilization of lactate by microbial communities from the human colon. *FEMS Microbiology Ecology,* **77**, 107-119. http://dx.doi.org/10.1111/j.1574-6941.2011.01086.x

Bell, M.J., Worrall, F., Smith, P., Bhogal, A., Black, H., Lilly, A., Barraclough, D. & Merrington, G. 2011. UK land-use change and its impact on SOC: 1925-2007. *Global Biogeochemical Cycles,* **25**, GB4015. http://dx.doi.org/10.1029/2010GB003881

Benavides, J., Maley, S., Pang, Y., Palarea, J., Eaton, S., Katzer, F., Innes, E.A., Buxton, D. & Chianini, F. 2011. Development of lesions and tissue distribution of parasite in lambs orally infected with sporulated oocysts of *Toxoplasma gondii*. *Veterinary Parasitology,* **179**, 209-215. http://dx.doi.org/10.1016/j.vetpar.2011.03.001

Bengough, A.G. & White, P.J. 2011. Plant responses to below-ground stresses. *Journal of Experimental Botany,* **62**, e1. http://dx.doi.org/10.1093/jxb/erq337

Bennett, A.E., Thomsen, M. & Strauss, S.Y. 2011. Multiple mechanisms enable invasive species to suppress native species. *American Journal of Botany,* **98**, 1086-1094. http://dx.doi.org/10.3732/ajb.1000177

Berbel, J., Martin-Ortega, J. & Mesa, P. 2011. A cost effectiveness analysis of water saving measures for the Water Framework Directive: the case of the Guadalquivir river basin in Southern Spain. *Water Resources Management*, **25**, 623-640. http://dx.doi.org/10.1007/s11269-010-9717-6

Bergfur, J., Demars, B.O.L., Stutter, M.I., Langan, S.J. & Friberg, N. 2012. The Tarland catchment initiative and its effect on stream water quality and macroinvertebrate indices. *Journal of Environmental Quality,* **41**, 314-321. http://dx.doi.org/10.2134/jeq2010.0537

Bernhardt-Romermann, M., Gray, A., Vanbergen, A.J., Berges, L., Bohner, A., Brooker, R.W., De Bruyn, L., De Cinti, B., Dirnbock, T., Grandin, U., Hester, A.J., Kanka, R., Klotz, S., Loucougaray, G., Lundin, L., Matteucci, G., Meszaros, I., Viktor, O., Preda, E., Prevosto, B., Pykala, J., Schmidt, W., Taylor, M.E., Vadineanu, A., Waldmann, T. & Stadler, J. 2011. Functional traits and local environment predict vegetation responses to disturbance: a pan-European multi-site experiment. *Journal of Ecology,* **99**, 777-787. http://dx.doi.org/10.1111/j.1365-2745.2011.01794.x

Birch, A.N.E., Begg, G.S. & Squire, G.R. 2011. How agro-ecological research helps to address food security issues under new IPM and

pesticide reduction policies for global crop production systems. *Journal of Experimental Botany,* **62**, 3251-3261. http://dx.doi.org/10.1093/jxb/err064

Birkel, C.B., Soulsby, C., Tetzlaff, D., Dunn, S. & Spezia, L. 2012. High-frequency storm event isotope sampling reveals time-variant transit time distributions and influence of diurnal cycles. *Hydrological Processes,* **26**, 308-316. http://dx.doi.org/10.1002/hyp.8210

Bisi, F., Newey, S., Nodari, M., Wauters, L.A., Harrison, A., Thirgood, S. & Martinoli, A. 2011. The strong and the hungry: bias in capture methods for mountain hares *Lepus timidus*. *Wildlife Biology,* **17**, 311-316. http://dx.doi.org/10.2981/10-133

Bjorkman, M., Klingen, I., Birch, A.N.E., Bones, A.M., Bruce, T.J.A., Johansen, T.J., Meadow, R., Molmann, J., Seljasen, R., Smart, L.E. & Stewart, D. 2011. Phytochemicals of brassicaceae in plant protection and human health - Influences of climate, environment and agronomic practice. *Phytochemistry,* **72**, 538-556. http://dx.doi.org/10.1016/j.phytochem.2011.01.014

Blackstock, K., Dinnie, L., Trench, H. & Miles, G. 2011. Co-researching the Cairngorms: Supporting the aims of, not just researching in, the Cairngorms NationalPark. *Scottish Geographical Journal,* **127**, 40-60. http://dx.doi.org/10.1080/14702541.2011.579573

Bohan, D.A., Powers, S.J., Champion, G., Haughton, A.J., Hawes, C., Squire, G., Cussans, J. & Mertens, S.K. 2011. Modelling rotations: can crop sequences explain arable weed seedbank abundance? *Weed Research,* **51**, 422-432. http://dx.doi.org/10.1111/j.1365-3180.2011.00860.x

Borras-Gelonch, G., Denti, M., Thomas, W.T.B. & Romagosa, I. 2012. Genetic control of pre-heading phases in the Steptoe x Morex barley population under different conditions of photoperiod and temperature. *Euphytica,* **183**, 303-321. http://dx.doi.org/10.1007/s10681-011-0526-7

Bradford, R.A., O'Sullivan, J.J., van der Craats, I.M., Krywkow, J., Rotko, P., Aaltonen, J., Bonaiuto, M., De Dominicis, S., Waylen, K. & Schelfaut, K. 2012. Risk perception - issues for flood management in Europe. *Natural Hazards and Earth System Sciences,* **12**, 2299-2309. http://dx.doi.org/10.5194/nhess-12-2299-2012

Bradshaw, J.E., Wilson, R.N. 2012. Kale population improvement and cultivar production. *Euphytica,* **184**, 275-288. http://dx.doi.org/10.1007/s10681-011-0612-x

Branch, T.A., Austin, J.D., Acevedo-Whitehouse, K., Gordon, I.J., Gompper, M.E., Katzner, T.E. & Pettorelli, N. 2012. Fisheries conservation and management: finding consensus in the midst of competing paradigms. *Animal Conservation,* **15**, 1-3. http://dx.doi.org/10.1111/j.1469-1795.2011.00502.x

Brewer, M.J., Tetzlaff, D., Malcolm, I.A. & Soulsby, C. 2011. Source distribution modelling for end-member mixing in hydrology. *Environmetrics,* **22**, 921-932. http://dx.doi.org/10.1002/env.1110

Brewer, M.J., Sulkava, M., Makinen, H., Korpela, M., Nojd, P. & Hollmen, J. 2011. Logistic fitting method for detecting onset and cessation of tree stem radius increase. *Intelligent Data Engineering and Automated Learning - Ideal 2011,* **6936**, 204-211.

Brittain, S.R., Cox, A.G., Tomos, A.D., Paterson, E., Siripinyanond, A. & Mcleod, C.W. 2012. Chemical speciation studies on DU contaminated soils using flow field flow fractionation linked to inductively coupled plasma mass spectrometry (FlFFF-ICP-MS). *Journal of Environmental Monitoring,* **14**, 782-790. http://dx.doi.org/10.1039/c2em10716c

Britton, A.J., Helliwell, R.C., Lilly, A., Dawson, L., Fisher, J.M., Coull, M. & Ross, J. 2011. An integrated assessment of ecosystem carbon pools and fluxes across an oceanic alpine toposequence. *Plant and Soil,* **345**, 287-302. http://dx.doi.org/10.1007/s11104-011-0781-3

Brooker, R. 2011. Reproducibility of species lists, visual cover estimates and frequency methods for recording high-mountain vegetation (vol 21, pg 1035, 2010). *Journal of Vegetation Science,* **22**, 955-955. http://dx.doi.org/10.1111/j.1654-1103.2011.01292.x

Brouwer, R., Martin-Ortega, J. 2012. Modeling self-censoring of polluter pays protest votes in stated preference research to support resource damage estimations in environmental liability. *Resource and Energy Economics,* **34**, 151-166. http://dx.doi.org/10.1016/j.reseneeco.2011.05.001

Brown, E.M., Gill, C.I.R., McDougall, G.J. & Stewart, D. 2012. Mechanisms underlying the anti-proliferative effects of berry components in in vitro models of colon cancer. *Current Pharmaceutical Biotechnology,* **13**, 200-209.

Brown, I., Poggio, L., Gimona, A. & Castellazzi, M. 2011. Climate change, drought risk and land capability for agriculture: implications for land use in Scotland. *Regional Environmental Change,* **11**, 503-518. http://dx.doi.org/10.1007/s10113-010-0163-z

Brown, K., Dilley, R. 2012. Ways of knowing for 'response-ability' in more-than-human encounters: the role of anticipatory knowledges in outdoor access with dogs. *Area,* **44**, 37-45. http://dx.doi.org/10.1111/j.1475-4762.2011.01059.x

Brown, K.M. 2012. Sharing public space across difference: attunement and the contested burdens of choreographing encounter. *Social & Cultural Geography,* **13**, 801-820. http://dx.doi.org/10.1080/14649365.2012.728614

Bryden, J.M., Johnson, T., Thomson, K.J. & Ferenczi, T. 2011. Modelling multifunctionality, territorial development, and policy scenarios in rural Europe: an alternative perspective on CAP Reform debates. *EuroChoices,* **10**, 9-16. http://dx.doi.org/10.1111/j.1746-692X.2011.00145.x

Buchanan, H.A.S., Kerr, W.J., Meier-Augenstein, W. & Daeid, N.N. 2011. Organic impurities, stable isotopes, or both: A comparison of instrumental and pattern recognition techniques for the profiling of 3,4-methylenedioxymethamphetamine. *Analytical Methods,* **3**, 2279-2288. http://dx.doi.org/10.1039/c1ay05088e

Buijs, A., Hovardas, T., Figari, H., Castro, P., Devine-Wright, P., Fischer, A., Mouro, C. & Selge, S. 2012. Understanding people's ideas on natural resource management: research on social representations of nature. *Society & Natural Resources,* **25**, 1167-1181. http://dx.doi.org/10.1080/08941920.2012.670369

Burthe, S., Butler, A., Searle, K.R., Hall, S.J.G., Thackeray, S.J. & Wanless, S. 2011. Demographic consequences of increased winter births in a large aseasonally breeding mammal (*Bos taurus*) in response to climate change. *Journal of Animal Ecology,* **80**, 1134-1144. http://dx.doi.org/10.1111/j.1365-2656.2011.01865.x

Burthe, S., Daunt, F., Butler, A., Elston, D.A., Frederiksen, M., Johns, D., Newell, M., Thackeray, S.J. & Wanless, S. 2012. Phenological trends and trophic mismatch across multiple levels of a North Sea pelagic food web. *Marine Ecology-Progress Series,* **454**, 119-+. http://dx.doi.org/10.3354/meps09520

Carpenter, D., Sherlock, E., Jones, D.T., Chiminoides, J., Writer, T., Neilson, R., Boag, B., Keith, A.M. & Eggleton, P. 2012. Mapping of earthworm distribution for the British Isles and Eire highlights the under-recording of an ecologically important group. *Biodiversity and Conservation,* **21**, 475-485. http://dx.doi.org/10.1007/s10531-011-0194-x

Ceccon, C., Panzacchi, P., Scandellari, F., Prandi, L., Ventura, M., Russo, B., Millard, P. & Tagliavini, M. 2011. Spatial and temporal effects of soil temperature and moisture and the relation to fine root density on root and soil respiration in a mature apple orchard. *Plant and Soil,* **342**, 195-206. http://dx.doi.org/10.1007/s11104-010-0684-8

Charkowski, A., Blanco, C., Condemine, G., Expert, D., Franza, T., Hayes, C., Hugouvieux-Cotte-Pattat, N., Solanilla, E.L., Low, D., Moleleki, L., Pirhonen, M., Pitman, A., Perna, N., Reverchon, S., Palenzuela, P.R., San Francisco, M., Toth, I., Tsuyumu, S., van der Waals, J., van der Wolf, J., Van Gijsegem, F., Yang, C.H. & Yedidia, I. 2012. The role of secretion systems and small molecules in soft-rot enterobacteriaceae pathogenicity. *Annual Review of Phytopathology,* **50**, 425-449. http://dx.doi.org/10.1146/annurev-phyto-081211-173013

Chase-Topping, M.E., Rosser, T., Allison, L.J., Courcier, E., Evans, J., McKendrick, I.J., Pearce, M.C., Handel, I., Caprioli, A., Karch, H., Hanson, M.F., Pollock, K.G.J., Locking, M.E., Woolhouse, M.E.J., Matthews, L., Low, J.C. & Gaily, D.L. 2012. Pathogenic potential to humans of bovine *escherichia coli* O26, Scotland. *Emerging Infectious Diseases,* **18**, 439-448. http://dx.doi.org/10.3201/eid1803.111236

Chen, X.W., Hedley, P.E., Morris, J., Liu, H., Niks, R.E. & Waugh, R. 2011. Combining genetical genomics and bulked segregant analysis-based differential expression: an approach to gene localization. *Theoretical and Applied Genetics,* **122**, 1375-1383. http://dx.doi.org/10.1007/s00122-011-1538-3

Chen, Y.P., Hocking, P.M., Wang, L., Povazay, B., Prashar, A., To, C.H., Erichsen, J.T., Feldkaemper, M., Hofer, B., Drexler, W., Schaeffel, F. & Guggenheim, J.A. 2011. Selective breeding for susceptibility to myopia reveals a gene-environment interaction. *Investigative Ophthalmology & Visual Science,* **52**, 4003-4011. http://dx.doi.org/10.1167/iovs.10-7044

Chen, Y.P., Prashar, A., Erichsen, J.T., To, C.H., Hocking, P.M. & Guggenheim, J.A. 2011. Heritability of ocular component dimensions in chickens: genetic variants controlling susceptibility to experimentally induced myopia and pretreatment eye size are distinct. *Investigative Ophthalmology & Visual Science,* **52**, 4012-4020. http://dx.doi.org/10.1167/iovs.10-7045

Choi, S.K., Yoon, J.Y., Canto, T. & Palukaitis, P. 2011. Replication of cucumber mosaic virus RNA 1 in cis requires functional helicase-like motifs of the 1a protein. *Virus Research,* **158**, 271-276. http://dx.doi.org/10.1016/j.virusres.2011.03.008

Chung, B.N., Palukaitis, P. 2011. Resistance to multiple viruses in transgenic tobacco expressing fused, tandem repeat, virus-derived double-stranded RNAs. *Virus Genes,* **43**, 454-464. http://dx.doi.org/10.1007/s11262-011-0655-z

Clark, K.E., Hartley, S.E. & Johnson, S.N. 2011. Does mother know best? The preference-performance hypothesis and parent-offspring conflict in aboveground-belowground herbivore life cycles. *Ecological Entomology,* **36**, 117-124. http://dx.doi.org/10.1111/j.1365-2311.2010.01248.x

Clark, K.E., Hartley, S.E., Brennan, R.M., Jennings, S.N., McMenemy, L.S., McNicol, J.W., Mitchell, C. & Johnson, S.N. 2012. Effects of cultivar and egg density on a colonizing vine weevil (*Otiorhynchus sulcatus*) population and its impacts on red raspberry growth and yield. *Crop Protection,* **32**, 76-82. http://dx.doi.org/10.1016/j.cropro.2011.10.008

Clark, K.E., Hartley, S.E., Brennan, R.M., MacKenzie, K. & Johnson, S.N. 2012. Investigating preference-performance relationships in aboveground-belowground life cycles: a laboratory and field study with the vine weevil (*Otiorhynchus sulcatus*). *Bulletin of Entomological Research,* **102**, 63-70. http://dx.doi.org/10.1017/S0007485311000368

Clements, M.N., Clutton-Brock, T.H., Albon, S.D., Pemberton, J.M. & Kruuk, L.E.B. 2011. Gestation length variation in a wild ungulate. *Functional Ecology,* **25**, 691-703. http://dx.doi.org/10.1111/j.1365-2435.2010.01812.x

Cole, L.J., Brocklehurst, S., McCracken, D.I., Harrison, W. & Robertson, D. 2012. Riparian field margins: their potential to enhance biodiversity in intensively managed Grasslands. *Insect Conservation and Diversity,* **5**, 86-94. http://dx.doi.org/10.1111/j.1752-4598.2011.00147.x

Comadran, J., Russell, J.R., Booth, A., Pswarayi, A., Ceccarelli, S., Grando, S., Stanca, A.M., Pecchioni, N., Akar, T., Al-Yassin, A., Benbelkacem, A., Ouabbou, H., Bort, J., van Eeuwijk, F.A., Thomas, W.T.B. & Romagosa, I. 2011. Mixed model association scans of multi-environmental trial data reveal major loci controlling yield and yield related traits in *Hordeum vulgare* in Mediterranean environments. *Theoretical and Applied Genetics,* **122**, 1363-1373. http://dx.doi.org/10.1007/s00122-011-1537-4

Convey, P., Hopkins, D.W., Roberts, S.J. & Tyler, A.N. 2011. Global southern limit of flowering plants and moss peat accumulation. *Polar Research,* **30**, http://dx.doi.org/10.3402/polar.v30i0.8929

Cook, N., Aziz, N., Hedley, P.E., Morris, J., Milne, L., Karley, A.J., Hubbard, S.F. & Russell, J.R. 2011. Transcriptome sequencing of an ecologically important graminivorous sawfly: a resource for marker development. *Conservation Genetics Resources,* **3**, 789-795. http://dx.doi.org/10.1007/s12686-011-9459-7

Cooper, J.M., Burton, D., Daniell, T.J., Griffiths, B.S. & Zebarth, B.J. 2011. Carbon mineralization kinetics and soil biological characteristics as influenced by manure addition in soil incubated at a range of temperatures. *European Journal of Soil Biology,* **47**, 392-399. http://dx.doi.org/10.1016/j.ejsobi.2011.07.010

Cooper, R., Hodgkins, R., Wadham, J. & Tranter, M. 2011. The hydrology of the proglacial zone of a high-Arctic glacier (Finsterwalderbreen, Svalbard): Sub-surface water fluxes and complete water budget. *Journal of Hydrology,* **406**, 88-96. http://dx.doi.org/10.1016/j.jhydrol.2011.06.008

Corby, H.D.L., Smith, D.L. & Sprent, J.I. 2011. Size, structure and nitrogen content of seeds of Fabaceae in relation to nodulation. *Botanical Journal of the Linnean Society,* **167**, 251-280. http://dx.doi.org/10.1111/j.1095-8339.2011.01174.x

Crawfurd, K.J., Raven, J.A., Wheeler, G.L., Baxter, E.J. & Joint, I. 2011. The response of *Thalassiosira pseudonana* to long-term exposure to increased CO_2 and decreased pH. *PLoS One,* **6**, e26695. http://dx.doi.org/10.1371/journal.pone.0026695

Cullen, D.W., Harwood, W., Smedley, M., Davies, H. & Taylor, M. 2011. Comparison of DNA walking methods for isolation of transgene-flanking regions in GM potato. *Molecular Biotechnology,* **49**, 19-31. http://dx.doi.org/10.1007/s12033-010-9371-5

Daeid, N.N., Meier-Augenstein, W. & Kemp, H.F. 2011.

