

CROSS-CUTTING THEMES PROGRESS REPORT 2006-08

Management Mechanisms of the Cross-Cutting Themes

Each MRP participating in Programmes 1, 2 and 3 appointed a Principle Investigator as a 'Champion' for each of the Cross-Cutting Themes (CCT). The Rowett's participation in Programme 4 is covered by one representative, as the work of this programme, while having relevance to the CCTs, does not map easily onto the reporting framework. RERAD representatives have also attended meetings of the CCT Champions. The Champions are:

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The Champions for all CCTs have met together three times, as well as in their separate themes as required. The first meeting was chaired by Adrian Newton but subsequently by a Champion from the hosting MRP who also arranged minute taking. The minutes are available for each of these meetings. The remit of the whole group was defined as:

To champion the CCTs within and between the MRPs and Programmes. This will add value by:

- enhancing communication and raising awareness
- encouraging collaboration
- stimulating interaction with RERAD to inform policy and influence funding priorities

To co-ordinate activities and provide a resource-base for the CCTs, an information management system (a portal) was set up, managed by Adrian Newton and supported by SCRI IT Department. All Champions and RERAD representatives have password-protected access to this portal which provides document storage, working space, version controlled shared documents, announcements, calendars and other resources. All agendas and minutes are readily accessible. Each CCT has a library of policy documents and documents for shared working.

An initial activity was a collation, summary and, in some cases, a publication of their respective MRP's portfolio of CCT-relevant research, several of which are appended to this document. Subsequently, Champions for each theme have been working on cross-MRP summaries of research encompassing both RERAD and externally-funded work with which it has synergies.

Reporting and co-ordination is primarily Main Research Providers (MRP)-based, but Cross-Cutting Champions also report CCT activity to the relevant Programme Co-ordinators. The reporting mechanisms are informal but the reports at MRP and CCT level are available on the portal for access by both MRP and RERAD Programme management.

The remit of Programme 4 lies outside the three Cross-Cutting Themes and is not considered further in this report. However we have included Programme 4 in discussions and in meetings of the CCT Champions, bringing greater cohesion to the work of the MRPs. The work of Programme 4 is included in the themes planned for the John Hope Gateway, a new facility being developed at RBGE, due to open in 2009, which will aid communication and dialogue with the public on the full range of MRP science.

KTE events featuring CCT activity have taken place at the Royal Highland Show, Edinburgh International Science Festival, and other venues. For example the Scottish Biodiversity Forum's Action Plan and Science Group (hosted by RBGE and organised jointly with the Macaulay, and Chaired by Professors Albon and Gibby) has delivered seminars on Climate Change (2006), the Ecosystem Approach in Conservation (2007), and Genetics and Biodiversity Conservation (2008). Another major thrust of the CCT Champions has been in raising awareness among colleagues with the aim of encouraging appreciation of the broader impacts of their research and advice on biodiversity, sustainability and climate change issues. This enhanced appreciation has been achieved by a variety of approaches, including the invitation of particular speakers to give seminars, discussions and presentations for staff, and informal means such as wide consultation on the content of promotional booklets and leaflets.

Despite having had no specific funding, workplans or milestones identified within the RERAD Programmes for CCT activities, the Champions have invested their time and resources from other sources and have made a good start in planning for future co-ordination and exploitation of research synergies across the MRPs. Significant achievements and contributions were made – the Climate Change group, for example, produced a discussion paper summarising current climate change work being done across the MRPs with suggestions of how this could be integrated more closely (Matthews *et al.*, 2008). This paper was subsequently incorporated into the RERAD Agriculture and Climate Change Stakeholders Group (ACCSG) Final Report. We recommend for the future that formally recognising and resourcing the CCT group would have benefits and would permit certain types of co-ordination activity that are difficult without dedicated resources. We recognise that each Programme will continue to focus on delivering the specified required outputs relevant to the CCTs. The CCTs will increasingly develop projects which deliver cross-MRP agreed outcomes in line with the strategy objectives being developed for the 2011-2016 funding period. We will seek funding for this from the Contract Research Fund, the UK Research Councils Living With Environmental Change (LWEC) and Development Funds as appropriate.

Progress in the ‘Responding to Climate Change’ Cross-Cutting Theme

Introduction

Climate change is widely recognised as the most serious environmental threat facing our planet today, and is becoming central to policy-making and land-use decision-making. Climate change predictions for Scotland (as a consequence of greenhouse gas (GHG) emissions) include increased temperatures, seasonal changes in precipitation patterns resulting in both drought and flooding/waterlogging, longer growing seasons and more extreme weather events. In the Scottish Government’s Climate Change Strategy, the need to move to a low-carbon economy by 2050 is emphasised, and, recognising that some climate change will occur even if emissions are successfully reduced, a range of potential adaptive responses is outlined. In June 2007, the Scottish Government announced the Scottish Climate Change Bill with a proposed target for reduction of GHG emissions of 80% by 2050. Studies are currently underway to evaluate possible means by which this target may be achieved. However, for the effective evolution of policies, the consequences of GHG reduction targets for Scotland’s environment, land use, and rural communities need to be better understood, as do the management systems needed to encourage sustainable landscapes in the face of changing climate.

All of the Programmes contribute to the Climate Change Cross-Cutting Theme, though to varying degrees. Research activity spans a range of disciplines, providing the ability to integrate natural and social sciences in understanding the drivers and biophysical responses of climate change, the economic efficiency of mitigation and adaptation actions, and the social contexts which under-pin government decision-making. Below are some highlights from the three Programmes, further details of which can be found in the relevant Programme reports.

