

Summary of research relevant to adaptation to climate change in the agricultural sector in Scotland

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1. Introduction

This note summarises Scottish research contributing to climate change adaptation in the agricultural sector in Scotland. It is structured as follows:

- Section 2 presents on-going research with relevance to adaptation policy for the agricultural sector;
- Section 3 gives some background on adaptation-relevant research under the Strategic Research Programme.

2. On-going Research

Climate Change Impact	Project	Project Highlights / Publications	Contact
Changes in Land Capability for Agriculture (LCA)	Revision of LCA and Future projections	<ul style="list-style-type: none"> • Present & future 2050s changes in LCA [UKCIP02] (Brown et al 2008) • Future 2050s changes in LCA [UKCP09] with Drought Risk (Brown et al 2011) • Present and future changes in Wetness Risks (workability and trafficability etc.) – currently in progress • Full Revision of LCA expected in 2012 (linked to Land Use Strategy) 	Iain Brown (JHI)

Changes in Crop Yields	Analysis of yield and inter-annual climate variability	<ul style="list-style-type: none"> Statistical analysis of changes in crop yields linked to key weather variables to evaluate climate sensitivity (paper in review) 	Iain Brown (JHI)
Direct/Indirect Changes in Cropping and Land Use Systems – implications for biodiversity, emissions etc.	Land Use Change Scenarios	<ul style="list-style-type: none"> Future Scenarios of Land Use Change based upon changes in LCA, policy targets and socioeconomic drivers (e.g. food security; low carbon economy) Scenarios evaluated using multi-criteria analysis for water quality (Dunn et al, 2011), biodiversity, C storage/emissions, or ecosystem services Pilot study – Deeside (Brown & Castellazzi, in review; Next stage – Scotland) Can be linked to Mitigation co-benefits Links to work being undertaken in ClimateXChange 	Iain Brown (JHI)
Changes in growing season, access period etc.	Agro-meteorological metrics	<ul style="list-style-type: none"> Present and future change in key metrics used by farmers to plan and manage their land Based upon UKCIPO2 (Matthews et al, 2008) Currently being updated to UKCP09 	Keith Matthews (JHI) and Mike Rivington (JHI)
Changes in current Land Use	Analysis of annual IACS (census) data	<ul style="list-style-type: none"> Detailed analysis at farm/field level of changes in land use over the last 12 years Used in reports to Pack Inquiry 	Keith Matthews (JHI)
Impacts of pests and diseases on crops	Crop yields and plant diseases	<ul style="list-style-type: none"> Implications of climate change on diseases, crop yields and food security. (Newton AC, Johnson SN, Gregory PJ, 2011 Euphytica 179, 3-18.) Climate change, plant diseases and food security, an overview. (Chakraborty S, Newton AC, 2011. Plant Pathology 60, 2-14.) 	Adrian Newton (JHI)
Impacts of pests and diseases on crops and livestock	Impacts, risks and options for crop and livestock production in response to climate change in Scotland	<ul style="list-style-type: none"> ClimateXChange Workstrand SRU1 (2011-2014). It will: analyse the likely effects of climate change on disease, health and welfare for crops and livestock and evaluate and prioritise adaptation and mitigation policy responses. 	Adrian Newton (JHI), Philip Skuce (Moredun), Malcolm Mitchell (SAC)

Impacts of pests and diseases on livestock	Parasite control and effects of climate change on risk of diseases to livestock	<ul style="list-style-type: none"> Supervised PhD and MSc Studentships Van Dijk J, Sargison ND, Kenyon F, Skuce PJ (2010); <i>Animal</i>, 4 : pp 377-392 Kenyon F, Sargison ND, Skuce, PJ, Jackson F, 2009 <i>Veterinary Parasitology</i> 163: 293-297 EU FP7 Project “GLOWORM”, Innovative and sustainable strategies to mitigate the impact of global (including climate) change on helminth infections in ruminants. Start date 1st Jan 2012 	M.R Hutchings (SAC) Link here and Philip Skuce et al (Moredun)
Impacts of diseases on crops	Control of ramularia leaf spot in a changing climate (CORACLE) 2009-2013	<ul style="list-style-type: none"> Aim is to improve scientific knowledge of Ramularia Leaf Spot disease in barley and apply it to developing robust disease control. 	S.J.P Oxley (SAC) Link here
Changes in soil conditions	Sustainable farm management aimed at reducing threats to soils under climate change (SmartSOIL) 2012-2015	<ul style="list-style-type: none"> A holistic approach to identify farming systems and agronomic practices that result in an optimised balance between crop productivity, restoration and maintenance of vital soil functions SmartSOIL decision support tool to support new approaches and technologies adapted to different European soils and categories of beneficiaries (farmers, farm advisory and extension services, and policy makers) 	Dominic Moran (SAC) Link here
Impacts on livestock	Climate Change Impacts On The Livestock Sector 2007-2008	<ul style="list-style-type: none"> Review to estimate future livestock numbers and location Modelling of climate related changes to grassland/forage production Development of an impacts inventory across key livestock species and value those impacts in monetary terms Development of an adaptations inventory and conduct a cost-benefit appraisal of adaptation plans Recommendations on ‘optimal’ adaptation in the UK livestock sector 	Dominic Moran (SAC) Link here