Investigating the provenance of un-dyed spun cotton fibre using multi-isotope profiles and chemometric analysis. *Rapid Communications in Mass Spectrometry,* **25**, 1812-1816. http://dx.doi.org/10.1002/rcm.5046

Davison, J., Opik, M., Daniell, T.J., Moora, M. & Zobel, M. 2011. Arbuscular mycorrhizal fungal communities in plant roots are not random assemblages. *Fems Microbiology Ecology,* **78**, 103-115. http://dx.doi.org/10.1111/j.1574-6941.2011.01103.x

Dawson, J.J.C., Tetzlaff, D., Speed, M., Hrachowitz, M. & Soulsby, C. 2011. Seasonal controls on DOC dynamics in nested upland catchments in NE Scotland. *Hydrological Processes,* **25**, 1647-1658. http://dx.doi.org/10.1002/hyp.7925

de Boer, J.M., Borm, T.J.A., Jesse, T., Brugmans, B., Tang, X.M., Bryan, G.J., Bakker, J., van Eck, H.J. & Visser, R.G.F. 2011. A hybrid BAC physical map of potato: a framework for sequencing a heterozygous genome. *BMC Genomics,* **12**, 594. http://dx.doi.org/10.1186/1471-2164-12-594

de Cárcer, D.A., Cuív, P.Ó., Wang, T., Kang, S., Worthley, D., Whitehall, V., Gordon, I.J., McSweeney, C., Leggett, B. & Morrison, M. 2011. Numerical ecology validates a biogeographical distribution and gender-based effect on mucosa-associated bacteria along the human colon. *ISME Journal,* **5**, 801-809. http://dx.doi.org/10.1038/ismej.2010.177

de Oliveira, C.M.G., Monteiro, A.R. & Blok, V.C. 2011. Morphological and molecular diagnostics for plant-parasitic nematodes: working together to get the identification done. *Tropical Plant Pathology,* **36**, 65-73.

de Roos, B., Wanders, A.J., Wood, S., Horgan, G., Rucklige, G., Reid, M., Siebelink, E. & Brouwer, I.A. 2011. A high intake of industrial or ruminant trans fatty acids does not affect the plasma proteome in healthy men. *Proteomics,* **11**, 3928-3934. http://dx.doi.org/10.1002/pmic.201100163

De Smet, I., White, P.J., Bengough, A.G., Dupuy, L., Parizot, B., Casimiro, I., Heidstra, R., Laskowski, M., Lepetit, M., Hochholdinger, F., Draye, X., Zhang, H.M., Broadley, M.R., Peret, B., Hammond, J.P., Fukaki, H., Mooney, S., Lynch, J.P., Nacry, P., Schurr, U., Laplaze, L., Benfey, P., Beeckman, T. & Bennett, M. 2012. Analyzing lateral root development: how to move forward. *Plant Cell,* **24**, 15-20. http://dx.doi.org/10.1105/tpc.111.094292

Debeljak, M., Squire, G.R., Kocev, D., Hawes, C., Young, M.W. & Dzeroski, S. 2011. Analysis of time series data on agroecosystem vegetation using predictive clustering trees. *Ecological Modelling,* **222**, 2524-2529. http://dx.doi.org/10.1016/j.ecolmodel.2010.10.021

Deflorio, G., Horgan, G., Woodward, S. & Fossdal, C.G. 2011. Gene expression profiles, phenolics and lignin of Sitka spruce bark and sapwood before and after wounding and inoculation with *Heterobasidion annosum*. *Physiological and Molecular Plant Pathology,* **75**, 180-187. http://dx.doi.org/10.1016/j.pmpp.2011.02.002

DeGabriel, J.L., Albon, S.D., Fielding, D.A., Riach, D.J., Westaway, S. & Irvine, R.J. 2011. The presence of sheep leads to increases in plant diversity and reductions in the impact of deer on heather. *Journal of Applied Ecology,* **48**, 1269-1277. http://dx.doi.org/10.1111/j.1365-2664.2011.02032.x

Demars, B.O.L., Manson, J.R., Olafsson, J.S., Gislason, G.M., Gudmundsdottir, R., Woodward, G., Reiss, J., Pichler, D.E., Rasmussen, J.J. & Friberg, N. 2011. Temperature and the metabolic balance of streams. *Freshwater Biology,* **56**, 1106-1121. http://dx.doi.org/10.1111/j.1365-2427.2010.02554.x

Demars, B.O.L., Manson, J.R., Olafsson, J.S., Gislason, G.M. & Friberg, N. 2011. Stream hydraulics and temperature determine the metabolism of geothermal Icelandic streams. *Knowledge and Management of Aquatic Ecosystems,* **402**, 05. http://dx.doi.org/10.1051/kmae/2011046

Deng, W.N., Jeng, D.S., Toorop, P.E., Squire, G.R. & Iannetta, P.P.M. 2012. A mathematical model of mucilage expansion in myxospermous seeds of *Capsella bursa-pastoris* (shepherd's purse). *Annals of Botany,* **109**, 419-427. http://dx.doi.org/10.1093/aob/mcr296

Devos, Y., Hails, R.S., Messean, A., Perry, J.N. & Squire, G.R. 2012. Feral genetically modified herbicide tolerant oilseed rape from seed import spills: are concerns scientifically justified? *Transgenic Research,* **21**, 1-21. http://dx.doi.org/10.1007/s11248-011-9515-9

Dick, J., Andrews, C., Beaumont, D.A., Benham, S., Brooks, D.R., Corbett, S., Lloyd, D., McMillan, S., Monteith, D.T., Pilgrim, E.S., Rose, R., Scott, A., Scott, T., Smith, R.I., Taylor, C., Taylor, M., Turner, A. & Watson, H. 2011. A comparison of ecosystem services delivered by 11 long-term monitoring sites in the UK environmental change network. *Environmetrics,* **22**, 639-648. http://dx.doi.org/10.1002/env.1069

Dinnie, E., Blackstock, K.L. & Dilley, R. 2012. Landscapes of challenge and change: contested views of the Cairngorms National Park. *Landscape Research,* **37**, 451-466. http://dx.doi.org/10.1080/01426397.2012.696598

Dolan, A., MacFarlane, S.A., McGavin, W.J., Brennan, R.M. & McNicol, J.W. 2011. *Blackcurrant reversion virus*: validation of an improved diagnostic test, accelerating testing in breeding and certification of blackcurrrants. *Journal of Berry Research,* **1**, 201-208. http://dx.doi.org/10.3233/JBR-2011-021

Donn, S., Neilson, R., Griffiths, B.S. & Daniell, T.J. 2011. Greater coverage of the phylum Nematoda in SSU rDNA studies. *Biology and Fertility of Soils,* **47**, 333-339. http://dx.doi.org/10.1007/s00374-010-0534-0

Donn, S., Neilson, R., Griffiths, B.S. & Daniell, T.J. 2012. A novel molecular approach for rapid assessment of soil nematode assemblages - variation, validation and potential applications. *Methods in Ecology and Evolution,* **3**, 12-23. http://dx.doi.org/10.1111/j.2041-210X.2011.00145.x

Donnelly, R.E., Katzner, T., Gordon, I.J., Gompper, M.E., Redpath, S., Garner, T.W.J., Altwegg, R., Reed, D.H., Acevedo-Whitehouse, K. & Pettorelli, N. 2011. Putting the eco back in ecotourism. *Animal Conservation,* **14**, 325-327. http://dx.doi.org/10.1111/j.1469-1795.2011.00468.x

Duarte, I.M., Almeida, M.T.M., Duarte, M.M., Brown, D.J.F. & Neilson, R. 2011. Molecular diagnosis of trichodorid species from Portugal. *Plant Pathology,* **60**, 586-594. http://dx.doi.org/10.1111/j.1365-3059.2010.02401.x

Dunn, S.M., Darling, W.G., Birkel, C. & Bacon, J.R. 2012. The role of groundwater characteristics in catchment recovery from nitrate pollution. *Hydrology Research,* **43**, 560-575. http://dx.doi.org/10.2166/nh.2012.020

Dupuy, L.X. 2011. Modelling root systems using oriented density distributions. *Numerical Analysis and Applied Mathematics ICNAAM 2011: International Conference on Numerical Analysis and Applied Mathematics,* **1389**, 726-729. http://dx.doi.org/10.1063/1.3636834

Dyer, G.A., Gonzalez, C. & Lopera, D.C. 2011. Informal "seed'' systems and the management of gene flow in traditional agroecosystems: the case of Cassava in Cauca, Colombia. *PLoS One,* **6**, http://dx.doi.org/10.1371/journal.pone.0029067

Dyer, G.A., Taylor, J.E. 2011. The corn price surge: impacts on rural Mexico. *World Development,* **39**, 1878-1887. http://dx.doi.org/10.1016/j.worlddev.2011.04.032

Elston, D.A., Nevison, I.M., Scott, W.A., Sier, A.R.J. & Morecroft, M.D. 2011. Power calculations for monitoring studies: a case study with alternative models for random variation. *Environmetrics,* **22**, 618-625. http://dx.doi.org/10.1002/env.1096

Evans, J., Knight, H., McKendrick, I.J., Stevenson, H., Barbudo, A.V., Gunn, G.J. & Low, J.C. 2011. Prevalence of *Escherichia coli* O157: H7 and serogroups O26, O103, O111 and O145 in sheep presented for slaughter in Scotland. *Journal of Medical Microbiology,* **60**, 653-660. http://dx.doi.org/10.1099/jmm.0.028415-0

Evely, A.C., Pinard, M., Reed, M.S. & Fazey, I. 2011. High levels of participation in conservation projects enhance learning. *Conservation Letters,* **4**, 116-126. http://dx.doi.org/10.1111/j.1755-263X.2010.00152.x

Farmer, J., Matthews, R., Smith, J.U., Smith, P. & Singh, B.K. 2011. Assessing existing peatland models for their applicability for modelling greenhouse gas emissions from tropical peat soils. *Current Opinion in Environmental Sustainability,* **3**, 339-349. http://dx.doi.org/10.1016/j.cosust.2011.08.010

Feliciano, D. & Mendes, A. 2011. A first assessment of the success of forest owners' organizations in North and Central Portugal in increasing membership and the provision of services. *SEEFOR – South-East European Forestry*, **2**, 1-12.http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=113725

Fischer, A., Glenk, K. 2011. One model fits all? On the moderating role of emotional engagement and confusion in the elicitation of preferences for climate change adaptation policies. *Ecological Economics,* **70**, 1178-1188. http://dx.doi.org/10.1016/j.ecolecon.2011.01.014

Fischer, A., Langers, F., Bednar-Friedl, B., Geamana, N. & Skogen, K. 2011. Mental representations of animal and plant species in their social contexts: Results from a survey across Europe. *Journal of Environmental Psychology,* **31**, 118-128. http://dx.doi.org/10.1016/j.jenvp.2010.05.005

Fischer, A., Peters, V., Vavra, J., Neebe, M. & Megyesi, B. 2011. Energy use, climate change and folk psychology: does sustainability have a chance? Results from a qualitative study in five European countries. *Global Environmental Change-Human and Policy Dimensions,* **21**, 1025-1034. http://dx.doi.org/10.1016/j.gloenvcha.2011.04.008

Fitton, N., Ejerenwa, C.P., Bhogal, A., Edgington, P., Black, H., Lilly, A., Barraclough, D., Worrall, F., Hillier, J. & Smith, P. 2011. Greenhouse gas mitigation potential of agricultural land in Great Britain. *Soil Use and Management,* **27**, 491-501. http://dx.doi.org/10.1111/j.1475-2743.2011.00365.x

Flower, K., Thomas, D., Heather, J., Ramasubramanyan, S., Jones, S. & Sinclair, A.J. 2011. Epigenetic control of viral life-cycle by a DNA-methylation dependent transcription factor. *PLoS One,* **6**, e25922. http://dx.doi.org/10.1371/journal.pone.0025922

Francez, A.J., Pinay, G., Josselin, N. & Williams, B.L. 2011. Denitrification triggered by nitrogen addition in *Sphagnum magellanicum* peat. *Biogeochemistry,* **106**, 435-441. http://dx.doi.org/10.1007/s10533-010-9523-5

Frank, T., Rohlig, R.M., Davies, H.V., Barros, E. & Engel, K.H. 2012. Metabolite profiling of maize kernels-genetic modification versus environmental influence. *Journal of Agricultural and Food Chemistry,* **60**, 3005-3012. http://dx.doi.org/10.1021/jf204167t

Frederiksen, M., Elston, D.A., Edwards, M., Mann, A.D. & Wanless, S. 2011. Mechanisms of long-term decline in size of lesser sandeels in the North Sea explored using a growth and phenology model. *Marine Ecology-Progress Series,* **432**, 137-147. http://dx.doi.org/10.3354/meps09177

Fridley, J.D., Grime, J.P., Huston, M.A., Pierce, S., Smart, S.M., Thompson, K., Borger, L., Brooker, R.W., Cerabolini, B.E.L., Gross, N., Liancourt, P., Michalet, R. & Le Bagousse-Pinguet, Y. 2012. Comment on "productivity is a poor predictor of plant species richness". *Science,* **335**, 1441. http://dx.doi.org/10.1126/science.1215042

Frimpong, K.A., Yawson, D.O., Baggs, E.M. & Agyarko, K. 2011. Does incorporation of cowpea-maize residue mixes influence nitrous oxide emission and mineral nitrogen release in a tropical luvisol? *Nutrient Cycling in Agroecosystems,* **91**, 281-292. http://dx.doi.org/10.1007/s10705-011-9461-1

Fuschino, J.R., Guschina, I.A., Dobson, G., Yan, N.D., Harwood, J.L. & Arts, M.T. 2011. Rising water temperatures alter lipid dynamics and reduce N-3 essential fatty acid concentrations in Scenedesmus obliquus (Chlorophyta). *Journal of Phycology,* **47**, 763-774. http://dx.doi.org/10.1111/j.1529-8817.2011.01024.x

Gao, W., Ren, T., Bengough, A.G., Auneau, L., Watts, C.W. & Whalley, W.R. 2012. Predicting penetrometer resistance from the compression characteristic of soil. *Soil Science Society of America Journal,* **76**, 361-369. http://dx.doi.org/10.2136/sssaj2011.0217

Garcia-Palacios, P., Bowker, M.A., Chapman, S.J., Maestre, F.T., Soliveres, S., Gallardo, A., Valladares, F., Guerrero, C. & Escudero, A. 2011. Early-successional vegetation changes after roadside prairie restoration modify processes related with soil functioning by changing microbial functional diversity. *Soil Biology & Biochemistry,* **43**, 1245-1253. http://dx.doi.org/10.1016/j.soilbio.2011.02.014

Garcia-Pausas, J., Paterson, E. 2011. Microbial community abundance and structure are determinants of soil organic matter mineralisation in the presence of labile carbon. *Soil Biology & Biochemistry,* **43**, 1705-1713. http://dx.doi.org/10.1016/j.soilbio.2011.04.016

George, D.M., Rind, F.C., Bendall, M.W., Taylor, M.A. & Gatehouse, A.M.R. 2012. Developmental studies of transgenic maize expressing Cry1Ab on the African stem borer, *Busseola fusca*; effects on midgut cellular structure. *Pest Management Science,* **68**, 330-339. http://dx.doi.org/10.1002/ps.2260

Gilbert, L., Maffey, G.L., Ramsay, S.L. & Hester, A.J. 2012. The effect of deer management on the abundance of Ixodes ricinus in Scotland. *Ecological Applications,* **22**, 658-667.

Gilbert, L., Williamson, K.A. & Graves, J.A. 2012. Male attractiveness regulates daughter fecundity non-genetically via maternal investment. *Proceedings of the Royal Society B-Biological Sciences,* **279**, 523-528. http://dx.doi.org/10.1098/rspb.2011.0962

Gilroy, E.M., Breen, S., Whisson, S.C., Squires, J., Hein, I., Kaczmarek, M., Turnbull, D., Boevink, P.C., Lokossou, A., Cano, L.M., Morales, J., Avrova, A.O., Pritchard, L., Randall, E., Lees, A., Govers, F., van West, P., Kamoun, S., Vleeshouwers, V.G.A.A., Cooke, D.E.L. & Birch, P.R.J. 2011. Presence/absence, differential

expression and sequence polymorphisms between PiAVR2 and PiAVR2-like in *Phytophthora infestans* determine virulence on R2 plants. *New Phytologist,* **191**, 763-776. http://dx.doi.org/10.1111/j.1469-8137.2011.03736.x

Gilroy, E.M., Taylor, R.M., Hein, I., Boevink, P., Sadanandom, A. & Birch, P.R.J. 2011. CMPG1-dependent cell death follows perception of diverse pathogen elicitors at the host plasma membrane and is suppressed by *Phytophthora infestans* RXLR effector AVR3a. *New Phytologist,* **190**, 653-666. http://dx.doi.org/10.1111/j.1469-8137.2011.03643.x

Gimona, A. & Polhill, J.G. 2011. Exploring robustness of biodiversity policy with a coupled metacommunity and agent-based model. *Journal of Land Use Science,* **6**, 175-193. http://dx.doi.org/10.1080/1747423X.2011.558601

Glasner, J.D., Yang, C.H., Reverchon, S., Hugouvieux-Cotte-Pattat, N., Condemine, G., Bohin, J.P., Van Gijsegem, F., Yang, S.H., Franza, T., Expert, D., Plunkett, G., Francisco, M.J.S., Charkowski, A.O., Py, B., Bell, K., Rauscher, L., Rodriguez-Palenzuela, P., Toussaint, A., Holeva, M.C., He, S.Y., Douet, V., Boccara, M., Blanco, C., Toth, I., Anderson, B.D., Biehl, B.S., Mau, B., Flynn, S.M., Barras, F., Lindeberg, M., Birch, P.R.J., Tsuyumu, S., Shi, X.Y., Hibbing, M., Yap, M.N., Carpentier, M., Dassa, E., Umehara, M., Kim, J.F., Rusch, M., Soni, P., Mayhew, G.F., Fouts, D.E., Gill, S.R., Blattner, F.R., Keen, N.T. & Perna, N.T. 2011. Genome sequence of the plant-pathogenic Bacterium *Dickeya dadantii* 3937. *Journal of Bacteriology,* **193**, 2076-2077. http://dx.doi.org/10.1128/JB.01513-10

Goddard, P.J. 2011. Welfare assessment in sheep. *In Practice,* **33**, 508-516. http://dx.doi.org/10.1136/inp.d7316

Gomez-Limon, J.A. & Martin-Ortega, J. 2011. Agua, economia y territorio: nuevos enfoques de la Directiva Marco del agua para la gestion del recurso. *Estudios de Economía Aplicada,* **29**, 1-29.