Progress

In Programme 1 the work packages concern either the genetics or pathology of potatoes, cereals and soft fruit in the context of sustainable systems with focus on the abiotic and biotic stresses (WP 1.4 and WP 1.5) that will be affected under the likely climate change scenarios for Scotland. There are implications for yield and quality (which are likely to be negatively affected) and pest and pathogen attacks (which are likely to increase). Moreover there are likely to be less predictable effects as a consequence of changed precipitation patterns and more extreme weather events. The potato pathology work package (WP 1.5) in particular has made an assessment of the likely changes in pest and pathogen challenges including the effects of climate change on aphid populations transmitting viruses to potatoes, and *Phytophthora infestans* populations causing late blight on potatoes. In work package 1.4, *Rhynchosporium secalis* populations on barley are being monitored and analysed to help devise strategies for effective resistance deployment, safeguarding the health status of Scottish crops. Solutions via both breeding for resistance and development of crop protection methodologies are central to these work packages. Integrating these with continued improvements in quality and yield in new cultivars is pursued through the networks with crop geneticists in the genetics work packages (WP 1.1, WP 1.2 and WP 1.3). Lack of chilling is already affecting synchrony of bud break in woody perennials such as blackcurrants. This and related problems are tackled in WP1.3. Climate change may also offer new opportunities for extended growing seasons and changed crop distribution.

In Programme 2, work on the impact of climate change on animal health, disease risk and welfare lies within all five work packages and has begun to address issues of adaptation and mitigation. These activities have been complemented and enhanced by a number of other competitively funded projects, including major commissions from Defra and through LINK.

In WP 2.1, an active viral surveillance programme provides horizon-scanning for potential disease threats as a result of climate change, such as the vector-borne diseases Bluetongue, West Nile virus and Louping Ill. WP 2.2 concentrates on the epidemiology and control of bacterial diseases e.g. haemorrhagic septicaemia, a disease limited normally to SE Asia and Africa, but which may be of increasing relevance to the UK as a result of climate change. Similarly, in WP 2.3, the predicted changes in the Scottish climate are likely to favour the establishment and survival of the free-living stages of a number of key helminth parasites and their intermediate hosts e.g. the highly pathogenic nematode, *Haemonchus contortus* and the liver fluke, *Fasciola hepatica* and also ectoparasites, such as poultry red mite and sheep scab. Control of these parasites is being further compromised by the inexorable spread of anthelmintic resistance. Climate matching and simulation modelling is used to predict changes in environmental distributions of parasites and livestock-parasite interactions in the environment and identifying emerging disease risks. Adaptive approaches include vaccine development, improved detection of anthelmintic resistance, genetic selection and modified management, especially feeding, strategies.

WP 2.4 contributes to the Climate Change Theme by reducing losses and wastage and the environmental footprint of livestock systems. Economic modelling is being used to understand how changes in animal welfare will affect GHG emissions. Improving survival and vigour of young animals, reducing losses from disease, improving productive lifespan and improving product quality, efficiency and 'fit' with market needs all make important contributions to cutting GHG emissions per kilogram of product.

In WP 2.5 the impacts of climate change on livestock systems have been reviewed and, particularly, the impact of livestock systems on GHG emissions. In dairy systems, genetic selection can be used to reduce methane production per litre of milk production, but choice of management system can produce conflicting benefits in methane or nitrogen wastage. We have reviewed approaches to quantifying GHG emissions from livestock farms. Several papers have been presented, or are in press, on GHG emissions from dairying systems.

In Programme 3, work has focused on the impacts that future climate change may have on the ecology, soils, hydrology and landscapes of Scotland, and on ways in which communities will respond, both in relation to mitigation of GHG emissions and through adaptation. For example, WP 3.2 and WP 3.3 includes studies of climate change impacts on fundamental soil processes including carbon loss/sequestration, and on the spatial distribution of N₂O emissions across the country. In WP 3.4 and WP 3.5, impacts of climate change on extreme flows, dissolved organic carbon, thermal regimes, and aquatic life in streams are being investigated, and the value that society places on flood control assessed. A model predicting nitrate leaching under different climate change scenarios at the national scale is also being developed. Work in WP 3.6 and WP 3.7 is investigating the impact of climate change on species distributions, genetic diversity and potential for adaptation and its impact on particular ecosystems including woodlands, pine forests, and machair. In WP 3.1

work has included the impacts of climate change on agricultural systems, examining how GHG emissions may be reduced from such systems, and how the agricultural industry may adapt to warmer temperature and altered precipitation patterns. This has synergies with landscape-scale research (WP 3.8) which is assessing the impact of climate change scenarios on land capability for agriculture, as well as investigating different policy instruments to reduce GHG emissions from the land use sector. The social acceptability of forestry as a mitigation option is being evaluated, and productivity of bioenergy crops is being modelled, as is carbon sequestration rates under these crops. Future landscapes, including features such as wind turbines, are being evaluated by stakeholders using a visual landscape theatre.

Outputs

The CCT Champions have raised awareness of climate change aspects of research carried out by all the MRPs both within the Programmes and more widely, through seminars, workshops, publications and through the popular media. A website has also been created at <http://www.macaulay.ac.uk/collab/mrpcc/>. This acts as a gateway to climate change-related research going on in the individual MRPs. It is hoped that further development of the website will provide a more integrated interface to this work. Each MRP has produced a brochure/document summarising their climate change research, including that funded by RERAD. These have been published in some cases.

The Climate Change Champions have attended events elsewhere to inform, advise and liaise with other groups and organisations (e.g. Scottish Natural Heritage (SNH), Scottish Climate Change Impacts Programme (SCCIP)) working on the climate change agenda. The objective is not only better communication of the RERAD-funded work that the MRPs are carrying out and its relevance, but also obtaining views and feedback from potential beneficiaries, the public and end-users. Examples are included in Annex 1.

A significant indicator of MRP expertise and effectiveness has been success in adding value to the RERAD programme through winning additional research contracts. A good example is the ongoing project being conducted for Defra and the UK Committee on Climate Change (UKCCC) to determine UK marginal cost curves, abatement scenario analysis and to achieve the ability to model future policy on mitigation for the agriculture, forestry, land-use and land-use change sector for the coming decades. Other grants range from a Defra project on adaptation in the UK livestock sector to research on chilling requirement in blackcurrants. Several proposals to the EU use RERAD-commissioned work to leverage funding.

In some cases, the Champions coordinated their Institute responses to various Scottish Government consultations, for example, those of the Scottish Climate Change Bill, and the Forest Commission Scotland Climate Change Action Plan, drawing on expertise gathered from across the work packages of the relevant Programmes.

Forward look

We will continue to further develop our ideas on integrating climate change research across the MRPs. This will include:

- Further development of the website (<http://www.macaulay.ac.uk/collab/mrpcc/>) to help to draw this work more closely together.

- Evaluating potential conceptual frameworks (e.g. climate change interactions with ecosystem services) to facilitate this integration*.
- Modelling GHG abatement potential and the refinement of abatement cost curves for agriculture, land use and land use change following on from an ongoing Defra project for the UKCCC*.
- Holding a joint workshop to raise the awareness of climate change-related research within and between MRPs.
- Identifying funding opportunities for joint-MRP climate change-related research projects such as the Contract Research Fund particularly for marked* projects.
- Seeking funding to establish fellowships and studentships for interdisciplinary joint working between MRPs, connecting the resources distributed across the MRPs.
- Developing structures and mechanisms within our MRPs for strengthening the cross-cutting nature of the Theme.
- Exploring the potential for a joint position paper provisionally entitled 'Quantifying the impacts of climate change on the environment of Scotland' where we will try to determine the likely economic cost to Scotland's rural sector of specified scenarios of climate change and prioritise the research targets needed for optimising our responses*.
- Considering the influence of climate change on diet and health in the Scottish population.
- Consider how to incorporate the work of Programme 4 more closely into the Climate Change cross-cutting theme.

We will also increase the relevance of the MRP climate change-related work both within and more widely by:

- Seeking opportunities to contribute to the development of the Scottish Government's policies to respond to climate change (e.g. the follow-up to recommendations from the ACCSG report).
- Contributing to the development of the post-2011 RERAD funding strategy, in particular the suggested 'Local Response to Global Change' theme.
- Organising a joint workshop with policy advisors and other stakeholders (possibly on the implications of responses to climate change on tradeoffs and synergies between ecosystem services).
- Linking with other relevant organisations within Scotland (e.g. SEPA, SNH, SNIFFER, SCCIP, SASA).
- Applying methods and approaches developed in the Scottish context to global climate change research, such as avoided tropical deforestation*.
- Learning from international/global experience for application within Scotland.

Progress in the 'Protecting Biodiversity' Cross-Cutting Theme

Introduction

Biodiversity lies at the heart of a sustainable future for mankind yet the current loss of biodiversity globally has increased, under man's influence, to a rate thought to be equivalent to that of the five great extinction events since advanced life appeared on this planet. Natural and managed ecosystems contribute greatly to human well-being by furnishing food, fibre, fuel, and medicines. They also provide a wide range of services essential to man which affect the provision of nutrients, water, air and the modulation of the planet's climate. The loss of species and the damage to

ecosystems affects the planet's own life support systems and can provide positive feedback to global climate change. Many of the habitats and associated species on which we put high nature conservation value are intimately linked with cropping and more particularly livestock grazing systems. Even in managed cropping systems, biodiversity is crucial to production and sustainability, regulating nutrient cycling, affecting water supply and maintaining soil structure. The relatively few crop species on which man depends for food have a large store of unused genetic diversity in cultivated types and wild relatives which is a very valuable resource for the adaptation of crops to rapidly changing climates. Similarly, the conservation of rare breeds of livestock is seen as a potentially important source of genetic variation to adapt to environmental change. The diversity of both animal and plant pathogens and the factors driving changes in their distribution also has a major impact on rural sustainability. In Scotland we also have particular heritage and conservation issues, with internationally important populations and communities of birds, cryptogamic plants and arctic-alpine species, all of them vulnerable to global climate change.

The high loss of biodiversity globally has inspired governmental action at various levels, beginning with the Convention on Biological Diversity in 1992, and including a challenging commitment at EU level for member states to halt biodiversity loss by 2010. In Scotland, a strategy for the protection of biodiversity over a 25 year period was published in 2004 (*Scotland's Biodiversity: It's in Your Hands*). This Strategy and its associated *Implementation Plans* contain elements which cover the conservation of species and habitats, landscape and ecosystem-level issues, social aspects including public awareness, integration and co-ordination, and the knowledge base. Providing support to land managers for maintaining and enhancing biodiversity is also a major component of the *Scottish Rural Development Plan*.