Gontikaki, E., Mayor, D.J., Thornton, B., Black, K. & Witte, U. 2011. Processing of C-13-labelled diatoms by a bathyal community at sub-zero temperatures. *Marine Ecology-Progress Series,* **421**, 39-50. http://dx.doi.org/10.3354/meps08892

Gontikaki, E., Polymenakou, P.N., Thornton, B., Narayanaswamy, B.E., Black, K., Tselepides, A. & Witte, U. 2012. Microbial response to organic matter enrichment in the oligotrophic Levantine Basin (Eastern Mediterranean). *Geomicrobiology Journal,* **29**, 648-655. http://dx.doi.org/10.1080/01490451.2011.605822

Graham, J., Hackett, C.A., Smith, K., Woodhead, M., MacKenzie, K., Tierney, I., Cooke, D., Bayer, M. & Jennings, N. 2011. Towards an understanding of the nature of resistance to Phytophthora root rot in red raspberry. *Theoretical and Applied Genetics,* **123**, 585-601. http://dx.doi.org/10.1007/s00122-011-1609-5

Granger, S.J., Bol, R., Hawkins, J.M.B., White, S.M., Naden, P.S., Old, G.H., Marsh, J.K., Bilotta, G.S., Brazier, R.E., Macleod, C.J.A. & Haygarth, P.M. 2011. Using artificial fluorescent particles as tracers of livestock wastes within an agricultural catchment. *Science of the Total Environment,* **409**, 1095-1103. http://dx.doi.org/10.1016/j.scitotenv.2010.12.005

Gregory, P.J., George, T.S. 2011. Feeding nine billion: the challenge to sustainable crop production. *Journal of Experimental Botany,* **62**, 5233-5239. http://dx.doi.org/10.1093/jxb/err232

Griffiths, B.S., Daniell, T.J., Donn, S. & Neilson, R. 2012. Bioindication potential of using molecular characterisation of the nematode community: Response to soil tillage. *European Journal of Soil Biology,* **49**, 92-97. http://dx.doi.org/10.1016/j.ejsobi.2011.09.002

Grundy, K.C., Woodward, S., Genney, D.R. & Taylor, A.F.S. 2012. A molecular approach to explore the extent of the threatened fungus *Hypocreopsis rhododendri* within wood. *Fungal Biology,* **116**, 354-362. http://dx.doi.org/10.1016/j.funbio.2011.12.002

Grzegorczyk, M., Husmeier, D. & Rahnenfuhrer, J. 2011. Modelling non-stationary dynamic gene regulatory processes with the BGM model. *Computational Statistics,* **26**, 199-218. http://dx.doi.org/10.1007/s00180-010-0201-9

Grzegorczyk, M., Husmeier, D. 2011. Non-homogeneous dynamic Bayesian networks for continuous data. *Machine Learning,* **83**, 355-419. http://dx.doi.org/10.1007/s10994-010-5230-7

Gurung, A.B., von Dach, S.W., Price, M.F., Aspinall, R., Balsiger, J., Baron, J.S., Sharma, E., Greenwood, G. & Kohler, T. 2012. Global change and the world's mountains - research needs and emerging themes for sustainable development. A synthesis from the 2010 Perth II Conference. *Mountain Research and Development,* **32**, S47-S54. http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00084.S1

Gutleb, A.C., Lilienthal, H., Erhard, H.W., Zimmer, K.E., Skaare, J.U. & Ropstad, E. 2011. Effects of pre- and postnatal polychlorinated biphenyl exposure on emotional reactivity observed in lambs before weaning. *Ecotoxicology and Environmental Safety,* **74**, 1396-1401. http://dx.doi.org/10.1016/j.ecoenv.2011.03.004

Gyaneshwar, P., Hirsch, A.M., Moulin, L., Chen, W.M., Elliott, G.N., Bontemps, C., Estrada-de los Santos, P., Gross, E., dos Reis, F.B., Sprent, J.I., Young, J.P.W. & James, E.K. 2011. Legume-nodulating betaproteobacteria: diversity, host range, and future prospects. *Molecular Plant-Microbe Interactions,* **24**, 1276-1288. http://dx.doi.org/10.1094/MPMI-06-11-0172

Haanes, H., Roed, K.H., Perez-Espona, S. & Rosef, O. 2011. Low genetic variation support bottlenecks in Scandinavian red deer. *European Journal of Wildlife Research,* **57**, 1137-1150. http://dx.doi.org/10.1007/s10344-011-0527-9

Haegeman, A., Jones, J.T. & Danchin, E.G.J. 2011. Horizontal gene transfer in nematodes: A catalyst for plant parasitism? *Molecular Plant-Microbe Interactions,* **24**, 879-887. http://dx.doi.org/10.1094/MPMI-03-11-0055

Haegeman, A., Mantelin, S., Jones, J.T. & Gheysen, G. 2012. Functional roles of effectors of plant-parasitic nematodes. *Gene,* **492**, 19-31. http://dx.doi.org/10.1016/j.gene.2011.10.040

Hagemann, N., Prager, K. 2011. Shortcomings of political instruments for agricultural soil conservation. *Berichte Uber Landwirtschaft,* **89**, 331-350.

Hallett, P.D., Kutilek, M. & Lichner, L. 2011. Division or addition? New breeds of interdisciplinary research involving hydrology (Comments to the Discussion Paper of Prof. Philippe C. Baveye). *Journal of Hydrology,* **406**, 146-147. http://dx.doi.org/10.1016/j.jhydrol.2011.05.055

Halliday, A.M., Lainson, F.A., Yaga, R., Inglis, N.F., Bridgett, S., Nath, M. & Knox, D.P. 2012. Transcriptional changes in *Teladorsagia circumcincta* upon encountering host tissue of differing immune status. *Parasitology,* **139**, 387-405. http://dx.doi.org/10.1017/S0031182011002010

Hammond, J.P., Broadley, M.R., Bowen, H.C., Spracklen, W.P., Hayden, R.M. & White, P.J. 2011. Gene expression changes in phosphorus deficient potato (*Solanum tuberosum* L.) leaves and

the potential for diagnostic gene expression markers. *PLoS One,* **6**, e24606. http://dx.doi.org/10.1371/journal.pone.0024606

Hammond, J.P., Mayes, S., Bowen, H.C., Graham, N.S., Hayden, R.M., Love, C.G., Spracklen, W.P., Wang, J., Welham, S.J., White, P.J., King, G.J. & Broadley, M.R. 2011. Regulatory hotspots are associated with plant gene expression under varying soil phosphorus supply in *Brassica rapa*. *Plant Physiology,* **156**, 1230-1241. http://dx.doi.org/10.1104/pp.111.175612

Hammond, J.P., White, P.J. 2011. Sugar signaling in root responses to low phosphorus availability. *Plant Physiology,* **156**, 1033-1040. http://dx.doi.org/10.1104/pp.111.175380

Haregeweyn, N., Melesse, B., Tsunekawa, A., Tsubo, M., Meshesha, D. & Balana, B.B. 2012. Reservoir sedimentation and its mitigating strategies: a case study of Angereb reservoir (NW Ethiopia). *Journal of Soils and Sediments,* **12**, 291-305. http://dx.doi.org/10.1007/s11368-011-0447-z

Hart, D.J., Fairweather-Tait, S.J., Broadley, M.R., Dickinson, S.J., Foot, I., Knott, P., McGrath, S.P., Mowat, H., Norman, K., Scott, P.R., Stroud, J.L., Tucker, M., White, P.J., Zhao, F.J. & Hurst, R. 2011. Selenium concentration and speciation in biofortified flour and bread: Retention of selenium during grain biofortification, processing and production of Se-enriched food. *Food Chemistry,* **126**, 1771-1778. http://dx.doi.org/10.1016/j.foodchem.2010.12.079

Hepburn, C.D., Pritchard, D.W., Cornwall, C.E., Mcleod, R.J., Beardall, J., Raven, J.A. & Hurd, C.L. 2011. Diversity of carbon use strategies in a kelp forest community: implications for a high CO_2 ocean. *Global Change Biology,* **17**, 2488-2497. http://dx.doi.org/10.1111/j.1365-2486.2011.02411.x

Hill, P.W., Quilliam, R.S., Deluca, T.H., Farrar, J., Farrell, M., Roberts, P., Newsham, K.K., Hopkins, D.W., Bardgett, R.D. & Jones, D.L. 2011. Acquisition and assimilation of nitrogen as peptide-bound and D-enantiomers of amino acids by wheat. *PLoS One,* **6**, e19220. http://dx.doi.org/10.1371/journal.pone.0019220

Hill, P.W., Farrar, J., Roberts, P., Farrell, M., Grant, H., Newsham, K.K., Hopkins, D.W., Bardgett, R.D. & Jones, D.L. 2011. Vascular plant success in a warming Antarctic may be due to efficient nitrogen acquisition. *Nature Climate Change,* **1**, 50-53. http://dx.doi.org/10.1038/NCLIMATE1060

Hockland, S., Niere, B., Grenier, E., Blok, V., Phillips, M., Den Nijs, L., Anthoine, G., Pickup, J. & Viaene, N. 2012. An evaluation of the implications of virulence in non-European populations of *Globodera pallida* and *G. rostochiensis* for potato cultivation in Europe. *Nematology,* **14**, 1-13. http://dx.doi.org/10.1163/138855411X587112

Hofinger, B.J., Russell, J.R., Bass, C.G., Baldwin, T., Dos Reis, M., Hedley, P.E., Li, Y.D., Macaulay, M., Waugh, R., Hammond-Kosack, K.E. & Kanyuka, K. 2011. An exceptionally high nucleotide and haplotype diversity and a signature of positive selection for the eIF4E resistance gene in barley are revealed by allele mining and phylogenetic analyses of natural populations. *Molecular Ecology,* **20**, 3653-3668. http://dx.doi.org/10.1111/j.1365-294X.2011.05201.x

Hogenhout, S.A., Bos, J.I.B. 2011. Effector proteins that modulate plant-insect interactions. *Current Opinion in Plant Biology,* **14**, 422-428. http://dx.doi.org/10.1016/j.pbi.2011.05.003

Holobinko, A., Meier-Augenstein, W., Kemp, H.F., Prowse, T. & Ford, S.M. 2011. H-2 stable isotope analysis of human tooth enamel: a new tool for forensic human provenancing? *Rapid Communications in Mass Spectrometry,* **25**, 910-916. http://dx.doi.org/10.1002/rcm.4942

Hooftman, D.A.P., Flavell, A.J., Jansen, H., den Nijs, H.C.M., Syed, N.H., Sorensen, A.P., Orozco-ter Wengel, P. & van de Wiel, C.C.M. 2011. Locus-dependent selection in crop-wild hybrids of lettuce under field conditions and its implication for GM crop development. *Evolutionary Applications,* **4**, 648-659. http://dx.doi.org/10.1111/j.1752-4571.2011.00188.x

Hoolahan, A.H., Blok, V.C., Gibson, T. & Dowton, M. 2011. Paternal leakage of mitochondrial DNA in experimental crosses of populations of the potato cyst nematode *Globodera pallida*. *Genetica,* **139**, 1509-1519. http://dx.doi.org/10.1007/s10709-012-9650-0

Hoolahan, A.H., Blok, V.C., Gibson, T. & Dowton, M. 2012. Evidence of animal mtDNA recombination between divergent populations of the potato cyst nematode *Globodera pallida*. *Genetica,* **140**, 19-29. http://dx.doi.org/10.1007/s10709-012-9651-z

Horgan, G.W. 2011. The behaviour of a neutral model of weight regulated only by body mass. *Journal of Theoretical Biology,* **270**, 1-6. http://dx.doi.org/10.1016/j.jtbi.2010.11.001

Hough, R.L., Booth, P., Avery, L.M., Rhind, S., Crews, C., Bacon, J., Campbell, C.D. & Tompkins, D. 2012. Risk assessment of the use of PAS100 green composts in sheep and cattle production in Scotland. *Waste Management,* **32**, 117-130. http://dx.doi.org/10.1016/j.wasman.2011.08.008

Hugron, S., Andersen, R., Poulin, M. & Rochefort, L. 2011. Natural plant colonization of borrow pits in boreal forest highlands of eastern Canada. *Botany-Botanique,* **89**, 451-465. http://dx.doi.org/10.1139/B11-036

Iason, G.R., O'Reilly-Wapstra, J.M., Brewer, M.J., Summers, R.W. & Moore, B. 2011. Do multiple herbivores maintain chemical diversity of Scots pine monoterpenes? *Philosophical Transactions of the Royal Society B-Biological Sciences,* **366**, 1337-1345. http://dx.doi.org/10.1098/rstb.2010.0236

Iavazzo, P., Adamo, P., Boni, M., Hillier, S. & Zampella, M. 2012. Mineralogy and chemical forms of lead and zinc in abandoned mine wastes and soils: An example from Morocco. *Journal of Geochemical Exploration,* **113**, 56-67. http://dx.doi.org/10.1016/j.gexplo.2011.06.001

Ibarra, J.T., Galvez, N., Gimona, A., Altamirano, T.A., Rojas, I., Hester, A., Laker, J. & Bonacic, C. 2012. Rufous-legged owl (*Strix rufipes*) and Austral pygmy owl (*Glaucidium nanum*) stand use in a gradient of disrupted and old growth Andean temperate forests, Chile. *Studies on Neotropical Fauna and Environment,* **47**, 33-40. http://dx.doi.org/10.1080/01650521.2012.665632

Irbe, I., Andersone, I., Andersons, B., Noldt, G., Dizhbite, T., Kurnosova, N., Nuopponen, M. & Stewart, D. 2011. Characterisation of the initial degradation stage of Scots pine (*Pinus sylvestris* L.) sapwood after attack by brown-rot fungus *Coniophora puteana*. *Biodegradation,* **22**, 719-728. http://dx.doi.org/10.1007/s10532-010-9449-6

James, A.B., Syed, N.H., Bordage, S., Marshall, J., Nimmo, G.A., Jenkins, G.I., Herzyk, P., Brown, J.W.S. & Nimmo, H.G. 2012. Alternative splicing mediates responses of the Arabidopsis circadian clock to temperature changes. *Plant Cell,* **24**, 961-981. http://dx.doi.org/10.1105/tpc.111.093948

James, M.C., Furness, R.W., Bowman, A.S., Forbes, K.J. & Gilbert, L. 2011. The importance of passerine birds as tick hosts and in the

transmission of *Borrelia burgdorferi*, the agent of lyme disease: a case study from Scotland. *Ibis,* **153**, 293-302. http://dx.doi.org/10.1111/j.1474-919X.2011.01111.x

Jayakody, S., Sibbald, A.M., Mayes, R.W., Hooper, R.J., Gordon, I.J. & Lambin, X. 2011. Effects of human disturbance on the diet composition of wild red deer (*Cervus elaphus*). *European Journal of Wildlife Research,* **57**, 939-948. http://dx.doi.org/10.1007/s10344-011-0508-z

Jiang, N., Wang, M.H., Jia, T.Y., Wang, L., Leach, L., Hackett, C., Marshall, D. & Luo, Z.W. 2011. A robust statistical method for association-based eQTL analysis. *PLoS One,* **6**, e23192. http://dx.doi.org/10.1371/journal.pone.0023192

Johnson, D., Vachon, J., Britton, A.J. & Helliwell, R.C. 2011. Drought alters carbon fluxes in alpine snowbed ecosystems through contrasting impacts on graminoids and forbs. *New Phytologist,* **190**, 740-749. http://dx.doi.org/10.1111/j.1469-8137.2010.03613.x

Jones, E.O., Webb, S.D., Ruiz-Fons, F.J., Albon, S. & Gilbert, L. 2011. The effect of landscape heterogeneity and host movement on a tick-borne pathogen. *Theoretical Ecology,* **4**, 435-448. http://dx.doi.org/10.1007/s12080-010-0087-8

Jupe, F., Pritchard, L., Etherington, G.J., MacKenzie, K., Cock, P.J.A., Wright, F., Sharma, S.K., Bolser, D., Bryan, G.J., Jones, J.D.G. & Hein, I. 2012. Identification and localisation of the NB-LRR gene family within the potato genome. *BMC Genomics,* **13**, 75 http://dx.doi.org/10.1186/1471-2164-13-75

Kalendar, R., Flavell, A.J., Ellis, T.H.N., Sjakste, T., Moisy, C. & Schulman, A.H. 2011. Analysis of plant diversity with retrotransposon-based molecular markers. *Heredity,* **106**, 520-530. http://dx.doi.org/10.1038/hdy.2010.93

Kalyna, M., Simpson, C.G., Syed, N.H., Lewandowska, D., Marquez, Y., Kusenda, B., Marshall, J., Fuller, J., Cardle, L., McNicol, J., Dinh, H.Q., Barta, A. & Brown, J.W.S. 2012. Alternative splicing and nonsense-mediated decay modulate expression of important regulatory genes in Arabidopsis. *Nucleic Acids Research,* **40**, 2454-2469. http://dx.doi.org/10.1093/nar/gkr932

Karami, N., Clemente, R., Moreno-Jimenez, E., Lepp, N.W. & Beesley, L. 2011. Efficiency of green waste compost and biochar soil amendments for reducing lead and copper mobility and uptake to ryegrass. *Journal of Hazardous Materials,* **191**, 41-48. http://dx.doi.org/10.1016/j.jhazmat.2011.04.025

Karley, A.J., Valentine, T.A. & Squire, G.R. 2011. Dwarf alleles differentially affect barley root traits influencing nitrogen acquisition under low nutrient supply. *Journal of Experimental Botany,* **62**, 3917-3927. http://dx.doi.org/10.1093/jxb/err089

Kennedy, E., Curran, J., Mayes, B., McEvoy, M., Murphy, J.P. & O'Donovan, M. 2011. Restricting dairy cow access time to pasture in early lactation: the effects on milk production, grazing behaviour and dry matter intake. *Animal,* **5**, 1805-1813. http://dx.doi.org/10.1017/S1751731111000826

Kerchev, P.I., Pellny, T.K., Vivancos, P.D., Kiddle, G., Hedden, P., Driscoll, S., Vanacker, H., Verrier, P., Hancock, R.D. & Foyer, C.H. 2011. The transcription factor ABI4 is required for the ascorbic acid-dependent regulation of growth and regulation of Jasmonate-dependent defense signaling pathways in arabidopsis. *Plant Cell,* **23**, 3319-3334. http://dx.doi.org/10.1105/tpc.111.090100

Kerchev, P.I., Fenton, B., Foyer, C.H. & Hancock, R.D. 2012. Infestation of potato (*Solanum tuberosum* L.) by the peach-potato aphid (*Myzus persicae* Sulzer) alters cellular redox status and is influenced by ascorbate. *Plant Cell and Environment,* **35**, 430-440. http://dx.doi.org/10.1111/j.1365-3040.2011.02395.x

Kerchev, P.I., Fenton, B., Foyer, C.H. & Hancock, R.D. 2012. Plant responses to insect herbivory: interactions between photosynthesis, reactive oxygen species and hormonal signalling pathways. *Plant Cell and Environment,* **35**, 441-453. http://dx.doi.org/10.1111/j.1365-3040.2011.02399.x