The contribution the MRPs can make to the effort to protect Scotland's biodiversity and to ensure that existing biodiversity is managed appropriately consists of five main threads identified at a meeting of Biodiversity CCT Champions in January 2008:

- Conservation and Heritage
- Biodiversity and Sustainability
- Biodiversity and Change
- The Uses of Biodiversity
- Tools for Understanding Biodiversity

Progress

Given the policy focus outlined above, there is a substantial amount of biodiversity-oriented research being conducted across the research Programmes. For example, in Programme 1 the role of functional biodiversity in the preservation of arable ecosystem function is being addressed in WP1.7, the scientific details of which are available in the work package report. In the crop genetics and crop pathology work packages (WP 1.1 to 1.5), the conservation, increased understanding and appropriate exploitation of crop and wild relative biodiversity is enabling appropriate responses to the challenges of adapting crops to shifts in climatic zones and their associated pathogen pressures.

Programme 2 contributes evidence-based knowledge that underpins the development of sustainable livestock production systems through improved animal health, management and welfare. Animal disease impacts governments, trade, rural

communities, animal and human health. Thus there are shared benefits from disease control by ensuring that Scotland's producers are able to compete on world markets. Disease control requires an understanding of which pathogens are causing disease, how pathogens initiate disease and how animals resist or recover from infections. Several work packages in Programme 2 (WPs 2.1-2.3) are studying the impact of the genetic diversity of the animal host or pathogen, and include shifts in vectors occurring as a direct result of climate change. These specialised aspects of the impact of changes in the diversity of pathogens link to other work on non-pathogen diversity. Within WP 2.5 there is a suite of research making progress in developing options for the maintenance of upland heathland and lowland grassland biodiversity, including the use of different livestock breeds with a wider variety of traits, including different diet preferences and, consequently different foraging behaviour.

Programme 3 includes two specifically biodiversity-oriented work packages which link closely to each other and to other WPs in the wider programme. WP 3.6 (*Functioning of species, habitats and ecosystems*) links particularly with work addressing soil, in particular integrating above-ground and below-ground processes and the functional role of previously poorly understood diversity (WPs 3.2 and 3.3) and, to a lesser degree freshwater systems, particularly through riparian ecosystems (WPs 3.4 and 3.5). While WP 3.7 (*Management of biodiversity change*) not only links with these WPs but also with others addressing farming systems (WP 3.1) and the natural heritage at landscape scales (WP 3.8). From an upland and lowland grazing management perspective, there are also very close links between WP 3.7 and the work package dealing with sustainable livestock systems (WP 2.5). From an arable perspective, there are close links between the farming systems work package (WP 3.1) and the work package dealing with sustainable crop systems (WP 1.7).

Outputs

The CCT Champions and other MRP staff have disseminated outputs of the research relevant to Protecting Biodiversity to a variety of target audiences. In addition to producing MRP-specific promotional material, a wide range of Knowledge Exchange activities have been undertaken, including participation in seminars and workshops, participation in relevant committees and working groups, and in developing and executing a number of high-Professorile presentations to end-users and the public, examples of which are listed in Annex 1. These KE activities range from organising a one-day conference for NGOs, government representatives and researchers on *Supporting Natura 2000 sites: current practice and emerging issues* to demonstrating to the public and to VIPs the value of potato biodiversity in a time of climate change at the Royal Highland Show, Ingliston, and other venues.

Many of the scientific publications and other outputs from specific research projects arise from and are reported at the individual work package level. However, the Biodiversity CCT Champions have also been active working together to improve communication between researchers, NGOs and government relating to biodiversity. Examples of this include the Macaulay and RBGE-led Scottish Biodiversity Forum annual one day meeting on *Incorporating the Ecosystem Approach in the Conservation of Biodiversity* in March 2007 and *Genetic Diversity in Conservation and Sustainability* in March 2008, active links between SCRI biodiversity researchers and local Biodiversity Partnership groups, joint projects between RBGE and SNH and several SAC activities through its centrally-coordinated Knowledge Transfer programme (*Success Through Knowledge*). A list of specific examples of output in relation to this CCT can be found in Annex 1.

Forward Look

We propose to build on and enhance the collaboration across MRPs on biodiversity issues through a range of measures in the second part of the RERAD Programmes. These activities include:

- Establish a web site to advertise, coordinate and enhance biodiversity-related activities in the MRPs using the five threads outlined above (p15).
- Hold workshops specifically on biodiversity and its interaction with the other two CCTs, to raise awareness and encourage collaboration amongst the MRPs.
- Identify funding opportunities to enhance collaboration across the MRPs on biodiversity.
- Arrange additional workshops such as the Edinburgh Consortium for Rural Researchers (ECRR) one day conference on *Scotland's changing rural biodiversity: policy action and needs* to be held May 2009.
- Continue to play a leading role in the Ministerially-led Scottish Biodiversity Committee, in particular through it's Action Plan and Science Group.
- Continue to develop participation in the UK Biodiversity Research Advisory Group (UK BRAG).
- Represent Scottish interests at UK Plant Genetic Resources Group and help the development of the new Scottish Landraces Group.
- Identify funding opportunities to enhance collaboration across the MRPs on biodiversity.
- Continue with and seek additional international projects to enhance, our links with researchers internationally, including such projects as ALARM where BioSS is collaborating in an EU project with 67 organisations in 35 countries to develop an integrated risk assessment for biodiversity in the terrestrial and freshwater ecosystems of Europe, focusing on four key pressures: climate change, environmental pollution, invasive species, and loss of pollinators.
- Investigate additional impacts of biodiversity on human well-being, such as how food nutritive and economic values are maintained in local rather than imported fruits and vegetables, and how a diversity of animal strains may affect nutritive value.
- Use these areas of work to increase involvement of Programme 4 in the Cross Cutting Theme.
- Open the John Hope Gateway at RBGE in 2009 to provide a platform for direct dialogue with the public on all the Cross Cutting Themes and Programme 4.

The Champions also intend to explore further the link between climate change and biodiversity change, to develop further predictions of the likely adaptation of natural populations, and the prospects for appropriate directed management including the assistance of shifts in the distributions of ecosystem and key component organisms as climate change becomes inevitable.

Progress in the 'Environmental, Social and Economic Sustainability' Cross-Cutting Theme

Introduction

Sustainability is a key characteristic of socio-ecological systems threatened by natural and anthropogenic drivers and pressures of environmental change (Brundtland report of 1990). Its importance is attested in the Scottish Government's

commitment to sustainable rural development for farmers and crofters are responsible for nearly 75% of Scotland's land. If we are to meet our ever increasing demands for fuel and food, this land must be managed in a way that provides economic growth and social justice for all rural users without causing damage to the environment. The main aim of this Cross-Cutting Theme is to inform the development of evidence-based policy and practice that ensures the environmental, social and economic sustainability of rural Scotland.

The three research programmes, together with BioSS, each contribute a significant body of complementary research to the theme. In Programme 1, new management practices and crop varieties are being developed to allow reduced inputs, increased resource use efficiency and improved sustainability and resilience of the arable ecosystem. Much of the focus of the research conducted in Programme 2, contributes to the development of more sustainable systems of livestock production through better management of animal health and welfare. In Programme 3, environment, land use and rural stewardship, is seen as intimately related to the overall sustainability of the Scottish economy because of reciprocal transfers of goods and services. BioSS contributes to this research through the provision of consultancy and collaborative links with MRPs to deliver their work package and CCT objectives, and through the development of underpinning methodology in BioSS' three research themes of bioinformatics, mathematical modelling and statistics.

Thus, the wide range of skills, resources and research areas represented across these programmes together contribute to the key government objectives of improving environmental, social and economic sustainability and creating a wealthier, fairer, healthier, greener and smarter Scotland.

Progress

Within work packages 1.1, 1.2 and 1.3 of Programme 1 advanced genomics skills are being used to identify the characteristics of new barley, potato and soft fruit varieties for environmentally and economically sustainable production. Identifying characteristics such as increased yield and yield quality, while improving water and nutrient use efficiency and stress tolerance, all result in the opportunity for reducing inputs and therefore improving environmental and economic sustainability. WP 1.3, 1.4 and 1.5 are contributing towards sustainable crop production by developing environmentally benign and cost effective ways to reduce the incidence of crop diseases. By understanding how pest and pathogen populations change, and how they interact with their host plants and the wider environment, the work packages are investigating ways to monitor, predict and avoid disease through integrated crop management strategies and improved durable resistance of soft fruit, barley and potato varieties. Finally, in WP 1.7, crop traits, rotations and associated soil and weed management practices (including a range of tillage and herbicide regimes) are being identified to achieve high yield whilst maintaining the biophysical resilience and ecological sustainability of arable systems. This research aims to identify a balance of different functional types of organisms to satisfy economic, aesthetic and environmental functions of arable habitats.

Programme 2: Disease control in livestock herds and flocks is an essential component of economic success by increasing financial benefit for individual producers and ensuring the supply of safe, healthy, locally produced food with a reduced carbon footprint. The foot and mouth disease crisis of 2001, clearly

demonstrated the significant cost of animal disease to the rural economy. Infectious disease continues to pose a significant threat to livestock farming and also to public health with recent examples being the emergence of blue-tongue virus and avian flu. Work in WP 2.1, 2.2 and 2.3 is focussing on devising novel diagnostics and control strategies against endemic viral, bacterial and parasitic diseases. By linking epidemiological research with economic appraisal of the costs and benefits of control options we are able to devise sustainable strategies for disease control. Research on animal welfare (WP 2.4) addresses both public concerns about animals' experiences in farming systems and analyses linkages between animal welfare, production, trade and the environment to contribute to multi-faceted appraisals of the contribution of welfare management to sustainability. Options for exploiting genetic selection to combine improvements in economically important and environmentally relevant traits provide a major platform for future, sustainable, strategies for farmed livestock (WP 2.5). Work on the sustainability of dairy and of hill livestock systems is closely linked with WP 3.1.

Programme 3 explicitly addresses three aspects of sustainability (social, economic and environmental) in both WP 3.1 *Sustainable Farming Systems* and also in WP 3.8 which focuses on the protection and enhancement of landscapes and the promotion of sustainable rural communities. WP 3.2 and WP 3.3 address soils, with WP 3.2 focussing on risk-based assessment bio-physical threats to soil quality and sustainability and WP 3.3 on inter-disciplinary approaches to assessing soil values, including social valuation. WP 3.4 and WP 3.5 address water quality with the sustainable multiple use of water a central theme.