Khalid, A., Arshad, M., Anjum, M., Mahmood, T. & Dawson, L. 2011. The anaerobic digestion of solid organic waste. *Waste Management,* **31**, 1737-1744. http://dx.doi.org/10.1016/j.wasman.2011.03.021

Kikuchi, T., Cotton, J.A., Dalzell, J.J., Hasegawa, K., Kanzaki, N., McVeigh, P., Takanashi, T., Tsai, I.J., Assefa, S.A., Cock, P.J.A., Otto, T.D., Hunt, M., Reid, A.J., Sanchez-Flores, A., Tsuchihara, K., Yokoi, T., Larsson, M.C., Miwa, J., Maule, A.G., Sahashi, N., Jones, J.T. & Berriman, M. 2011. Genomic insights into the origin of parasitism in the emerging plant pathogen *Bursaphelenchus xylophilus*. *PLoS Pathogens,* **7**, e1002219. http://dx.doi.org/10.1371/journal.ppat.1002219

Kikvidze, Z., Suzuki, M. & Brooker, R. 2011. Conceptualizing importance: response to Freckleton and Rees. *Trends in Ecology & Evolution,* **26**, 499-500. http://dx.doi.org/10.1016/j.tree.2011.06.012

Kikvidze, Z., Suzuki, M. & Brooker, R. 2011. Importance versus intensity of ecological effects: why context matters. *Trends in Ecology & Evolution,* **26**, 383-388. http://dx.doi.org/10.1016/j.tree.2011.04.003

Kikvidze, Z., Michalet, R., Brooker, R.W., Cavieres, L.A., Lortie, C.J., Pugnaire, F.I. & Callaway, R.M. 2011. Climatic drivers of plant-plant interactions and diversity in alpine communities. *Alpine Botany,* **121**, 63-70. http://dx.doi.org/10.1007/s00035-010-0085-x

Knapp, C.W., McCluskey, S.M., Singh, B.K., Campbell, C.D., Hudson, G. & Graham, D.W. 2011. Antibiotic resistance gene abundances correlate with metal and geochemical conditions in archived Scottish soils. *PLoS One,* **6**, e27300. http://dx.doi.org/10.1371/journal.pone.0027300

Koikkalainen, R.K., Dawson, L.A., Mayes, R.W. & Smith, J.U. 2011. Effect of plant species, nitrogen fertilizer and grass age on the dynamics of intra-aggregate SOM. *Soil Biology & Biochemistry,* **43**, 1104-1107. http://dx.doi.org/10.1016/j.soilbio.2011.01.021

Kuster, E.C., Bierman, S.M., Klotz, S. & Kuhn, I. 2011. Modelling the impact of climate and land use change on the geographical distribution of leaf anatomy in a temperate flora. *Ecography,* **34**, 507-518. http://dx.doi.org/10.1111/j.1600-0587.2010.05892.x

Lambe, N.R., Richardson, R.I., Macfarlane, J.M., Nevison, I., Haresign, W., Matika, O. & Bunger, L. 2011. Genotypic effects of the Texel muscling QTL (TM-QTL) on meat quality in purebred Texel lambs. *Meat Science,* **89**, 125-132. http://dx.doi.org/10.1016/j.meatsci.2011.03.014

Lambers, H., Brundrett, M.C., Raven, J.A. & Hopper, S.D. 2011. Plant mineral nutrition in ancient landscapes: high plant species diversity on infertile soils is linked to functional diversity for nutritional strategies. *Plant and Soil,* **348**, 7-27. http://dx.doi.org/10.1007/s11104-011-0977-6

Lapierre, H., Holtrop, G., Calder, A.G., Renaud, J. & Lobley, G.E. 2012. Is D-methionine bioavailable to the dairy cow? *Journal of*

Dairy Science, **95**, 353-362.
http://dx.doi.org/10.3168/jds.2011-4553

Lawson, D.J., Holtrop, G. & Flint, H. 2011. Bayesian analysis of non-linear differential equation models with application to a gut microbial ecosystem. *Biometrical Journal,* **53**, 543-556.
http://dx.doi.org/10.1002/bimj.201000250

Lennon, J.J., Beale, C.M., Reid, C.L., Kent, M. & Pakeman, R.J. 2011. Are richness patterns of common and rare species equally well explained by environmental variables? *Ecography,* **34**, 529-539. http://dx.doi.org/10.1111/j.1600-0587.2010.06669.x

Lewis, F., Butler, A. & Gilbert, L. 2011. A unified approach to model selection using the likelihood ratio test. *Methods in Ecology and Evolution,* **2**, 155-162.
http://dx.doi.org/10.1111/j.2041-210X.2010.00063.x

Lian, X.M., Zhang, T.Z., Cao, Y.C., Su, J.P. & Thirgood, S. 2011. Road proximity and traffic flow perceived as potential predation risks: evidence from the Tibetan antelope in the Kekexili National Nature Reserve, China. *Wildlife Research,* **38** , 141-146.
http://dx.doi.org/10.1071/WR10158

Limpens, J., Granath, G., Gunnarsson, U., Aerts, R., Bayley, S., Bragazza, L., Bubier, J., Buttler, A., van den Berg, L.J.L., Francez, A.J., Gerdol, R., Grosvernier, P., Heijmans, M.M.P.D., Hoosbeek, M.R., Hotes, S., Ilomets, M., Leith, I., Mitchell, E.A.D., Moore, T., Nilsson, M.B., Nordbakken, J.F., Rochefort, L., Rydin, H., Sheppard, L.J., Thormann, M., Wiedermann, M.M., Williams, B.L. & Xu, B. 2011. Climatic modifiers of the response to nitrogen deposition in peat-forming *Sphagnum* mosses: a meta-analysis. *New Phytologist,* **191**, 496-507.
http://dx.doi.org/10.1111/j.1469-8137.2011.03680.x

Littlewood, N.A. 2011. Black scoter at Murcar and Blackdog, June - August 2011 - a first for North-east Scotland. *Scottish Birds,* **31**, 288-290.

Littlewood, N.A. 2011. *Philophorus cinnamopterus* (Kirschbaum, 1865) (HET.: MIRIDAE) in Edinburgh - a new species for Scotland. *Entomologist's Journal and Record of Variation,* **123**, 53-54.

Littlewood, N.A., Stewart, A.J.A. & Woodcock, B.A. 2012. Science into practice - how can fundamental science contribute to better management of grasslands for invertebrates? *Insect Conservation and Diversity,* **5**, 1-8.
http://dx.doi.org/10.1111/j.1752-4598.2011.00174.x

Littlewood, N.A., Pakeman, R.J. & Pozsgai, G. 2012. Grazing impacts on Auchenorrhyncha diversity and abundance on a Scottish upland estate. *Insect Conservation and Diversity,* **5**, 67-74.
http://dx.doi.org/10.1111/j.1752-4598.2011.00135.x

Lloyd, L.J., Foster, T., Rhodes, P., Rhind, S.M. & Gardner, D.S. 2012. Protein-energy malnutrition during early gestation in sheep blunts fetal renal vascular and nephron development and compromises adult renal function. *Journal of Physiology-London,* **590**, 377-393. http://dx.doi.org/10.1113/jphysiol.2011.220186

Lochlainn, S.O., Amoah, S., Graham, N.S., Alamer, K., Rios, J.J., Kurup, S., Stoute, A., Hammond, J.P., Ostergaard, L., King, G.J., White, P.J. & Broadley, M.R. 2011. High Resolution Melt (HRM) analysis is an efficient tool to genotype EMS mutants in complex crop genomes. *Plant Methods,* **7**, 43.
http://dx.doi.org/10.1186/1746-4811-7-43

Looseley, M.E., Newton, A.C., Atkins, S.D., Fitt, B.D.L., Fraaije, B.A., Thomas, W.T.B., Keith, R., Macaulay, M., Lynott, J. & Harrap, D. 2012. Genetic basis of control of *Rhynchosporium secalis* infection and symptom expression in barley. *Euphytica,* **184**, 47-56.
http://dx.doi.org/10.1007/s10681-011-0485-z

Luo, S.N., Tai, H., Zebarth, B., Li, X.Q., Millard, P., De Koeyer, D. & Xiong, X.Y. 2011. Sample collection protocol effects on quantification of gene expression in potato leaf tissue. *Plant Molecular Biology Reporter,* **29**, 369-378.
http://dx.doi.org/10.1007/s11105-010-0239-4

Macdonald, C.A., Clark, I.M., Zhao, F.J., Hirsch, P.R., Singh, B.K. & McGrath, S.P. 2011. Long-term impacts of zinc and copper enriched sewage sludge additions on bacterial, archaeal and fungal communities in arable and grassland soils. *Soil Biology & Biochemistry,* **43**, 932-941.
http://dx.doi.org/10.1016/j.soilbio.2011.01.004

MacKenzie, K., Hackett, C.A. 2012. Association mapping in a simulated barley population. *Euphytica,* **183**, 337-347.
http://dx.doi.org/10.1007/s10681-011-0505-z

Macleod, C.J.A., Falloon, P.D., Evans, R. & Haygarth, P.M. 2012. The effects of climate change on the mobilization of diffuse substances from agricultural systems. *Advances in Agronomy,* **115**, 41-77. http://dx.doi.org/10.1016/B978-0-12-394276-0.00002-0

Malosetti, M., van Eeuwijk, F.A., Boer, M.P., Casas, A.M., Elia, M., Moralejo, M., Bhat, P.R., Ramsay, L. & Molina-Cano, J.L. 2011. Gene and QTL detection in a three-way barley cross under selection by a mixed model with kinship information using SNPs. *Theoretical and Applied Genetics,* **122**, 1605-1616.
http://dx.doi.org/10.1007/s00122-011-1558-z

Mann, A.N., O'Reilly-Wapstra, J.M., Iason, G.R., Sanson, G., Davies, N.W., Tilyard, P., Williams, D. & Potts, B.M. 2012. Mammalian herbivores reveal marked genetic divergence among populations of an endangered plant species. *Oikos,* **121**, 268-276.
http://dx.doi.org/10.1111/j.1600-0706.2011.19667.x

Marcon, M., Mariano, K., Braga, R.A., Paglis, C.M., Scalco, M.S. & Horgan, G.W. 2011. Estimation of total leaf area in perennial plants using image analysis. *Revista Brasileira de Engenharia Agrícola e Ambiental*, **15**, 96-101.
http://dx.doi.org/10.1590/S1415-43662011000100014

Marconi, M., Giordano, M. & Raven, J.A. 2011. Impact of taxonomy, geography, and depth on delta C-13 and delta N-15 variation in a large collection of macroalgae. *Journal of Phycology,* **47**, 1023-1035.
http://dx.doi.org/10.1111/j.1529-8817.2011.01045.x

Martin, P. & Johnson, S.N. 2011. Evidence that elevated CO_2 reduces resistance to the European large raspberry aphid in some raspberry cultivars. *Journal of Applied Entomology,* **135**, 237-240.
http://dx.doi.org/10.1111/j.1439-0418.2010.01544.x

Martin-Fernández, J.A., Palarea-Albaladejo, J. & Barceló-Vidal, C. 2011. Técnicas composicionales para concentraciones geoquímicas por debajo del límite de detección. *Boletín Instituto Geológico y Minero de Espana*, **122**, 459-468.

Martin-Ortega, J. 2011. The costs of adaptation to climate change in freshwater systems: the state-of-play. *Revista Espanola de Economia Agraria y de los Recursos Naturales,* **11**, 3-26

Martin-Ortega, J., Brouwer, R. & Aiking, H. 2011. Application of a value-based equivalency method to assess environmental damage compensation under the European Environmental Liability Directive. *Journal of Environmental Management,* **92**, 1461-1470.
http://dx.doi.org/10.1016/j.jenvman.2010.12.001

Martin-Ortega, J., Giannoccaro, G. & Berbel, J. 2011. Environmental and resource costs under water scarcity conditions: an estimation in the context of the European Water Framework

Directive. *Water Resources Management,* **25**, 1615-1633. http://dx.doi.org/10.1007/s11269-010-9764-z

Martin-Ortega, J., Gonzalez-Eguino, M. & Markandya, A. 2012. The costs of drought: the 2007/2008 case of Barcelona. *Water Policy,* **14**, 539-560. http://dx.doi.org/10.2166/wp.2011.121

Martin, P., Johnson, S.N. 2011. Evidence that elevated CO_2 reduces resistance to the European large raspberry aphid in some raspberry cultivars. *Journal of Applied Entomology,* **135**, 237-240. http://dx.doi.org/10.1111/j.1439-0418.2010.01544.x

Martinez-Padilla, J., Vinuela, J. 2011. Hatching asynchrony and brood reduction influence immune response in Common Kestrel *Falco tinnunculus* nestlings. *Ibis,* **153**, 601-610.

Massa, A.N., Childs, K.L., Lin, H.N., Bryan, G.J., Giuliano, G. & Buell, C.R. 2011. The transcriptome of the reference potato genome *Solanum tuberosum* group phureja clone DM1-3 516R44. *PloS One,* **6**, e26801. http://dx.doi.org/10.1371/journal.pone.0026801

Matthews, R. & Dyer, G. 2011. Evaluating the impacts of REDD+ at subnational scales: are our frameworks and models good enough? *Carbon Management*, **2**, 517-527. http://dx.doi.org/10.4155/cmt.11.52

Mattila, P.H., Hellstrom, J., McDougall, G., Dobson, G., Pihlava, J.M., Tiirikka, T., Stewart, D. & Karjalainen, R. 2011. Polyphenol and vitamin C contents in European commercial blackcurrant juice products. *Food Chemistry,* **127**, 1216-1223. http://dx.doi.org/10.1016/j.foodchem.2011.01.129

Mayer, C.D., Lorent, J. & Horgan, G.W. 2011. Exploratory analysis of multiple omics datasets using the adjusted RV coefficient. *Statistical Applications in Genetics and Molecular Biology,* **10**, 1-27. http://dx.doi.org/10.2202/1544-6115.1540

Mayer, K.F.X., Martis, M., Hedley, P.E., Simkova, H., Liu, H., Morris, J.A., Steuernagel, B., Taudien, S., Roessner, S., Gundlach, H., Kubalakova, M., Suchankova, P., Murat, F., Felder, M., Nussbaumer, T., Graner, A., Salse, J., Endo, T., Sakai, H., Tanaka, T., Itoh, T., Sato, K., Platzer, M., Matsumoto, T., Scholz, U., Dolezel, J., Waugh, R. & Stein, N. 2011. Unlocking the barley genome by chromosomal and comparative genomics. *Plant Cell,* **23**, 1249-1263. http://dx.doi.org/10.1105/tpc.110.082537

Mayor, D.J., Cook, K., Thornton, B., Walsham, P., Witte, U.F.M., Zuur, A.F. & Anderson, T.R. 2011. Absorption efficiencies and basal turnover of C, N and fatty acids in a marine Calanoid copepod. *Functional Ecology,* **25**, 509-518. http://dx.doi.org/10.1111/j.1365-2435.2010.01791.x

McDougall, G.J., Martinussen, I., Junttila, O., Verrall, S. & Stewart, D. 2011. Assessing the influence of genotype and temperature on polyphenol composition in cloudberry (*Rubus chamaemorus* L.) using a novel mass spectrometric method. *Journal of Agricultural and Food Chemistry,* **59**, 10860-10868. http://dx.doi.org/10.1021/jf202083b

McGavin, W.J., Cock, P.J.A. & MacFarlane, S.A. 2011. Partial sequence and RT-PCR diagnostic test for the plant rhabdovirus Raspberry vein chlorosis virus. *Plant Pathology,* **60**, 462-467. http://dx.doi.org/10.1111/j.1365-3059.2010.02387.x

McGavin, W.J., Mitchell, C., Cock, P.J.A., Wright, K.M. & MacFarlane, S.A. 2012. Raspberry leaf blotch virus, a putative new member of the genus Emaravirus, encodes a novel genomic RNA. *Journal of General Virology,* **93**, 430-437. http://dx.doi.org/10.1099/vir.0.037937-0

McGeoch, S.C., Holtrop, G., Fyfe, C., Lobley, G.E., Pearson, D.W.M., Abraham, P., Megson, I.L., MacRury, S.M. & Johnstone, A.M. 2011. Food intake and dietary glycaemic index in free-living adults with and without type 2 diabetes mellitus. *Nutrients,* **3**, 683-693. http://dx.doi.org/10.3390/nu3060683

McIntosh, B.S., Ascough, J.C., Twery, M., Chew, J., Elmahdi, A., Haase, D., Harou, J.J., Hepting, D., Cuddy, S., Jakeman, A.J., Chen, S., Kassahun, A., Lautenbach, S., Matthews, K., Merritt, W., Quinn, N.W.T., Rodriguez-Roda, I., Sieber, S., Stavenga, M., Sulis, A., Ticehurst, J., Volk, M., Wrobel, M., van Delden, H., El-Sawah, S., Rizzoli, A. & Voinov, A. 2011. Environmental decision support systems (EDSS) development - Challenges and best practices. *Environmental Modelling & Software,* **26**, 1389-1402. http://dx.doi.org/10.1016/j.envsoft.2011.09.009

McKeown, N.K., Bishop, J.L., Cuadros, J., Hillier, S., Amador, E., Makarewicz, H.D., Parente, M. & Silver, E.A. 2011. Interpretation of reflectance spectra of clay mineral-silica mixtures: implications for martian clay mineralogy at Mawrth Vallis. *Clays and Clay Minerals,* **59**, 400-415. http://dx.doi.org/10.1346/CCMN.2011.0590404

McLean, M.H., Murray, G.I., Stewart, K.N., Norrie, G., Mayer, C.-D., Hold, G.L., Thompson, J., Fyfe, M., Hope, M., Mowat, N.A.G., Drew, J.E. & El-Omar, E.M. 2011. The inflammatory microenvironment in colorectal neoplasia. *PLoS One*, **6**, e15366. http://dx.doi.org/10.1371/journal.pone.0015366

Mcnally, R.R., Toth, I.K., Cock, P.J.A., Pritchard, L., Hedley, P.E., Morris, J.A., Zhao, Y.F. & Sundin, G.W. 2012. Genetic characterization of the HrpL regulon of the fire blight pathogen *Erwinia amylovora* reveals novel virulence factors. *Molecular Plant Pathology,* **13**, 160-173. http://dx.doi.org/10.1111/j.1364-3703.2011.00738.x

Meharg, A.A., Edwards, K.J., Schofield, J.E., Raab, A., Feldmann, J., Moran, A., Bryant, C.L., Thornton, B. & Dawson, J.J.C. 2012. First comprehensive peat depositional records for tin, lead and copper associated with the antiquity of Europe's largest cassiterite deposits. *Journal of Archaeological Science,* **39**, 717-727. http://dx.doi.org/10.1016/j.jas.2011.10.037

Meier-Augenstein, W., Chartrand, M.M.G., Kemp, H.F. & St-Jean, G. 2011. An inter-laboratory comparative study into sample preparation for both reproducible and repeatable forensic H-2 isotope analysis of human hair by continuous flow isotope ratio mass spectrometry. *Rapid Communications in Mass Spectrometry,* **25**, 3331-3338. http://dx.doi.org/10.1002/rcm.5235