In this programme two distinct approaches to sustainability assessment are adopted. First, bio-physical assessments of particular natural resources such as soils, water and biodiversity (particularly WP 3.2, WP 3.4 and WP 3.6) are made, and risk-based assessments to sustainability threats are explored. Second, sustainable solutions to resource management challenges are constructed through effective stakeholder engagement and new institutional design. This is especially evident in WP 3.5 in relation to improving water quality to meet Water Framework Directive demands, but also WP 3.3 WP 3.5, WP 3.7 and WP 3.8 where an understanding of stakeholder perceptions of water the quality of water, soil, biodiversity and landscape, respectively, can be seen to frame behaviours and decisions.

A range of modelling and statistical epidemiology work has been carried out at BioSS in collaboration with Programmes 1 and 2. This work enhances understanding of disease dynamics and risks in agricultural systems and aims to enhance rural sustainability by reducing the economic and environmental costs of disease. This work promises more sustainable management of disease by reducing economic costs and biodiversity impacts.

BioSS is also involved in ALARM (Assessing LArge scale environmental Risks for biodiversity with tested Methods - www.alarmproject.net), which is a project of the 6th Framework Programme of the European Union, involving over 200 scientists working in 67 organisations in 35 countries. In collaboration with other ALARM partners and via consultation with policy representatives and stakeholders, BioSS has developed a conceptual framework and database structure for this toolkit. A key goal is to integrate such risk assessments with three socio-economic scenarios which describe a broad spectrum of European policy choices ranging from liberalisation and rapid economic growth, to a more environmentally sustainable scenario.

Outputs

The CCT Champions have raised awareness across all programmes and institutes of the need for, and importance of, research on sustainability and have identified specific work areas that contribute to the development of economic, social and environmental sustainability in rural Scotland. We have placed emphasis on adding value to the relevant research by taking part in various knowledge exchange activities with policy makers, scientists, specific stakeholder groups and members of the public in general. We have also highlighted areas particularly relevant to this theme in press releases, roadshows and workshops for end users. Examples of these activities are listed in Annex 1.

Scientific outputs are detailed at the work package level in the relevant Programme reports. However, some examples worth highlighting here include: the development of a spatial land use change database for Scotland to analyse trends in sustainability; the development of indicators of system resilience, sustainability and change in agricultural landscapes; research to understand the motivations of those involved in food supply chains towards improving sustainability

Forward Look

Since the start of the Programmes in 2006, there has been considerable progress within each of the research areas relating to sustainability as outlined above. Our approach for the future is to develop a robust definition of sustainability and indicators against which to assess the impacts of future environmental and political changes.

Given this accumulating body of research, we are now in a position to develop a sustainability assessment framework to enable the screening of the research outputs. This framework will be based on perceptions from different stakeholders - policy makers, researchers and end users - regarding sustainability. Findings to date will be screened against the agreed sustainability criteria. This will provide a synthetic overview of sustainability impacts as perceived by different stakeholders and provide a body of data to enable alternative social constructions of sustainability to be explored.

We propose the following approach:

1. Collate interim results from the Work Packages.
2. On the basis of a review of literature and these results, develop a working definition of environmental, economic and social sustainability.
3. Organise a series of three workshops at MI, SCRI and SAC, with research, policy and practice stakeholders to develop a set of indicators of sustainability.
4. Develop a process through which broad sustainability impacts can be assessed with reference to the indicator set identified above.
5. Consider the interaction between livestock production, food quality and nutrition for the Scottish population.

We acknowledge the emerging discipline of sustainability science and have used its approaches and ideas within water-related work in WP3.5 and in the proposed sustainability assessment described above. We recognise the competing theoretical constructs (from ecological modernisation to transition theory) and will use these to

guide explorations of what contributes to the failure of socio-ecological systems to be sustainable and to explore transitions towards sustainable outcomes.

Alongside this process of definition and indicator development, experimental opportunities will be sought to bring together strands of research from across work packages, programmes and institutes to test hypotheses on optimal system solutions. Existing farm scale resources across the MRPs will be used for these purposes but advantage will also be taken to use other resources (through collaboration or commercial agreement) as appropriate.

Annex 1 – Examples of Outputs

Climate Change:

- Defra consultation event: 'The UK Agricultural and Rural Economy: Impacts of Climate Change' (Adrian Newton);
- Providing expert speakers for the British Association for the Advancement of Science/SEERAD Public Event on Climate Change (Peter Gregory);
- Invited Plenary Lecture at the Thirty-Ninth Agricultural Research Modellers Group Meeting, Royal Society, London, March 30, 2007 (Robin Matthews);
- Invited Keynote Address at "Science, Technology and Climate Change Adaptation in Africa" conference in Johannesburg, South Africa 19-22 November 2007 (Robin Mathews);
- Edinburgh International Science Festival – talk entitled "Climate Change: Winners and Losers" (Robin Matthews) and a "Ticking Time Bomb" interactive educational exhibition for school children (Moredun);
- Invited talk entitled "Finding integrated solutions" at Sharing Good Practice event organised by SNH on "Adapting to Climate Change: working with nature to build resilience" at the Festival Theatre in Edinburgh. (Robin Matthews);
- Invited talk on "Climate change and landscape-scale conservation" delivered to the Scottish Biodiversity Forum Annual Conference, 2006. (Chris Ellis);
- HGCA Conference on the Impacts of Climate Change (Peter Gregory);
- Royal Geographic Society invited speaker: (Adrian Newton), Climate Change – 'Possible Impacts on Agricultural Systems. Global Warming: What do I care'. Royal Geographic Society with IBG;
- 'Reducing greenhouse gas emissions from livestock - some economic considerations' Livestock and Global Climate Change (D. Moran), BSAS, INRA, ICARDA, EAAP, OEP, IRESA, CIRAD, ILRI International Conference Livestock and Global Climate Change 17-20 May 2008, Tunisia (conference part-funded by RERAD);
- "New challenges for the control of helminth parasites of Scottish livestock in the face of climate change" . Oral presentation at BSAS "Livestock and Global Climate Change" Conference, 17-20 May, 2008, Tunisia (P.Skuce, Moredun);
- Talk on Climate Change Threats to Biodiversity, at the Cryptogam Conservation Ecology Conference – Mid-Sweden University, Sundsvall (Chris Ellis);
- Invited speaker on 'Climate Change: Implications for agriculture' (Adrian Newton)
- Edinburgh Consortium for Rural Research Climate Change Impacts Seminar - 7 Nov 2007; (D. Moran);
- Richard Price Chief, Economist Defra talk at SAC on the Shadow Price of Carbon (chaired by D. Moran);
- Climate Change special session organised at 2008 Agricultural Economics Society Conference, Royal Agricultural College, Cirencester, Professor Robert