Merz, U., Lees, A.K., Sullivan, L., Schwarzel, R., Hebeisen, T., Kirk, H.G., Bouchek-Mechiche, K. & Hofferbert, H.R. 2012. Powdery scab resistance in *Solanum tuberosum*: an assessment of cultivar x environment effect. *Plant Pathology,* **61**, 29-36. http://dx.doi.org/10.1111/j.1365-3059.2011.02489.x

Millard, P., Way, D.A. 2011. Tree competition and defense against herbivores: currency matters when counting the cost. *Tree Physiology,* **31**, 579-581. http://dx.doi.org/10.1093/treephys/tpr053

Minet, E., Goodhue, R., Coxon, C.E., Kalin, R.M. & Meier-Augenstein, W. 2011. Simplifying and improving the extraction of nitrate from freshwater for stable isotope analyses. *Journal of Environmental Monitoring,* **13**, 2062-2066. http://dx.doi.org/10.1039/C1EM10289C

Minh, N.D., Hough, R.L., Thuy, L.T., Nyberg, Y., Mai, L.B., Vinh, N.C., Khai, N.M. & Oborn, I. 2012. Assessing dietary exposure to cadmium in a metal recycling community in Vietnam: age and gender aspects. *Science of the Total Environment,* **416**, 164-171.

http://dx.doi.org/10.1016/j.scitotenv.2011.11.068

Mitchell, C., Brennan, R.M., Cross, J.V. & Johnson, S.N. 2011. Arthropod pests of currant and gooseberry crops in the UK: their biology, management and future prospects. *Agricultural and Forest Entomology,* **13**, 221-237. http://dx.doi.org/10.1111/j.1461-9563.2010.00513.x

Mitchell, R.J., Keith, A.M., Potts, J.M., Ross, J., Reid, E. & Dawson, L.A. 2012. Overstory and understory vegetation interact to alter soil community composition and activity. *Plant and Soil,* **352**, 65-84. http://dx.doi.org/10.1007/s11104-011-0980-y

Mitchell, R.J., Hester, A.J., Campbell, C.D., Chapman, S.J., Cameron, C.M., Hewison, R.L. & Potts, J.M. 2012. Explaining the variation in the soil microbial community: do vegetation composition and soil chemistry explain the same or different parts of the microbial variation? *Plant and Soil,* **351**, 355-362. http://dx.doi.org/10.1007/s11104-011-0968-7

Moles, A.T., Wallis, I.R., Foley, W.J., Warton, D.I., Stegen, J.C., Bisigato, A.J., Cella-Pizarro, L., Clark, C.J., Cohen, P.S., Cornwell, W.K., Edwards, W., Ejrnaes, R., Gonzales-Ojeda, T., Graae, B.J., Hay, G., Lumbwe, F.C., Magana-Rodriguez, B., Moore, B.D., Peri, P.L., Poulsen, J.R., Veldtman, R., von Zeipel, H., Andrew, N.R., Boulter, S.L., Borer, E.T., Campon, F.F., Coll, M., Farji-Brener, A.G., De Gabriel, J., Jurado, E., Kyhn, L.A., Low, B., Mulder, C.P.H., Reardon-Smith, K., Rodriguez-Velazquez, J., Seabloom, E.W., Vesk, P.A., van Cauter, A., Waldram, M.S., Zheng, Z., Blendinger, P.G., Enquist, B.J., Facelli, J.M., Knight, T., Majer, J.D., Martinez-Ramos, M., McQuillan, P. & Prior, L.D. 2011. Putting plant resistance traits on the map: a test of the idea that plants are better defended at lower latitudes. *New Phytologist,* **191**, 777-788. http://dx.doi.org/10.1111/j.1469-8137.2011.03732.x

Moran, D., MacLeod, M., Wall, E., Eory, V., McVittie, A., Barnes, A., Rees, R.M., Topp, C.F.E., Pajot, G., Matthews, R., Smith, P. & Moxey, A. 2011. Developing carbon budgets for UK agriculture, land-use, land-use change and forestry out to 2022. *Climatic Change,* **105**, 529-553. http://dx.doi.org/10.1007/s10584-010-9898-2

Moreno, F.C., Gordon, I.J., Wright, A.D., Benvenutti, M.A. & Saumell, C.A. 2011. *In vitro* anthelmintic efficacy of plant with potential antiparasitic effect against gastrointestinal nematode parasites of cattle and goats. *Archivos de Medicina Veterinaria,* **42**, 155-163.

Moreno-Jimenez, E., Beesley, L., Lepp, N.W., Dickinson, N.M., Hartley, W. & Clemente, R. 2011. Field sampling of soil pore water to evaluate trace element mobility and associated environmental risk. *Environmental Pollution,* **159**, 3078-3085. http://dx.doi.org/10.1016/j.envpol.2011.04.004

Morris, W.L., Ducreux, L.J.M., Shepherd, T., Lewinsohn, E., Davidovich-Rikanati, R., Sitrit, Y. & Taylor, M.A. 2011. Utilisation of the MVA pathway to produce elevated levels of the sesquiterpene alpha-copaene in potato tubers. *Phytochemistry,* **72**, 2288-2293. http://dx.doi.org/10.1016/j.phytochem.2011.08.023

Munang, R.T., Thiaw, I. & Rivington, M. 2011. Ecosystem management: Tomorrow's approach to enhancing food security under a changing climate. *Sustainability,* **3**, 937-954. http://dx.doi.org/10.3390/su3070937

Murray, P.J., Gregory, P.J., Granger, S.J., Headon, D.M. & Johnson, S.N. 2011. Dispersal of soil-dwelling clover root weevil (*Sitona lepidus* Gyllenhal; Coleoptera: Curculionidae) larvae in mixed plant communities. *Applied Soil Ecology,* **46**, 422-425. http://dx.doi.org/10.1016/j.apsoil.2010.09.008

Nazaries, L., Tate, K.R., Ross, D.J., Singh, J., Dando, J., Saggar, S., Baggs, E.M., Millard, P., Murrell, J.C. & Singh, B.K. 2011. Response of methanotrophic communities to afforestation and reforestation in New Zealand. *Isme Journal,* **5**, 1832-1836. http://dx.doi.org/10.1038/ismej.2011.62

Newton, A.C., Guy, D.C. 2011. Scale and spatial structure effects on the outcome of barley cultivar mixture trials for disease control. *Field Crops Research,* **123**, 74-79. http://dx.doi.org/10.1016/j.fcr.2011.05.002

Newton, A.C., Flavell, A.J., George, T.S., Leat, P., Mullholland, B., Ramsay, L., Revoredo-Giha, C., Russell, J., Steffenson, B.J., Swanston, J.S., Thomas, W.T.B., Waugh, R., White, P.J. & Bingham, I.J. 2011. Crops that feed the world 4. Barley: a resilient crop? Strengths and weaknesses in the context of food security. *Food Security,* **3**, 141-178. http://dx.doi.org/10.1007/s12571-011-0126-3

Newton, A.C., Johnson, S.N. & Gregory, P.J. 2011. Implications of climate change for diseases, crop yields and food security. *Euphytica,* **179**, 3-18. http://dx.doi.org/10.1007/s10681-011-0359-4

Newton, A.C., Guy, D.C., Bengough, A.G., Gordon, D.C., McKenzie, B.M., Sun, B., Valentine, T.A. & Hallett, P.D. 2012. Soil tillage effects on the efficacy of cultivars and their mixtures in winter barley. *Field Crops Research,* **128**, 91-100. http://dx.doi.org/10.1016/j.fcr.2011.12.004

Nielsen, U.N., Osler, G.H.R., Campbell, C.D., Burslem, D.F.R.P. & Van der Wal, R. 2012. Predictors of fine-scale spatial variation in soil mite and microbe community composition differ between biotic groups and habitats. *Pedobiologia,* **55**, 83-91. http://dx.doi.org/10.1016/j.pedobi.2011.11.002

Nijnik, M., Miller, D.R., Nijnik, A., Fiorini, S., Vogt, N., Brondizio, E. & Morrice, J.G. 2011. Public participation for planning the sustainable use of natural resources and landscape changes: methodology development. *International Journal of Interdisciplinary Social Sciences,* **5**, 303-320. http://iji.cgpublisher.com/product/pub.88/prod.1343

Norici, A., Bazzoni, A.M., Pugnetti, A., Raven, J.A. & Giordano, M. 2011. Impact of irradiance on the C allocation in the coastal marine diatom *Skeletonema marinoi* Sarno and Zingone. *Plant Cell and Environment,* **34**, 1666-1677. http://dx.doi.org/10.1111/j.1365-3040.2011.02362.x

Nunn, F.G., Burgess, S.T.G., Innocent, G., Nisbet, A.J., Bates, P. & Huntley, J.F. 2011. Development of a serodiagnostic test for sheep scab using recombinant protein Pso o 2. *Molecular and Cellular Probes,* **25**, 212-218. http://dx.doi.org/10.1016/j.mcp.2011.09.002

Nwankno, A.J., Gordon, S.L., Verrall, S.R., Brennan, R.M. & Hancock, R.D. 2012. Treatment with fungicides influences phytochemical quality of blackcurrant juice. *Annals of Applied Biology,* **160**, 86-96. http://dx.doi.org/10.1111/j.1744-7348.2011.00523.x

Nwosu, F., Morris, J., Lund, V.A., Stewart, D., Ross, H.A. & McDougall, G.J. 2011. Anti-proliferative and potential anti-diabetic effects of phenolic-rich extracts from edible marine algae. *Food Chemistry,* **126**, 1006-1012.

http://dx.doi.org/10.1016/j.foodchem.2010.11.111

O'Malley-James, J.T., Raven, J.A., Cockell, C.S. & Greaves, J.S. 2012. Life and light: exotic photosynthesis in binary and multiple-star systems. *Astrobiology,* **12**, 115-124. http://dx.doi.org/10.1089/ast.2011.0678

O'Sullivan, J.J., Bradford, R.A., Bonaiuto, M., De Dominicis, S., Rotko, P., Aaltonen, J., Waylen, K. & Langan, S.J. 2012. Enhancing flood resilience through improved risk communications. *Natural Hazards and Earth System Sciences,* **12**, 2271-2282. http://dx.doi.org/10.5194/nhess-12-2271-2012

Okello, E.J., McDougall, G.J., Kumar, S. & Seal, C.J. 2011. In vitro protective effects of colon-available extract of *Camellia sinensis* (tea) against hydrogen peroxide and beta-amyloid (A beta(1-42)) induced cytotoxicity in differentiated PC12 cells. *Phytomedicine,* **18**, 691-696. http://dx.doi.org/10.1016/j.phymed.2010.11.004

Old, G.H., Naden, P.S., Granger, S.J., Bilotta, G.S., Brazier, R.E., Macleod, C.J.A., Krueger, T., Bol, R., Hawkins, J.M.B., Haygarth, P. & Freer, J. 2012. A novel application of natural fluorescence to understand the sources and transport pathways of pollutants from livestock farming in small headwater catchments. *Science of the Total Environment,* **417**, 169-182. http://dx.doi.org/10.1016/j.scitotenv.2011.12.013

Oliveira, C.M.G., Monteiro, A.R. & Blok, V.C. 2011. Morphological and molecular diagnostics for plant-parastic nematodes: working together to get the identification done. *Tropical Plant Pathology,* **36**, 65-73.

Orskov, E.R. 2011. Goat production on a global basis. *Small Ruminant Research,* **98**, 9-11. http://dx.doi.org/10.1016/j.smallrumres.2011.03.009

Pakeman, R.J. 2011. Functional diversity indices reveal the impacts of land use intensification on plant community assembly. *Journal of Ecology,* **99**, 1143-1151. http://dx.doi.org/10.1111/j.1365-2745.2011.01853.x

Pakeman, R.J., Lennon, J.J. & Brooker, R.W. 2011. Trait assembly in plant assemblages and its modulation by productivity and disturbance. *Oecologia,* **167**, 209-218. http://dx.doi.org/10.1007/s00442-011-1980-6

Pakeman, R.J. 2011. Multivariate identification of plant functional response and effect traits in an agricultural landscape. *Ecology,* **92**, 1353-1365.

Pakeman, R.J., Eastwood, A. & Scobie, A. 2011. Leaf dry matter content as a predictor of grassland litter decomposition: a test of the 'mass ratio hypothesis'. *Plant and Soil,* **342**, 49-57. http://dx.doi.org/10.1007/s11104-010-0664-z

Pakeman, R.J., Huband, S., Kriel, A. & Lewis, R. 2011. Changes in the management of Scottish machair communities and associated habitats from the 1970s to the present. *Scottish Geographical Journal,* **127**, 267-287. http://dx.doi.org/10.1080/14702541.2012.666262

Pakeman, R.J., Small, J.L. & Torvell, L. 2012. Edaphic factors influence the longevity of seeds in the soil. *Plant Ecology,* **213**, 57-65. http://dx.doi.org/10.1007/s11258-011-0006-0

Paterson, E., Sim, A., Osborne, S.M. & Murray, P.J. 2011. Long-term exclusion of plant-inputs to soil reduces the functional capacity of microbial communities to mineralise recalcitrant root-derived carbon sources. *Soil Biology & Biochemistry,* **43**, 1873-1880. http://dx.doi.org/10.1016/j.soilbio.2011.05.006

Paterson, E., Neilson, R., Midwood, A.J., Osborne, S.M., Sim, A., Thornton, B. & Millard, P. 2011. Altered food web structure and C-flux pathways associated with mineralisation of organic amendments to agricultural soil. *Applied Soil Ecology,* **48**, 107-116. http://dx.doi.org/10.1016/j.apsoil.2011.04.006

Pelser, P.B., Abbott, R.J., Comes, H.P., Milton, J.J., Moller, M., Looseley, M.E., Cron, G.V., Barcelona, J.F., Kennedy, A.H., Watson, L.E., Barone, R., Hernandez, F. & Kadereit, J.W. 2012. The genetic ghost of an invasion past: colonization and extinction revealed by historical hybridization in Senecio. *Molecular Ecology,* **21**, 369-387. http://dx.doi.org/10.1111/j.1365-294X.2011.05399.x

Peng, X., Hallett, P.D., Zhang, B. & Horn, R. 2011. Physical response of rigid and non-rigid soils to analogues of biological exudates. *European Journal of Soil Science,* **62**, 676-684. http://dx.doi.org/10.1111/j.1365-2389.2011.01383.x

Perez-Espona, S., Perez-Barberia, F.J. & Pemberton, J.M. 2011. Assessing the impact of past wapiti introductions into Scottish Highland red deer populations using a Y chromosome marker. *Mammalian Biology,* **76**, 640-643. http://dx.doi.org/10.1016/j.mambio.2010.10.001

Perez-Mendoza, D., Coulthurst, S.J., Humphris, S., Campbell, E., Welch, M., Toth, I.K. & Salmond, G.P.C. 2011. A multi-repeat adhesin of the phytopathogen, *Pectobacterium atrosepticum*, is secreted by a Type I pathway and is subject to complex regulation involving a non-canonical diguanylate cyclase. *Molecular Microbiology,* **82**, 719-733. http://dx.doi.org/10.1111/j.1365-2958.2011.07849.x

Pignotti, E., Edwards, P., Gotts, N. & Polhill, G. 2011. Enhancing workflow with a semantic description of scientific intent. *Journal of Web Semantics,* **9**, 222-244. http://dx.doi.org/10.1016/j.websem.2011.05.001

Pocar, P., Fiandanese, N., Secchi, C., Berrini, A., Fischer, B., Schmidt, J.S., Schaedlich, K., Rhind, S.M., Zhang, Z.L. & Borromeo, V. 2012. Effects of polychlorinated biphenyls in CD-1 mice: reproductive toxicity and intergenerational transmission. *Toxicological Sciences,* **126**, 213-226. http://dx.doi.org/10.1093/toxsci/kfr327

Poggio, L., Soille, P. 2011. A probabilistic approach to river network detection in digital elevation models. *Catena,* **87**, 341-350. http://dx.doi.org/10.1016/j.catena.2011.07.001

Polechova, J., Barton, N. & Marion, G. 2011. Species' range: adaptation in space and time (vol 174, pg E186, 2009). *American Naturalist,* **177**, 546-547. http://dx.doi.org/10.1086/659642

Polhill, J.G., Gimona, A. & Aspinall, R.J. 2011. Agent-based modelling of land use effects on ecosystem processes and services. *Journal of Land Use Science,* **6**, 75-81. http://dx.doi.org/10.1080/1747423X.2011.558603

Porter, R., Norman, R. & Gilbert, L. 2011. Controlling tick-borne diseases through domestic animal management: a theoretical approach. *Theoretical Ecology,* **4**, 321-339. http://dx.doi.org/10.1007/s12080-010-0080-2

Pozsgai, G., Littlewood, N.A. 2011. Changes in the phenology of the ground beetle *Pterostichus madidus*. *Insect Science,* **18**, 462-472. http://dx.doi.org/10.1111/j.1744-7917.2011.01416.x

Prager, K. 2011. Adaptives management in naturschutz und landschaftspflege - die rolle von gruppen und Vverbänden in Europa (Adaptive management in nature conservation and landscape management - The role of groups and associations in Europe). *Natur und Landschaft,* **86**, 343-349.

Prager, K. 2011. Becoming a behavioral science researcher. A guide to producing research that matters. *International Journal of Social Research Methodology,* **14**, 327-328.

Prager, K., Prazan, J. & Penov, I. 2012. Soil conservation in transition countries: the role of institutions. *Environmental Policy and Governance,* **22**, 55-73. http://dx.doi.org/10.1002/eet.592

Prager, K., Reed, M. & Scott, A. 2012. Encouraging collaboration for the provision of ecosystem services at a landscape scale-Rethinking agri-environmental payments. *Land Use Policy,* **29**, 244-249. http://dx.doi.org/10.1016/j.landusepol.2011.06.012

Prager, K., Schuler, J., Helming, K., Zander, P., Ratinger, T. & Hagedorn, K. 2011. Soil degradation, farming practices, institutions and policy responses: An analytical framework. *Land Degradation and Development,* **22**, 32-46. http://dx.doi.org/10.1002/ldr.979

Prior, G.L., Evans, D.M., Redpath, S., Thirgood, S.J. & Monaghan, P. 2011. Birds bias offspring sex ratio in response to livestock grazing. *Biology Letters,* **7**, 958-960. http://dx.doi.org/10.1098/rsbl.2011.0264

Pritchard, L., Birch, P. 2011. A systems biology perspective on plant-microbe interactions: Biochemical and structural targets of pathogen effectors. *Plant Science,* **180**, 584-603. http://dx.doi.org/10.1016/j.plantsci.2010.12.008

Psaltopoulos, D., Skuras, D. & Thomson, K.J. 2011. Employment effects of private investment initiatives in rural areas of southern Europe: a regional SAM approach. *Agricultural Economics Review (Greek Association of Agricultural Economists),* **12**, 50-61. http://www.eng.auth.gr/mattas/12_2_5.pdf

Rakitina, D.V., Taliansky, M., Brown, J.W.S. & Kalinina, N.O. 2011. Two RNA-binding sites in plant fibrillarin provide interactions with various RNA substrates. *Nucleic Acids Research,* **39**, 8869-8880. http://dx.doi.org/10.1093/nar/gkr594

Rasmussen, J.J., Baattrup-Pedersen, A., Riis, T. & Friberg, N. 2011. Stream ecosystem properties and processes along a temperature gradient. *Aquatic Ecology,* **45**, 231-242. http://dx.doi.org/10.1007/s10452-010-9349-1

Raven, J.A. 2011. The cost of photoinhibition. *Physiologia Plantarum,* **142**, 87-104. http://dx.doi.org/10.1111/j.1399-3054.2011.01465.x

Raven, J.A. 2011. Effects on marine algae of changed seawater chemistry with increasing atmospheric CO_2. *Biology and Environment: Proceedings of the Royal Irish Academy,* **111B**, 1-17. http://dx.doi.org/10.3318/BIOE.2011.01

Raven, J.A., Giordano, M., Beardall, J. & Maberly, S.C. 2011. Algal and aquatic plant carbon concentrating mechanisms in relation to environmental change. *Photosynthesis Research,* **109**, 281-296. http://dx.doi.org/10.1007/s11120-011-9632-6

Raven, J.A., Giordano, M., Beardall, J. & Maberly, S.C. 2012. Algal evolution in relation to atmospheric CO_2: carboxylases, carbon-concentrating mechanisms and carbon oxidation cycles. *Philosophical Transactions of the Royal Society B-Biological Sciences,* **367**, 493-507. http://dx.doi.org/10.1098/rstb.2011.0212

Rhee, Y.J., Hillier, S. & Gadd, G.M. 2012. Lead transformation to pyromorphite by fungi. *Current Biology,* **22**, 237-241. http://dx.doi.org/10.1016/j.cub.2011.12.017

Rhind, S.M., Kyle, C.E., Kerr, C., Osprey, M. & Zhang, Z.L. 2011. Effect of duration of exposure to sewage sludge-treated pastures on liver tissue accumulation of persistent endocrine disrupting compounds (EDCs) in sheep. *Science of the Total Environment,* **409**, 3850-3856. http://dx.doi.org/10.1016/j.scitotenv.2011.03.021

Roberts, D.M., Schofield, P.G., Donn, S. & Daniell, T.J. 2012. Directed terminal restriction analysis tool (DRAT): an aid to enzyme selection for directed terminal-restriction fragment length polymorphisms. *Methods in Ecology and Evolution,* **3** , 24-28. http://dx.doi.org/10.1111/j.2041-210X.2011.00139.x

Roberts, W.M., Stutter, M.I. & Haygarth, P.M. 2012. Phosphorus retention and remobilization in vegetated buffer strips: a review. *Journal of Environmental Quality,* **41**, 389-399. http://dx.doi.org/10.2134/jeq2010.0543

Rojas, I., Becerra, P., Galvez, N., Laker, J., Bonacic, C. & Hester, A. 2011. Relationship between fragmentation, degradation and native and exotic species richness in an Andean temperate forest of Chile. *Gayana Botanica,* **68**, 163-175.

Ronfort, C., Souchere, V., Martin, P., Sebillotte, C., Castellazzi, M.S., Barbottin, A., Meynard, J.M. & Laignel, B. 2011. Methodology for land use change scenario assessment for runoff impacts: A case study in a north-western European Loess belt region (Pays de Caux, France). *Catena,* **86**, 36-48. http://dx.doi.org/10.1016/j.catena.2011.02.004

Rosling, A., Cox, F., Cruz-Martinez, K., Ihrmark, K., Grelet, G.A., Lindahl, B.D., Menkis, A. & James, T.Y. 2011. Archaeorhizomycetes: unearthing an ancient class of ubiquitous soil fungi. *Science,* **333**, 876-879. http://dx.doi.org/10.1126/science.1206958

Ross, H.A., Morris, W.L., Ducreux, L.J.M., Hancock, R.D., Verrall, S.R., Morris, J.A., Tucker, G.A., Stewart, D., Hedley, P.E., McDougall, G.J. & Taylor, M.A. 2011. Pectin engineering to modify product quality in potato. *Plant Biotechnology Journal,* **9**, 848-856. http://dx.doi.org/10.1111/j.1467-7652.2011.00591.x

Rubio-Aliaga, I., de Roos, B., Duthie, S.J., Crosley, L.K., Mayer, C., Horgan, G., Colquhoun, I.J., Le Gall, G., Huber, F., Kremer, W., Rychlik, M., Wopereis, S., van Ommen, B., Schmidt, G., Heim, C., Bouwman, F.G., Mariman, E.C., Mulholland, F., Johnson, I.T., Polley, A.C., Elliott, R.M. & Daniel, H. 2011. Metabolomics of prolonged fasting in humans reveals new catabolic markers. *Metabolomics,* **7**, 375-387. http://dx.doi.org/10.1007/s11306-010-0255-2

Rungapamestry, V., McMonagle, J., Reynolds, C., Rucklidge, G., Reid, M., Duncan, G., Ross, K., Horgan, G., Toomey, S., Moloney, A.P., de Roos, B. & Roche, H.M. 2012. Inter-organ proteomic analysis reveals insights into the molecular mechanisms underlying the anti-diabetic effects of cis-9, trans-11-conjugated linoleic acid in ob/ob mice. *Proteomics,* **12**, 461-476. http://dx.doi.org/10.1002/pmic.201100312

Russell, J., Dawson, I.K., Flavell, A.J., Steffenson, B., Weltzien, E., Booth, A., Ceccarelli, S., Grando, S. & Waugh, R. 2011. Analysis of > 1000 single nucleotide polymorphisms in geographically matched samples of landrace and wild barley indicates secondary contact and chromosome-level differences in diversity around domestication genes. *New Phytologist,* **191**, 564-578. http://dx.doi.org/10.1111/j.1469-8137.2011.03704.x

Russell, J.R., Bayer, M., Booth, C., Cardle, L., Hackett, C.A., Hedley, P.E., Jorgensen, L., Morris, J.A. & Brennan, R.M. 2011. Identification, utilisation and mapping of novel transcriptome-based markers from blackcurrant (*Ribes nigrum*). *BMC Plant*

Biology, **11**, 147. http://dx.doi.org/10.1186/1471-2229-11-147

Russell, W.R., Gratz, S.W., Duncan, S.H., Holtrop, G., Ince, J., Scobbie, L., Duncan, G., Johnstone, A.M., Lobley, G.E., Wallace, R.J., Duthie, G.G. & Flint, H.J. 2011. High-protein, reduced-carbohydrate weight-loss diets promote metabolite profiles likely to be detrimental to colonic health. *American Journal of Clinical Nutrition,* **93**, 1062-1072. http://dx.doi.org/10.3945/ajcn.110.002188

Sait, M., Clark, E.M., Wheelhouse, N., Spalding, L., Livingstone, M., Sachseh, K., Markey, B.K., Magnino, S., Siarkou, V.I., Vretou, E., Caro, M.R., Yaga, R., Lainson, F.A., Smith, D.G.E., Wright, F. & Longbottom, D. 2011. Genetic variability of Chlamydophila abortus strains assessed by PCR-RFLP analysis of polymorphic membrane protein-encoding genes. *Veterinary Microbiology,* **151**, 284-290. http://dx.doi.org/10.1016/j.vetmic.2011.03.005

Salmela, M.J., Cavers, S., Cottrell, J.E., Iason, G.R. & Ennos, R.A. 2011. Seasonal patterns of photochemical capacity and spring phenology reveal genetic differentiation among native Scots pine (*Pinus sylvestris* L.) populations in Scotland. *Forest Ecology and Management,* **262**, 1020-1029. http://dx.doi.org/10.1016/j.foreco.2011.05.037

Sandilands, V., Brocklehurst, S., Sparks, N., Baker, L., McGovern, R., Thorp, B. & Pearson, D. 2011. Assessing leg health in chickens using a force plate and gait scoring: How many birds is enough? *Veterinary Record,* **168**, 77. http://dx.doi.org/10.1136/vr.c5978

Santos, P.M., Thornton, B. & Corsi, M. 2012. Adaptation of the C-4 grass *Panicum maximum* to defoliation is related to plasticity of N uptake, mobilisation and allocation patterns. *Scientia Agricola,* **69**, 293-299.

Scibetta, S., Schena, L., Chimento, A., Cacciola, S.O. & Cooke, D.E.L. 2012. A molecular method to assess Phytophthora diversity in environmental samples. *Journal of Microbiological Methods,* **88**, 356-368. http://dx.doi.org/10.1016/j.mimet.2011.12.012

Scott, V., Kettle, H. & Merchant, C.J. 2011. Sensitivity analysis of an ocean carbon cycle model in the North Atlantic: an investigation of parameters affecting the air-sea CO_2 flux, primary production and export of detritus. *Ocean Science,* **7**, 405-419. http://dx.doi.org/10.5194/os-7-405-2011

Selge, S., Fischer, A. & Van der Wal, R. 2011. Public and professional views on invasive non-native species - a qualitative social scientific investigation. *Biological Conservation,* **144**, 3089-3097. http://dx.doi.org/10.1016/j.biocon.2011.09.014

Selge, S., Fischer, A. 2011. How people familiarize themselves with complex ecological concepts - anchoring of social representations of invasive non-native species. *Journal of Community & Applied Social Psychology,* **21**, 297-311. http://dx.doi.org/10.1002/casp.1075

Semashko, M.A., Rakitina, D.V., Gonzalez, I., Canto, T., Kalinina, N.O. & Taliansky, M.E. 2012. Movement protein of hordeivirus interacts in vitro and *in vivo* with coilin, a major structural protein of Cajal bodies. *Doklady Biochemistry and Biophysics,* **442**, 57-60. http://dx.doi.org/10.1134/S1607672912010164

Shahinnia, F., Druka, A., Franckowiak, J., Morgante, M., Waugh, R. & Stein, N. 2012. High resolution mapping of Dense spike-ar (dsp.ar) to the genetic centromere of barley chromosome 7H. *Theoretical and Applied Genetics,* **124**, 373-384. http://dx.doi.org/10.1007/s00122-011-1712-7

Shaw, P., Brown, J. 2012. Nucleoli: composition, function, and dynamics. *Plant Physiology,* **158**, 44-51. http://dx.doi.org/10.1104/pp.111.188052

Shepherd, L.V.T., Fraser, P. & Stewart, D. 2011. Metabolomics: a second-generation platform for crop and food analysis. *Bioanalysis,* **3**, 1143-1159. http://dx.doi.org/10.4155/BIO.11.61

Sibbald, A.M., Hooper, R.J., Mcleod, J.E. & Gordon, I.J. 2011. Responses of red deer (*Cervus elaphus*) to regular disturbance by hill walkers. *European Journal of Wildlife Research,* **57**, 817-825. http://dx.doi.org/10.1007/s10344-011-0493-2

Silvar, C., Casas, A.M., Igartua, E., Ponce-Molina, L.J., Gracia, M.P., Schweizer, G., Herz, M., Flath, K., Waugh, R., Kopahnke, D. & Ordon, F. 2011. Resistance to powdery mildew in Spanish barley landraces is controlled by different sets of quantitative trait loci. *Theoretical and Applied Genetics,* **123**, 1019-1028. http://dx.doi.org/10.1007/s00122-011-1644-2

Singh, B.K., Tate, K., Thomas, N., Ross, D. & Singh, J. 2011. Differential effect of afforestation on nitrogen-fixing and denitrifying communities and potential implications for nitrogen cycling. *Soil Biology & Biochemistry,* **43**, 1426-1433. http://dx.doi.org/10.1016/j.soilbio.2011.03.007

Slee, B. 2011. Present opportunities for sustainable and multifunctional forest management for the development of rural areas. *EAI Speciale - Forests: a Millenary Heritage that Guarantees us Life,* **57**, 61-68. http://www.enea.it/it/produzione-scientifica/pdf-eai/speciale-forests/presentopportunities.pdf

Slee, B. 2011. Re-imagining forests as multifunctional and sustainable resources for a low carbon rural economy: the potential for forest-based rural development. *Revista Espanola de Dessarrollo Rural (Spanish Journal of Rural Development),* **2**, 37-50.

Smykal, P., Kenicer, G., Flavell, A.J., Corander, J., Kosterin, O., Redden, R.J., Ford, R., Coyne, C.J., Maxted, N., Ambrose, M.J. & Ellis, N.T.H. 2011. Phylogeny, phylogeography and genetic diversity of the Pisum genus. *Plant Genetic Resources - Characterization and Utilization,* **9**, 4-18. http://dx.doi.org/10.1017/S147926211000033X

Sonnenberg, R., Bransby, M.F., Bengough, A.G., Hallett, P.D. & Davies, M.C.R. 2012. Centrifuge modelling of soil slopes containing model plant roots. *Canadian Geotechnical Journal,* **49**, 1-17. http://dx.doi.org/10.1139/T11-081

Sparrow, A.D., Gregorich, E.G., Hopkins, D.W., Novis, P., Elberling, B. & Greenfield, L.G. 2011. Resource limitations on soil microbial activity in an Antarctic dry valley. *Soil Science Society of America Journal,* **75**, 2188-2197. http://dx.doi.org/10.2136/sssaj2010.0303

Speed, J.D.M., Austrheim, G., Hester, A.J. & Mysterud, A. 2011. Browsing interacts with climate to determine tree-ring increment. *Functional Ecology,* **25**, 1018-1023. http://dx.doi.org/10.1111/j.1365-2435.2011.01877.x

Speed, J.D.M., Austrheim, G., Hester, A.J. & Mysterud, A. 2011. Growth limitation of mountain birch caused by sheep browsing at the altitudinal treeline. *Forest Ecology and Management,* **261**, 1344-1352. http://dx.doi.org/10.1016/j.foreco.2011.01.017

Spencer, K.L., Suzuki, K. & Hillier, S. 2011. The development of rare earth element-labelled potassium-depleted clays for use as cohesive sediment tracers in aquatic environments. *Journal of Soils and Sediments,* **11**, 1052-1061. http://dx.doi.org/10.1007/s11368-011-0377-9

Spezia, L., Futter, M.N. & Brewer, M.J. 2011. Periodic multivariate normal hidden Markov models for the analysis of water quality

time series. *Environmetrics,* **22**, 304-317. http://dx.doi.org/10.1002/env.1051

Sprent, J.I. & Gehlot, H.S. 2011. Nodulated legumes in arid and semi-arid environments: are they important? *Plant Ecology and Diversity,* **3**, 211-219. http://dx.doi.org/10.1080/17550874.2010.538740

Squires, J., Gillespie, T., Schoelz, J.E. & Palukaitis, P. 2011. Excision and episomal replication of cauliflower mosaic virus integrated into a plant genome. *Plant Physiology,* **155**, 1908-1919. http://dx.doi.org/10.1104/pp.110.171611

Stockan, J.A., Langan, S.J. & Young, M.R. 2012. Investigating riparian margins for vegetation patterns and plant-environment relationships in Northeast Scotland. *Journal of Environmental Quality,* **41**, 364-372. http://dx.doi.org/10.2134/jeq2010.0518

Stopher, K.V., Nussey, D.H., Clutton-Brock, T.H., Guinness, F., Morris, A. & Pemberton, J.M. 2011. The red deer rut revisited: female excursions but no evidence females move to mate with preferred males. *Behavioral Ecology,* **22**, 808-818. http://dx.doi.org/10.1093/beheco/arr052

Street, L.E., Subke, J.A., Sommerkorn, M., Heinemeyer, A. & Williams, M. 2011. Turnover of recently assimilated carbon in arctic bryophytes. *Oecologia,* **167**, 325-337. http://dx.doi.org/10.1007/s00442-011-1988-y

Stutter, M.I., Lumsdon, D.G. & Rowland, A.P. 2011. Three representative UK moorland soils show differences in decadal release of dissolved organic carbon in response to environmental change. *Biogeosciences,* **8**, 3661-3675. http://dx.doi.org/10.5194/bg-8-3661-2011

Stutter, M.I., Chardon, W.J. & Kronvang, B. 2012. Riparian buffer strips as a multifunctional management tool in agricultural landscapes: introduction. *Journal of Environmental Quality,* **41**, 297-303. http://dx.doi.org/10.2134/jeq2011.0439

Stutter, M.I., Richards, S. 2012. Relationships between soil physicochemical, microbiological properties, and nutrient release in buffer soils compared to field soils. *Journal of Environmental Quality,* **41**, 400-409. http://dx.doi.org/10.2134/jeq2010.0456

Stutter, M.I., Shand, C.A., George, T.S., Blackwell, M.S.A., Bol, R., Mackay, R.L., Richardson, A.E., Condron, L.M., Turner, B.L. & Haygarth, P.M. 2012. Recovering phosphorus from soil: a root solution? *Environmental Science & Technology,* **46**, 1977-1978. http://dx.doi.org/10.1021/es2044745

Stutter, M.I., Dunn, S.M. & Lumsdon, D.G. 2012. Dissolved organic carbon dynamics in a UK podzolic moorland catchment: linking storm hydrochemistry, flow path analysis and sorption experiments. *Biogeosciences,* **9**, 2159-2175. http://dx.doi.org/10.5194/bg-9-2159-2012

Suarez-Moreno, Z.R., Caballero-Mellado, J., Coutinho, B.G., Mendonca-Previato, L., James, E.K. & Venturi, V. 2012. Common features of environmental and potentially beneficial plant-associated *Burkholderia*. *Microbial Ecology,* **63**, 249-266. http://dx.doi.org/10.1007/s00248-011-9929-1

Subedi, M., Hocking, T.J., Fullen, M.A., Mccrea, A.R. & Milne, E. 2011. Factors influencing the effectiveness of an agro-environmental project in China. *Outlook on Agriculture,* **40**, 157-163. http://dx.doi.org/10.5367/oa.2011.0036

Subramanian, N.K., White, P.J., Broadley, M.R. & Ramsay, G. 2011. The three-dimensional distribution of minerals in potato tubers. *Annals of Botany,* **107**, 681-691. http://dx.doi.org/10.1093/aob/mcr009

Sun, X.L., Gilroy, E.M., Chini, A., Nurmberg, P.L., Hein, I., Lacomme, C., Birch, P.R.J., Hussain, A., Yun, B.W. & Loake, G.J. 2011. ADS1 encodes a MATE-transporter that negatively regulates plant disease resistance. *New Phytologist,* **192**, 471-482. http://dx.doi.org/10.1111/j.1469-8137.2011.03820.x

Sutherland, L.A. 2011. Effectively organic: environmental gains on conventional farms through the market? *Land Use Policy,* **28**, 815-824. http://dx.doi.org/10.1016/j.landusepol.2011.01.009

Sutherland, L.A., Burton, R.J.F. 2011. Good farmers, good neighbours? The role of cultural capital in social capital development in a Scottish farming community. *Sociologia Ruralis,* **51**, 238-255. http://dx.doi.org/10.1111/j.1467-9523.2011.00536.x

Sutherland, W.J., Bellingan, L., Bellingham, J.R., Blackstock, J.J., Bloomfield, R.M., Bravo, M., Cadman, V.M., Cleevely, D.D., Clements, A., Cohen, A.S., Cope, D.R., Daemmrich, A.A., Devecchi, C., Anadon, L.D., Denegri, S., Doubleday, R., Dusic, N.R., Evans, R.J., Feng, W.Y., Godfray, H.C.J., Harris, P., Hartley, S.E., Hester, A.J., Holmes, J., Hughes, A., Hulme, M., Irwin, C., Jennings, R.C., Kass, G.S., Littlejohns, P., Marteau, T.M., Mckee, G., Millstone, E.P., Nuttall, W.J., Owens, S., Parker, M.M., Pearson, S., Petts, J., Ploszek, R., Pullin, A.S., Reid, G., Richards, K.S., Robinson, J.G., Shaxson, L., Sierra, L., Smith, B.G., Spiegelhalter, D.J., Stilgoe, J., Stirling, A., Tyler, C.P., Winickoff, D.E. & Zimmern, R.L. 2012. A collaboratively-derived science-policy research agenda. *PLoS One,* **7**, e31824. http://dx.doi.org/10.1371/journal.pone.0031824

Swanston, J.S., Middlefell-Williams, J.E., Forster, B.P. & Thomas, W.T.B. 2011. Effects of grain and malt beta-glucan on distilling quality in a population of hull-less barley. *Journal of the Institute of Brewing,* **117**, 389-393.