- Watson (Defra) and Dr Sam Fankhauser (Committee on Climate Change and partner IDEACarbon) (chaired by D. Moran);
- BBC Radio Scotland, BBC Radio Ulster, BBC Scotland television, STV;
 - Dundee Courier, Press and Journal, Sunday Post, The Scotsman, The Scottish Farmer, The Daily Telegraph, Sunday Mail, Belfast Newsletter, Farming Life, the Veterinary Record, Veterinary Times and various other press interviews, press releases (e.g. at IPCC launches) and articles;
 - MRP seminars (e.g. Professor James Curran, SEPA Head of Environmental Strategy and climate change expert, the Scottish Research Institutes' Annual Lecture by Professor Robert Watson, Chief Scientific Advisor to Defra);
 - Climate Change Special Seminar at RBGE, with speakers Professor. Terry Dawson (University of Southampton), Dr Rob Brooker (MLURI) and Professor Roy Thompson (University of Edinburgh) – chaired by Chris Ellis;
 - Robin Matthews and Adrian Newton were members of the Agriculture and Climate Change Stakeholder Group (ACCSG) which met bimonthly and produced a Final Report entitled "Climate Change and Scottish Agriculture: Report and Recommendations", and led discussions at the public consultation event at Peebles Hydro with the Minister;
 - Public launch event: 'How Scotland's science research institutes are meeting the challenge' - media news release: "Scots scientists at forefront of work to combat climate change" 19th March 2008, St Andrews House - Minister for Climate Change, Stewart Stevenson and Minister for Environment, Michael Russell briefing;
 - The Climate Change Champions met together for a workshop in November 2007 and subsequently produced the discussion paper 'Integrating climate change research across the Main Research Providers in Scotland' (Matthews *et al.*, 2008) which was submitted to RERAD in April, and also incorporated into the ACCSG Final Report as Annex D along with a summary of the work package remits themselves. This report forms part of the Scottish Government's mitigation and adaptation strategy to climate change.

Biodiversity:

- The Scottish Biodiversity Forum's Action Plan and Science Group: Meeting on Genetic diversity in conservation and sustainability, RBGE (organised by Mary Gibby and Steve Albon with speakers including Pete Hollingsworth, Adrian Newton and Gavin Ramsay);
- A press day was held at Moredun Research Institute in December 2007 where several of the projects contributing to this theme were presented to journalists;
- A Programme 2 Knowledge Exchange day was hosted by Moredun Research Institute in April 2008 where scientific highlights from the programme were presented to key stakeholders;
- Interactive demonstrations to the public during 2007 of the origins and uses of potato biodiversity, at the Royal Highland Show, Ingliston, Potatoes in Practice, the industry event held at SCRI, and the Dundee Flower and Food Festival;
- Public demonstration of barley diversity from 'Evolution Canyon' at the Royal Highland Show, Ingliston, 2008;
- A wide range of inputs at MRPs designed to raise awareness of the biodiversity CCT through meetings, internal documents and presentations;
- Participation in *Rural Environment* break-out group at one day event organised by the Scottish Government, Scotland Europa and HIE and concerned with *The*

Future of EU rural development and agriculture policy: Scottish stakeholder discussion (D McCracken, October 2007);