Swanston, J.S., Smith, P.L., Agu, R.C., Brosnan, J.M., Bringhurst, T.A. & Jack, F.R. 2012. Variation, across environments within the UK, in grain protein and grain hardness, in wheat varieties of differing distilling quality. *Field Crops Research,* **127**, 146-152. http://dx.doi.org/10.1016/j.fcr.2011.11.016

Swanston, J.S., Middlefell-Williams, J.F. 2012. The influence of steep regime and germination period on the malting properties of some hull-less barley lines. *Journal of the Institute of Brewing,* **118**, 186-191. http://dx.doi.org/10.1002/jib.21

Taylor, M.A., Fraser, P.D. 2011. Solanesol: added value from solanaceous waste. *Phytochemistry,* **72**, 1323-1327. http://dx.doi.org/10.1016/j.phytochem.2011.03.015

Thirugnanasambandam, A., Wright, K.M., Havis, N., Whisson, S.C. & Newton, A.C. 2011. Agrobacterium-mediated transformation of the barley pathogen *Ramularia collo-cygni* with fluorescent marker tags and live tissue imaging of infection development. *Plant Pathology,* **60**, 929-937. http://dx.doi.org/10.1111/j.1365-3059.2011.02440.x

Thirugnanasambandam, A., Wright, K.M., Atkins, S.D., Whisson, S.C. & Newton, A.C. 2011. Infection of Rrs1 barley by an incompatible race of the fungus *Rhynchosporium secalis* expressing the green fluorescent protein. *Plant Pathology,* **60**, 513-521. http://dx.doi.org/10.1111/j.1365-3059.2010.02393.x

Thomson, K.J. 2011. Challenges for research in the field of agricultural economics in the UK. *Roczniki Nauk Rolniczych,* **98**, 19-27.

Thonur, L., Maley, M., Gilray, J., Crook, T., Laming, E., Turnbull, D., Nath, M. & Willoughby, K. 2012. One-step multiplex real time RT-PCR for the detection of bovine respiratory syncytial virus,

bovine herpesvirus 1 and bovine parainfluenza virus 3. *BMC Veterinary Research,* **8**, 37. http://dx.doi.org/10.1186/1746-6148-8-37

Thornton, B., Zhang, Z.L., Mayes, R.W., Hogberg, M.N. & Midwood, A.J. 2011. Can gas chromatography combustion isotope ratio mass spectrometry be used to quantify organic compound abundance? *Rapid Communications in Mass Spectrometry,* **25**, 2433-2438. http://dx.doi.org/10.1002/rcm.5148

Tilsner, J., Linnik, O., Wright, K.M., Bell, K., Roberts, A.G., Lacomme, C., Cruz, S.S. & Oparka, K.J. 2012. The TGB1 movement protein of potato virus X reorganizes actin and endomembranes into the X-Body, a viral replication factory. *Plant Physiology,* **158**, 1359-1370. http://dx.doi.org/10.1104/pp.111.189605

Tolkamp, B.J., Allcroft, D.J., Barrio, J.P., Bley, T.A.G., Howie, J.A., Jacobsen, T.B., Morgan, C.A., Schweitzer, D.P.N., Wilkinson, S., Yeates, M.P. & Kyriazakis, I. 2011. The temporal structure of feeding behavior. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology,* **301**, R378-R393. http://dx.doi.org/10.1152/ajpregu.00661.2010

Toorop, P.E., Cuerva, R.C., Begg, G.S., Locardi, B., Squire, G.R. & Iannetta, P.P.M. 2012. Co-adaptation of seed dormancy and flowering time in the arable weed *Capsella bursa-pastoris* (shepherd's purse). *Annals of Botany,* **109**, 481-489. http://dx.doi.org/10.1093/aob/mcr301

Tordoff, G.M., Chamberlain, P.M., Crowther, T.W., Black, H.I.J., Jones, T.H., Stott, A. & Boddy, L. 2011. Invertebrate grazing affects nitrogen partitioning in the saprotrophic fungus *Phanerochaete velutina*. *Soil Biology & Biochemistry,* **43**, 2338-2346. http://dx.doi.org/10.1016/j.soilbio.2011.07.005

Toth, I.K., van der Wolf, J.M., Saddler, G., Lojkowska, E., Helias, V., Pirhonen, M., Tsror, L. & Elphinstone, J.G. 2011. Dickeya species: an emerging problem for potato production in Europe. *Plant Pathology,* **60**, 385-399. http://dx.doi.org/10.1111/j.1365-3059.2011.02427.x

Trinder, C.J., Brooker, R.W., Davidson, H. & Robinson, D. 2012. Dynamic trajectories of growth and nitrogen capture by competing plants. *New Phytologist,* **193**, 948-958. http://dx.doi.org/10.1111/j.1469-8137.2011.04020.x

Trinder, C.J., Brooker, R.W., Davidson, H. & Robinson, D. 2012. A new hammer to crack an old nut: interspecific competitive resource capture by plants is regulated by nutrient supply, not climate. *PLoS One,* **7**, e29413. http://dx.doi.org/10.1371/journal.pone.0029413

Upadhyaya, H.D., Dwivedi, S.L., Ambrose, M., Ellis, N., Berger, J., Smykal, P., Debouck, D., Duc, G., Dumet, D., Flavell, A., Sharma, S.K., Mallikarjuna, N. & Gowda, C.L.L. 2011. Legume genetic resources: management, diversity assessment, and utilization in crop improvement. *Euphytica,* **180**, 27-47. http://dx.doi.org/10.1007/s10681-011-0449-3

Urquhart, J., Courtney, P. & Slee, B. 2012. Private woodland owners' perspectives on multifunctionality in English woodlands. *Journal of Rural Studies,* **28**, 95-106. http://dx.doi.org/10.1016/j.jrurstud.2011.08.006

van der Heijden, G., Song, Y., Horgan, G., Polder, G., Dieleman, A., Bink, M., Palloix, A., van Eeuwijk, F. & Glasbey, C. 2012. SPICY: towards automated phenotyping of large pepper plants in the greenhouse. *Functional Plant Biology,* **39**, 870-877. http://dx.doi.org/10.1071/FP12019

van der Zee, R., Pisa, L., Andonov, S., Brodschneider, R., Charriere, J.D., Chlebo, R., Coffey, M.F., Crailsheim, K., Dahle, B., Gajda, A., Gray, A., Drazic, M.M., Higes, M., Kauko, L., Kence, A., Kence, M., Kezic, N., Kiprijanovska, H., Kralj, J., Kristiansen, P., Hernandez, R.M., Mutinelli, F., Nguyen, B.K., Otten, C., Ozkirim, A., Pernal, S.F., Peterson, M., Ramsay, G., Santrac, V., Soroker, V., Topolska, G., Uzunov, A., Vejsnaes, F., Wei, S. & Wilkins, S. 2012. Managed honey bee colony losses in Canada, China, Europe, Israel and Turkey, for the winters of 2008-9 and 2009-10. *Journal of Apicultural Research,* **51**, 91-114. http://dx.doi.org/10.3896/IBRA.1.51.1.12

van Dijk, J.P., Cankar, K., Hendriksen, P.J.M., Beenen, H.G., Zhu, M., Scheffer, S., Shepherd, L.V.T., Stewart, D., Davies, H.V., Leifert, C., Wilkockson, S.J., Gruden, K. & Kok, E.J. 2012. The identification and interpretation of differences in the transcriptomes of organically and conventionally grown potato tubers. *Journal of Agricultural and Food Chemistry,* **60**, 2090-2101. http://dx.doi.org/10.1021/jf204696w

van Doorn, W.G., Beers, E.P., Dangl, J.L., Franklin-Tong, V.E., Gallois, P., Hara-Nishimura, I., Jones, A.M., Kawai-Yamada, M., Lam, E., Mundy, J., Mur, L.A.J., Petersen, M., Smertenko, A., Taliansky, M., Van Breusegem, F., Wolpert, T., Woltering, E., Zhivotovsky, B. & Bozhkov, P.V. 2011. Morphological classification of plant cell deaths. *Cell Death and Differentiation,* **18**, 1241-1246. http://dx.doi.org/10.1038/cdd.2011.36

Vartapetian, A.B., Tuzhikov, A.I., Chichkova, N.V., Taliansky, M. & Wolpert, T.J. 2011. A plant alternative to animal caspases: subtilisin-like proteases. *Cell Death and Differentiation,* **18**, 1289-1297. http://dx.doi.org/10.1038/cdd.2011.49

Veresoglou, S.D., Mamolos, A.P., Thornton, B., Voulgari, O.K., Sen, R. & Veresoglou, D.S. 2011. Medium-term fertilization of grassland plant communities masks plant species-linked effects on soil microbial community structure. *Plant and Soil,* **344**, 187-196. http://dx.doi.org/10.1007/s11104-011-0739-5

Veronico, P., Melillo, M.T., Saponaro, C., Leonetti, P., Picardi, E. & Jones, J.T. 2011. A polygalacturonase-inhibiting protein with a role in pea defence against the cyst nematode *Heterodera goettingiana*. *Molecular Plant Pathology,* **12**, 275-287. http://dx.doi.org/10.1111/j.1364-3703.2010.00671.x

Vetukuri, R.R., Tian, Z.D., Avrova, A.O., Savenkov, E.I., Dixelius, C. & Whisson, S.C. 2011. Silencing of the PiAtvr3a effector-encoding gene from *Phytophthora infestans* by transcriptional fusion to a short interspersed element. *Fungal Biology,* **115**, 1225-1233. http://dx.doi.org/10.1016/j.funbio.2011.08.007

Vetukuri, R.R., Avrova, A.O., Grenville-Briggs, L.J., van West, P., Soderbom, F., Savenkov, E.I., Whisson, S.C. & Dixelius, C. 2011. Evidence for involvement of Dicer-like, argonaute and histone deacetylase proteins in gene silencing in *Phytophthora infestans*. *Molecular Plant Pathology,* **12**, 772-785. http://dx.doi.org/10.1111/J.1364-3703.2011.00710.X

Viñuela-Fernandez, I., Jones, E., McKendrick, I.J. & Molony, V. 2011. Quantitative assessment of increased sensitivity of chronic laminitic horses to hoof tester evoked pain. *Equine Veterinary Journal,* **43**, 62-68. http://dx.doi.org/10.1111/j.2042-3306.2010.00137.x

Vinten, A.J.A., Artz, R.R.E., Thomas, N., Potts, J.M., Avery, L., Langan, S.J., Watson, H., Cook, Y., Taylor, C., Abel, C., Reid, E. & Singh, B.K. 2011. Comparison of microbial community assays for the assessment of stream biofilm ecology. *Journal of Microbiological Methods,* **85**, 190-198. http://dx.doi.org/10.1016/j.mimet.2011.03.001

Wachowiak, W., Salmela, M.J., Ennos, R.A., Iason, G. & Cavers, S. 2011. High genetic diversity at the extreme range edge: nucleotide variation at nuclear loci in Scots pine (*Pinus sylvestris* L.) in Scotland. *Heredity,* **106**, 775-787. http://dx.doi.org/10.1038/hdy.2010.118

Wang, C., Wan, T.R. & Palmer, I.J. 2012. Automatic reconstruction of 3D environment using real terrain data and satellite images. *Intelligent Automation and Soft Computing,* **18**, 49-63.

Wang, D., Calla, B., Qi, M., Korban, S., Clough, S., Sundin, G., Toth, I. & Zhao, Y. 2011. Genome-wide identification of genes regulated by RcsB and RcsC in *Erwinia amylovora*. *Phytopathology,* **101**, S186-S186.

Wang, D.P., Qi, M.S., Calla, B., Korban, S.S., Clough, S.J., Cock, P.J.A., Sundin, G.W., Toth, I. & Zhao, Y.F. 2012. Genome-wide identification of genes regulated by the Rcs phosphorelay system in *Erwinia amylovora*. *Molecular Plant-Microbe Interactions,* **25**, 6-17. http://dx.doi.org/10.1094/MPMI-08-11-0207

Wang, M.H., Jiang, N., Jia, T.Y., Leach, L., Cockram, J., Waugh, R., Ramsay, L., Thomas, B. & Luo, Z.W. 2012. Genome-wide association mapping of agronomic and morphologic traits in highly structured populations of barley cultivars. *Theoretical and Applied Genetics,* **124**, 233-246. http://dx.doi.org/10.1007/s00122-011-1697-2

Warren, C.R. & McKee, A.J. 2011.The Scottish revolution? Evaluating the impacts of post devolution land reform. *Scottish Geographical Journal*, **127**, 17-39. http://dx.doi.org/10.1080/14702541.2011.579572

Wawra, S., Bain, J., Durward, E., de Bruijn, I., Minor, K.L., Matena, A., Lobach, L., Whisson, S.C., Bayer, P., Porter, A.J., Birch, P.R.J., Secombes, C.J. & van West, P. 2012. Host-targeting protein 1 (SpHtp1) from the oomycete *Saprolegnia parasitica* translocates specifically into fish cells in a tyrosine-O-sulphate-dependent manner. *Proceedings of the National Academy of Sciences of the United States of America,* **109**, 2096-2101. http://dx.doi.org/10.1073/pnas.1113775109

Waylen, K.A., Fischer, A., Mcgowan, P.J.K. & Milner-Gulland, E.J. 2012. Interactions between a collectivist culture and Buddhist teachings influence environmental concerns and behaviors in the Republic of Kalmykia, Russia. *Society & Natural Resources,* **25**, 1118-1133. http://dx.doi.org/10.1080/08941920.2012.663065

Wening, S., Croxford, A.E., Ford, C.S., Thomas, W.T.B., Forster, B.P., Okyere-Boateng, G., Nelson, S.P.C., Caligari, P.D.S. & Wilkinson, M.J. 2012. Ranking the value of germplasm: new oil palm (*Elaeis guineensis*) breeding stocks as a case study. *Annals of Applied Biology,* **160**, 145-156. http://dx.doi.org/10.1111/j.1744-7348.2011.00527.x

Whisson, S.C., Avrova, A.O., Boevink, P.C., Armstrong, M.R., Seman, Z.A., Hein, I. & Birch, P.R.J. 2011. Exploiting knowledge of pathogen effectors to enhance late blight resistance in potato. *Potato Research,* **54**, 325-340. http://dx.doi.org/10.1007/s11540-011-9197-y

White, P.J., Broadley, M.R., Hammond, J.P., Ramsay, G., Subramanian, N.K., Thompson, J. & Wright, G. 2012. Bio-fortification of potato tubers using foliar zinc-fertiliser. *Journal of Horticultural Science & Biotechnology,* **87**, 123-129.

Whitfield, S., Reed, M., Thomson, K., Christie, M., Stringer, L.C., Quinn, C.H., Anderson, R., Moxey, A. & Hubacek, K. 2011. Managing peatland ecosystem services: current UK policy and future challenges in a changing world. *Scottish Geographical Journal,* **127**, 209-230. http://dx.doi.org/10.1080/14702541.2011.616864

Woinarski, J.C.Z., Legge, S., Fitzsimons, J.A., Traill, B.J., Burbidge, A.A., Fisher, A., Firth, R.S.C., Gordon, I.J., Griffiths, A.D., Johnson, C.N., McKenzie, N.L., Palmer, C., Radford, I., Rankmore, B., Ritchie, E.G., Ward, S. & Ziembicki, M. 2011. The disappearing mammal fauna of northern Australia: context, cause, and response. *Conservation Letters,* **4**, 192-201. http://dx.doi.org/10.1111/j.1755-263X.2011.00164.x

Wuyts, N., Bengough, A.G., Roberts, T.J., Du, C.J., Bransby, M.F., McKenna, S.J. & Valentine, T.A. 2011. Automated motion estimation of root responses to sucrose in two *Arabidopsis thaliana* genotypes using confocal microscopy. *Planta,* **234**, 769-784. http://dx.doi.org/10.1007/s00425-011-1435-7

Xiao, H., Hourihan, J.M., Brown, L.J., McMahon, M., Stewart, D. & Hayes, J.D. 2011. Nrf2-mediated induction of antioxidant response element-driven gene expression by flavonoids is dependent on their chemical structure. *Toxicology,* **290**, 126-127. http://dx.doi.org/10.1016/j.tox.2011.09.046

Xin, G.S., Long, R.J., Guo, X.S., Irvine, J., Ding, L.M., Ding, L.L. & Shang, Z.H. 2011. Blood mineral status of grazing Tibetan sheep in the Northeast of the Qinghai-Tibetan Plateau. *Livestock Science,* **136**, 102-107. http://dx.doi.org/10.1016/j.livsci.2010.08.007

Xu, X., Pan, S.K., Cheng, S.F., Zhang, B., Mu, D.S., Ni, P.X., Zhang, G.Y., Yang, S., Li, R.Q., Wang, J., Orjeda, G., Guzman, F., Torres, M., Lozano, R., Ponce, O., Martinez, D., De la Cruz, G., Chakrabarti, S.K., Patil, V.U., Skryabin, K.G., Kuznetsov, B.B., Ravin, N.V., Kolganova, T.V., Beletsky, A.V., Mardanov, A.V., Di Genova, A., Bolser, D.M., Martin, D.M.A., Li, G.C., Yang, Y., Kuang, H.H., Hu, Q., Xiong, X.Y., Bishop, G.J., Sagredo, B., Mejia, N., Zagorski, W., Gromadka, R., Gawor, J., Szczesny, P., Huang, S.W., Zhang, Z.H., Liang, C.B., He, J., Li, Y., He, Y., Xu, J.F., Zhang, Y.J., Xie, B.Y., Du, Y.C., Qu, D.Y., Bonierbale, M., Ghislain, M., Herrera, M.D., Giuliano, G., Pietrella, M., Perrotta, G., Facella, P., O'Brien, K., Feingold, S.E., Barreiro, L.E., Massa, G.A., Diambra, L., Whitty, B.R., Vaillancourt, B., Lin, H.N., Massa, A., Geoffroy, M., Lundback, S., DellaPenna, D., Buell, C.R., Sharma, S.K., Marshall, D.F., Waugh, R., Bryan, G.J., Destefanis, M., Nagy, I., Milbourne, D., Thomson, S.J., Fiers, M., Jacobs, J.M.E., Nielsen, K.L., Sonderkaer, M., Iovene, M., Torres, G.A., Jiang, J.M., Veilleux, R.E., Bachem, C.W.B., de Boer, J., Borm, T., Kloosterman, B., van Eck, H., Datema, E., Hekkert, B.T.L., Goverse, A., Van Ham, R.C.H.J. & Visser, R.G.F. 2011. Genome sequence and analysis of the tuber crop potato. *Nature,* **475**, 189-U94. http://dx.doi.org/10.1038/nature10158

Yan, X., De Clercq, P., Han, R.C., Jones, J., Chen, S.L. & Moens, M. 2011. Osmotic responses of different strains of *Steinernema carpocapsae*. *Nematology,* **13**, 845-851. http://dx.doi.org/10.1163/138855411X554181

Yao, H., Gao, Y., Nicol, G.W., Campbell, C.D., Prosser, J.I., Zhang, L., Han, W. & Singh, B.K. 2011. Links between ammonia oxidizer community structure, abundance, and nitrification potential in acidic Soils. *Applied and Environmental Microbiology,* **77**, 4618-4625. http://dx.doi.org/10.1128/AEM.00136-11

Yao, H.Y., Campbell, C.D. & Qiao, X.R. 2011. Soil pH controls nitrification and carbon substrate utilization more than urea or charcoal in some highly acidic soils. *Biology and Fertility of Soils,* **47**, 515-522. http://dx.doi.org/10.1007/s00374-011-0554-4

Zakhrabekova, S., Gough, S.P., Braumann, I., Muller, A.H.,

Lundqvist, J., Ahmann, K., Dockter, C., Matyszczak, I., Kurowska, M., Druka, A., Waugh, R., Graner, A., Stein, N., Steuernagel, B., Lundqvist, U. & Hansson, M. 2012. Induced mutations in circadian clock regulator Mat-a facilitated short-season adaptation and range extension in cultivated barley. *Proceedings of the National Academy of Sciences of the United States of America,* **109**, 4326-4331. http://dx.doi.org/10.1073/pnas.1113009109

Zebarth, B.J., Tai, H.L., Luo, S.N., Millard, P., De Koeyer, D., Li, X.Q. & Xiong, X.Y. 2011. Differential gene expression as an indicator of nitrogen sufficiency in field-grown potato plants. *Plant and Soil,* **345**, 387-400. http://dx.doi.org/10.1007/s11104-011-0793-z

Zetsche, E., Thornton, B., Midwood, A.J. & Witte, U. 2011. Utilisation of different carbon sources in a shallow estuary identified through stable isotope techniques. *Continental Shelf Research,* **31**, 832-840. http://dx.doi.org/10.1016/j.csr.2011.02.006

Zetsche, E., Paterson, D.M., Lumsdon, D.G. & Witte, U. 2011. Temporal variation in the sediment permeability of an intertidal sandflat. *Marine Ecology-Progress Series,* **441**, 49-63. http://dx.doi.org/10.3354/meps09390

Zhang, Z.L., Rhind, S.M. 2011. Optimized determination of polybrominated diphenyl ethers and polychlorinated biphenyls in sheep serum by solid-phase extraction-gas chromatography-mass spectrometry. *Talanta,* **84**, 487-493. http://dx.doi.org/10.1016/j.talanta.2011.01.042

Research in Progress
at 1 October 2011

RESAS Core

Theme 1 Ecosystem Services

Theme 2 Water and Renewable Energy

Theme 3 Land Use

Theme 4 Economic Adaptation

Theme 5 Food

Theme 6 Health and Welfare

Theme 7 Healthy Safe Diets

Theme 8 Rural Communities

Strategic Partnership – Food and Drink

Strategic Partnership – Animal Science Excellence

Centre of Expertise – Climate Change

Centre of Expertise – Animal Disease Outbreaks

Centre of Expertise – Water

RESAS Contract Research Funding

SCR/921/09	Cell wall lignin programme: manipulating lignin to improve biofuel conversion of plant biomass.
SCR/925/09	Study the epidemiology of *Phytophthora ramorum* and *Phytophthora kernoviae* in managed gardens and heathland in Scotland.
SCR/926/09	Functional characterisation of novel pathogenicity genes of the parasitic nematode *Globodera pallida*.
SCR/929/11	An enduring pipeline to identify and utilise durable late blight disease resistance in potato.
BSS/038/10	Integrating the use of climate impact projections in the MRPs.
BSS/845/06	Epidemiology, population, health and infectious disease control.
IOM/848/08	Environmental determinants of public health in Scotland.
MLU/845/06	Epidemiology, population, health and infectious disease control.
MLU/847/08	The contribution of green and open space in public health and wellbeing.

External Research Contracts

Aviagen Ltd	Development of software package for the semi-automatic tracing of longitudinal cross-sections of poultry breast images
BBSRC (via University of Birmingham)	LoLa: Meiosis in barley: manipulating crossover frequency and distribution
BBSRC (via University of Dundee)	LoLa: What are the roles of oomycete RXLR effectors in the establishment of plant disease?
BBSRC (via University of Dundee)	Host translocation requirements of the cytoplasmic crinkler (CRN) effector protein family in *Phytophthora*
BBSRC (via University of Sussex)	Targeted mRNA degradation in *Drosophila spermatogenesis*
Belgian Government	PROBA-V: Evaluation of accuracy characteristics in heterogeneous zones
Bioforsk	Plant metabolites for healthy plants and healthy people
Commercial	Brassica breeding
Commercial	Potato breeding
Commercial	Blackcurrant breeding
Commercial	Lipid analysis
Commercial	Germination testing
Commercial	Environmental impact
Commercial	Land use/contaminated land assessment
Commercial	Soil survey
Commercial	Soil mapping
Commercial	Analytical services
Defra	Development of appropriate variety testing methodology for assessing nitrogen requirements of new varieties in trials undertaken for national listing
Defra (Darwin Initiative)	Building natural resource monitoring capacity in Ethiopia's key afro-montane ecosystems
Defra (via ADAS)	Improvements to the UK national inventory of greenhouse gases.
Defra (via Centre for Ecology and Hydrology)	Terrestrial umbrella: Effects of eutrophication and acidification on terrestrial ecosystems.
Defra (via Centre for Ecology and Hydrology)	Critical loads and dynamic modelling
Defra (via Duchy College)	Micropropagation for the conservation of rare species under threat of infection by *Phytophthora ramorum* and *P. kernoviae* in the UK
Defra (via Greenwich University)	Reducing energy usage and wastage by improving ethylene control of potato sprouting
Defra (via Moredun Research Institute)	Further work on host parasite interactions, including the potential for the control of sheep scab using immunological approaches and the development of diagnostic tools
Defra (via SAC)	Sustainable and effective control of potato blight: Matching fungicide inputs to cultivar resistance level
Defra (via SAC)	Welfare costs and benefits of existing and novel on-farm culling methods of poultry
Defra (via SAC)	Early environment effects on welfare, health and productivity
Defra (via SAC)	Study to determine whether cage-based breeding can meet the needs of game birds, and if not, to identify best practice
Defra LINK (via ADAS)	TRAMLINES: Practical cost-effective techniques to reduce pollution from tramlines in combinable crops: a field and catchment scale evaluation
Defra LINK (via AHDB/HDC)	SCEPTRE: Sustainable crop and environment production - targeted research for edibles
Defra LINK (via East Malling Research)	Developing biocontrol methods and their integration in sustainable pest and disease management in blackcurrant production
Defra LINK (via NIAB)	New wheat root ideotypes for yield performance in reduced input agriculture

Defra LINK (via SAC)	CORACLE: Control of *Ramularia* leaf spot in a changing climate
Defra/RESAS LINK	QUOATS: Harnessing new technologies for sustainable oat production and utilisation. (SCR/928/09)
E-Content Plus	GS soil - European soil information
EU	SPICY: Smart tools for prediction and improvement of crop yield
EU	Triticeae Genome: Genomics for Triticeae improvement
EU	PLAPROVA: Plant production of vaccines
EU	Meiosys: Systematic analysis of factors controlling meiotic recombination in higher plants
EU	NUECrops: Improving nutrient efficiency in major European food, feed and biofuel crops to reduce the negative environmental impact of crop production
EU	METAPRO: The development of tools and effective strategies for the optimisation of useful secondary metabolite production in plants
EU	Legume Futures: Legume supported cropping systems for Europe
EU	PURE: Pesticide use-and-risk production in European farming systems with integrated pest management
EU	EUBerry: The sustainable improvement of European berry production, quality and nutritional value in a changing environment: strawberries, currants, blackberries, blueberries and raspberries
EU	HUNT: Hunting for sustainability
EU	GILDED: Governance, infrastructure, lifestyle dynamics and energy demand
EU	REDD-ALERT: Reducing emissions from deforestation and degradation
EU	REFRESH: Restoration, protection and management of European freshwater ecosystems in a world of global change
EU	SPIRAL: Science-policy interfaces for biodiversity: research, action and learning
EU	LOCAW: Low carbon at work
EU	FARMPATH: Farming transitions: pathways towards regional sustainability of agriculture in Europe
EU	LandscapePartners: The contribution of multi-stakeholder partnerships to sustainable landscape management.
EU COST Action	COST Action 869: Nutrient mitigation options
EU Interreg IVB	Climafruit: Future-proofing the North Sea berry fruit industry in times of climate change
EU Interreg IVB	WaterCAP: A cluster project on water management in a changing climate, adaptation to new conditions, and promotion of new strategies
EU Interreg NSP	AQUARIUS: The farmer as water manager under changing climatic conditions
Forestry Commission	Modelling forestry impacts on water quality
German Government	LEGATO: Land use intensity and ecological engineering - assessment tools for risks and opportunities in irrigated rice-based production systems
Genomia	Validation of a high-throughput nematode molecular tool as a bio-indicator of soil health
Home-Grown Cereals Authority	Fungicide performance information for barley growers
Horticultural Development Council	Assessment of plant elicitors to induce resistance against head rot in broccoli
Horticultural Development Council	Reducing bacterial infection in seed onions through the use of plant elicitors
Horticultural Development Council/Genecom	Integrated pest management strategies for vine weevil
Innovation Portal	Desk top study of control of head rot in broccoli
International Atomic Energy Agency	SCRI barley mutation grids

International Atomic Energy Agency	Improving nutritional quality by altering concentrations of enhancing factors using induced mutation and biotechnology in crops
Monsanto Fund	Increased potato yields and farmers' incomes by establishing systems to support virus-free seed tuber production and demonstrating the benefits
NERC (via University of Aberdeen)	PolicyGrid II: Supporting inter-disciplinary evidence bases for scientific collaboration and policy making
NERC (via University of Aberdeen)	The importance of intra- and interspecific diversity of ectomycorrhizal fungi on ecosystem functioning
NERC (via University of East Anglia)	Valuation network
NERC (via University of East Anglia)	Virtual observatory pilot
Norwegian Forest and Landscape Institute	Cultural landscapes of tourism and hospitality
Norwegian Research Council	Structural changes in agriculture, rural communities and cultural landscapes
Norwegian Research Council	Reindeer heading and commodification of the outfields and commons in Southern-Sami
Norwegian Research Council	TICKLESS: Tick control in sheep in Norway
Potato Council/RERAD	Investigating the biology and appropriate control of *Dickeya solani* affecting GB potato production
Potato Council Ltd	Independent variety trials
Potato Council Ltd	GB late blight populations: monitoring and implications of population changes
Potato Council Ltd	Informing management of potato diseases through epidemiology and diagnostics
Potato Council Ltd	Aphids and virus transmission in seed potato crops
Potato Council Ltd	Research to support further development of the PCN model: understanding interactions in mixed populations and the potential for a second generation of PCN
Potato Council Ltd	Evaluation the effectiveness of mineral oils in minimising the spread of non-persistent viruses in potato crops in GB
Potato Council Ltd	Provision of comprehensive independent disease resistance ratings for potato varieties for the potato industry
Quality Meat Scotland	Soil sampling and analysis to inform disease management and soil health
Quality Meat Scotland	Farm Soil Carbon: Farm assessment of soil C status
RESAS/AHDB	A raspberry (*Rubus idaeus*) breeding consortium for the UK. (MRS/008/09)
RESAS/Defra/Potato Council	Sequencing the 'gene space' of potato chromosome IV, comparative analysis with tomato and development of a gene-based mapping platform. (SCR/920/08)
RESAS/Defra LINK (via John Innes Centre)	INSPYR: Integrated strategy to prevent mycotoxin risks
RESAS/GSK (HortLink)	Development of high profile germplasm for UK production of blueberries. (MRS/007/09)
RESAS/HDC (HortLink)	Developing breeding and selection tools to reduce spoilage of soft fruits and wastage in the supply chain. (SCR/924/09)
RESAS/Rothamsted International LINK	Producing low acrylamide risk potatoes. (SCR/923/09)
RESAS (via SAC)	Research towards an integrated measurement of meat eating quality
Robert Gordon University	GIS and remote-sensing course materials
Royal Society	Identification of aphid effector plant targets in solanaceous crops
Royal Society	Plant virus modulator of host defence interactions with plant cell components
Royal Society for the Protection of Birds	Social and environmental consequences of game bird shooting styles
Royal Society of Edinburgh/Scottish Government/ Marie Curie Actions 2010	Personal Research Fellowship – Dr Jorunn Bos

Scottish Agricultural College	Novel approaches for the management of cabbage root fly
Scottish Agricultural College	WildTech: Novel technologies for surveillance of emerging and re-emerging infections of wildlife
Scottish Catholic International Aid Fund	Kulima Programme
Scottish Executive	Malawi Development Fund: Strengthening potato development
Scottish Funding Council	Paraban sub-project on influence of environment on paraTB
Scottish Ministers	JANEEMO enterprises
Scottish Natural Heritage	Feasibility study: Translocation of species in northern or montane environments
Scottish Natural Heritage	The Scottish beaver trial monitoring programme
Scottish Natural Heritage	Managing and restoration blanket bog to benefit biodiversity and carbon balance
Scottish Natural Heritage	Surveillance of BAP priority lichens in Scotland
Scottish Natural Heritage	Development of a surveillance scheme for priority lichens and fungi in Scotland
Scottish Natural Heritage	Surveillance of priority terrestrial invertebrates
Scottish Natural Heritage	Deer performance and health data analysis
Scottish Natural Heritage	Linking macrohabitat and pressure data with freshwater pearl mussel distribution in the river Spey
Swedish University of Agricultural Sciences	Towards the mitigation of environmental and public health risks due to heavy metal contamination in irrigated rice-based systems in Vietnam
Swedish University of Agricultural Sciences	Stumps and invertebrate and fungal diversity
Technology Strategy Board	Breeding for physical resistance traits – protecting soft fruit crops from pests and pathogens
Technology Strategy Board	MIDRIB: Molecular improvement of disease resistance in barley
Technology Strategy Board	SIBLINGS: Symptomless infection of barley-resistance breeding and integrated crop protection strategies
Technology Strategy Board	FLN Potato: Strategies for quantifying and controlling free living nematode populations and consequent damage by *Tobacco rattle virus* to improve potato yield and quality
Technology Strategy Board	Application of association mapping and genomic sequencing to modern potato breeding
Technology Strategy Board	Development of a commercial laser isotope ratiometer for food adulteration analysis
Thomas Thomson and Innovation Portal	Analysis of fruit juices and related vegetable shelf-life extension
Universidada de Evora, Portugal	Genomic analysis of bacteria associated with pinewood nematode infection
University of Aarhus, Denmark	Ultrastructural analysis of rhizobial endocytosis in the model legume *Medicago truncatula*
University of Ghent, Belgium	EUMAINE: European Master of Science in Nematology
University of Glasgow, Scotland	Why some hosts have high parasite burdens and the implications for the design of sustainable control strategies
World Bank	Terms and reference for the outlook of trends and scenarios for the social, economic and environmental services of the South China Sea and East Asian Seas
Zhejiang Academy of Agricultural Sciences	Establish an international laboratory for sustainable pest and disease control

Postgraduate Studentships

Candidate	Project Title	Viva Passed	University of Registration
BREEN, Susan	Investigation of the recognition and host targets of the *Phytophthora infestans* effector PiAVR2	29/03/2012	Dundee
BROWN, Chris	A socio-economic study of bioenergy crop adoption in North East Scotland – an agent-based modelling approach	20/01/2012	Aberdeen
COOK, Nicki	Population genetics of the farmland sawfly *Dolerus aenus (Humenoptera, Symphyta)*	08/11/2011	Dundee
DALY, Paul	Downregulation of caffeic acid O-methyltransferase in barley to improve the efficiency of biofuel production	03/11/2011	Dundee
DAVIS, Jayne	Molecular reactions of potassium deficiency and pathogen resistance in barley	09/11/2011	Glasgow
FYANS, Joanna	The role of protein transport in the pathogenicity of *Streptomyces* spp.	31/08/2011	Dundee
GROUFAUD, Severine	Translocation of phytophthora effectors and their manipulation of host plant disease resistance	12/05/2011	Aberdeen
HEROLD, Miriam	Significance of fungal and bacterial denitrification in arable soil	29/10/2011	Aberdeen
KERCHEV, Pavel	Local and systemic responses to *Myzuz persicae* in *Arabidopsis*. A role for redox components	20/01/2012	Leeds
LLOYD, David	Genetic control of cooked potato tuber taste and texture	14/12/2011	Dundee
RATAJ, Katarzyna	Functional characterisation of the protein interaction domain of FPA	09/05/2011	Dundee
SCHMIDT, Sonja	Root responses to soil physical conditions and the role of root-particle contact	16/05/2011	Abertay
SELGE, Sebastian	Public and scientific discourses on biological invasions: Social representations of invasive non-native species in Scotland	12/12/2011	Aberdeen
SHAW, Jane	The role of Cajal bodies and their major scaffolding protein, Coiloin, in plant-virus interactions	02/12/2011	Dundee
SUBRAMANIAN, Nithya	Genetics of mineral accumulation in potato tubers	31/01/2012	Nottingham
THIRUGANSAMBANDAM, Amar	Role of seed-borne infection in *Rhynchosporium* and *Ramularia* epidemics in barley	20/12/2011	Dundee