- Lead organisation of the half-day *Agri-Environment* session with the biannual *Crop Protection Northern Britain* conference (D McCracken, 2006, 2008);
- Organisation of one-day seminar involving MRP researchers and representatives from SNH, RERAD and NGOs on *Supporting Natura 2000 sites: current practice and emerging issues* (D McCracken, November 2006);
- Invited keynote presentation on *Mosaics, models and management: the value of taking a landscape approach to farmland biodiversity studies* to one-day symposium on *Embedding an ecological approach in agricultural landscape: a way forward* held as part of the Ecological Society of Australia's annual conference (D McCracken, November 2007);
- Participation at two one-day integration events drawing together SAC research, consultancy and education colleagues to consider *Farming's retreat from the hills: implications* and *Rural sustainability: generating meaningful indicators of change and/or development processes* (D McCracken, January 2008 and April 2008, respectively);
- Member of organising committee for three day conference on *High value grassland: providing biodiversity, a clean environment and premium products* held at Keele University April 2007 (D McCracken Jan 2006-April 2007);
- Participation in the UK Biodiversity Research Advisory Group (UK BRAG) and circulation of relevant material to MRP CCT and research colleagues, and development of *Research needs for UK Biodiversity, a summary of the important knowledge gaps, identified by the UK Biodiversity Research Advisory Group*, http://www.jncc.gov.uk/pdf/BRAG_REPORT_2003-2006.pdf (D McCracken, S Albon, M Gibby, 2003-to-date);
- Participation on the *Defra Sustainable Agricultural LINK Programme Management Committee* (D McCracken, 2003-to-date);
- Edinburgh International Science Festival at RBGE - a wide range of events, including tours, talks, films, workshops, theatre shows, storytelling, drop in activities, Real Life Science events focused on mainly on biodiversity but also on sustainable living and climate change (All MRPs, April 07, 08);
- Organisation of display material for *Biodiversity* section of SAC stand at Royal Highland Show (D McCracken, June 2007, June 2008);
- Led development with consultancy and education colleagues of *Biodiversity on the Farm* CD aimed at Scottish school children aged 9-14 (D McCracken, Sept 2007 – July 2008);
- Presentation at IUCN UK National Conference: "Re-Introduction of Species in the UK: putting guidance into practice" (see <http://www.iucn-uk.org/Default.aspx?page=6873>) (M.Gibby January 2008);
- Membership of JNCC group to select and identify actions for BAP species and habitats, Scottish Biodiversity Committee Action Plan and Science Group, UK BRAG, Global Biodiversity Sub-Committee of Global Environmental Change Committee; Scottish Non-native Invasives Group. (D. McKean);
- Policy paper on DNA barcoding - DNA barcoding: potential users. *Genomics Society and Policy*, 3: 44-47;
- Development of and implementation by the Gateway Programme Advisory Group to support KE activities in the John Hope Gateway, currently under construction at the Royal Botanic Garden Edinburgh (R. Birnie (Chair), M.Gibby, M. Bennett, S. Bird, P. Taylor, A. Tibbs and others);
- Involvement in ALARM (Assessing Large scale environmental Risks for biodiversity with tested Methods), which is an EU project involving 67

organisations in 35 countries. The project aims to develop an integrated risk assessment for biodiversity in the terrestrial and freshwater ecosystems of Europe, focusing on four key pressures: climate change, environmental pollution, invasive species, and loss of pollinators. (BioSS);

- Delivery of tools to assist the assessment of biodiversity, including TOPALi, an interactive programme useful for comparing DNA sequences, and Curly Whirly, a program for 3D plotting of numerical data, useful for multivariate analysis of biodiversity data (BioSS).

Sustainability:

- LEAF Open Farm Sunday, SCRI, June 2006 and 2007;
- Internal workshops, seminars and presentations on sustainability and biodiversity;
- Living Field Study Centre – visits throughout the period from schools and members of the public and at the SCRI open days to learn about arable biodiversity and sustainable management;
- Meetings and discussions with >50 individual farmers engaged in arable biodiversity, sustainability and resilience surveys undertaken in 2007 and 2008;
- Potatoes in Practice (2007) - using green compost in agriculture;
- Cereal Solutions (July 2007) - Spring Barley mixtures for reduced herbicide/improved weed control;
- Approximately 200 scientific meetings and conferences on sustainability research as reported under WP1.7;
- Moredun Research Institute, Press day, December 2007 – with reports in 17 Scottish and national papers;
- Oil and Water workshop: Moredun Research Institute (March 2008), coordinated by Scottish Government, to improve knowledge exchange between scientists and policy makers;
- A programme 2 Knowledge Exchange day, Moredun Research Institute (April 2008) where scientific highlights on sustainability from the programme were presented to key stakeholders;
- Edinburgh International Science Festival 2008 and the Royal Highland Show, 2008 - An interactive exhibit aimed at primary school children to raise awareness of ticks and the diseases they transmit;
- Scientific highlights from this CCT were presented to farming and veterinarian groups during Moredun Foundation Regional Board meetings (May 2008);
- Series of talks to range of scientists on importance of incorporating sustainability into work on farming systems (EBRC Workshop at Moredun, Socio-Economics workshop at SCRI, and seminar at CECS, University of Edinburgh (A Renwick, October 2007);
- The Sustainability Champions met together for a workshop in November 2007 from which the discussion paper ('Sustainable Development Indicators – a literature review) was produced and a strategy for future development of sustainability indicators devised.

Annex 2 – Climate Change, Biodiversity and Sustainability publications.

(These are provided as separate pdf files)

- Climate Change Research at SCRI;
- Biodiversity Research at SCRI;
- Sustainability Research at SCRI;

- Success Through Knowledge Campaign leaflet (2008) SAC helping a changing world: animal welfare, healthy food, thriving communities, biodiversity, climate change;
- Ellis, C.J. and Gibby, M. (2007). Research on biodiversity and climate change at the Royal Botanic Garden Edinburgh. *BG Journal, Journal of the Botanic Gardens Conservation International*, 4: 22-25;
- Matthews, R., Newton, A., Ellis, C., Moran, D., Glasbey, C. and Skuce, P., 2008. Integrating climate change research across the Main Research Providers in Scotland. (Discussion paper). Main Research Providers Cross Cutting Theme for Climate Change Group. 8 pp;
- Sustainable Development Indicators – a literature review, 2008. Dunglinson, J. and Slee, B.