Opportunities	Healthy, Safe Diets	<ul style="list-style-type: none"> Help the Food & Drink industry and consumers exploit opportunities for innovation 	Paul Haggarty and Alan Rowe , Rowett Institute Link here
Impacts of diseases on crops	Durable disease resistance	<ul style="list-style-type: none"> Research to tackle the problems of new and emerging crop diseases. 	Professor Paul Birch and Dr Lesley Torrance (JHI) Link here
Changes in crop yields / impacts on crops	Artificially-changed environments	<ul style="list-style-type: none"> Research to enable the selection of better-adapted cultivars for sustainable production under climate change. 	Dr Rex Brennan (JHI) Link here
Changes in crop yields / impacts on crops	Biodiversity of model crops (barley and potato)	<ul style="list-style-type: none"> Research to support breeding for response to climatic and other changes. 	Dr Joanne Russell (barley) or Dr Gavin Ramsay (JHI) Link here
Changes in crop yields / impacts on crops	Manipulating recombination to improve crop breeding	<ul style="list-style-type: none"> Research to improve the speed and accuracy of plant breeding in response to climate change. 	Professor Claire Halpin or Dr Luke Ramsay (JHI) Link here
Impacts on crops	Functional interactions of crop ecology	<ul style="list-style-type: none"> Research on the resilience of cropping systems in response to environmental changes. The aim is to better define the components of the system that are necessary for arable systems to remain sustainable in the face of environmental change. 	Dr Cathy Hawes (JHI) Link here
Impacts on crops	Roots-soil interactions	<ul style="list-style-type: none"> Crop root systems will be subjected to increased stresses as a result of climate change. The relative importance of these stresses is being assessed so that we can better target particular crop cultivars to soil physical conditions. 	Dr Glyn Bengough (JHI) Link here
Impacts of diseases on crops	Biodiversity of pests and pathogens	<ul style="list-style-type: none"> The aim is to better understand the changing biodiversity of pests and pathogens. 	Dr David Cooke , Dr Ian Toth (JHI) Link here

Impacts of diseases on crops	Human and animal pathogens in the environment	<ul style="list-style-type: none"> The aim is to understand the role that plants play as alternative hosts for pathogens and how changes in the climate affect the outcomes of the bacteria-plant interactions. 	Dr Nicola Holden (JHI) Link here
Impacts on crops	Resistance/resilience to abiotic stresses and variable environments	<ul style="list-style-type: none"> The research will investigate into the mechanisms that allow certain plant types to withstand environmental stresses such as those from climate change. The aim is to support development of resilient plant types that are productive under the environmental stresses imposed by climate change. 	Dr Alison Karley (JHI) Link here
Opportunities	New functional crops	<ul style="list-style-type: none"> Development of new crops (including energy crops) to take advantage of more favourable growing conditions. 	Dr Derek Stewart (JHI) Link here
Changes in crop yields / impacts on crops	Complex interactions between plants and other organisms	<ul style="list-style-type: none"> The research focuses on whole crop systems and the interactions between crop plants and other organisms under climate change, aiming to understand how the system as a whole responds to change. 	Dr Scott Johnson (JHI) Link here
Impacts of diseases on crops	Virus vector populations	<ul style="list-style-type: none"> The research explores the impacts of climate change on local insect vector populations and the increase in vector-borne virus spread. Novel control measures are also being explored. 	Dr Brian Fenton (JHI) Link here
Impacts on crops	Impacts of Climate Change on crop pests, weeds and disease	<ul style="list-style-type: none"> Technical notes (2007): 'Impacts of Climate Change in Scotland on Crop Pests, Weeds and Disease' and 'Changes in Pests, Weeds and Diseases in Scotland in the last 20 years' 	Kairsty Topp (SAC)
Changes in soil erosion	Evaluation of land use, climate change and soil erosion	<ul style="list-style-type: none"> Assessment of erosion risk (water and wind) under different land uses with climate change scenarios Evaluation of adaptation strategies Planned work for ClimateXChange 	Iain Brown (JHI)

Climate change adaptation for Scottish rural land use	Relevant, effective and environmentally sustainable adaptation strategies for Scottish rural land use.	Part of the current Strategic Research Programme. Deliverables include: 1. Identification (inventory) of possible adaptation actions in the land use sector including for example: crop and livestock production systems, tourism and recreation industries, forestry, game management and other land uses. 2. Assessment of costs (including potential negative impacts), timing, acceptability and responsibility for implementing the adaptation actions identified; assessment of drivers for and barriers to uptake. 3. Methods for systematically identifying synergies and trade-offs between adaptation and mitigation actions.	Eileen Wall and Anita Wreford (SAC) Link here
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3. Background on the Strategic Research Programme: Research with some bearing on adaptation

Project	Brief summary	Contact	Directly Adaptation policy and/or Adaptation Programme relevant outputs
Strategic Research Programme 2005 - 2010			
Work Package 1.1 Barley Genetics	Barley is Scotland’s most important arable crop. There were two adaptation-relevant outputs from this work package: (i) the identification of tools (genes, markers, knowledge) to allow breeders to select crop varieties for future Scottish climate; and (ii) exploring the potential for bringing the harvest forward (early cropping) whilst maintaining or increasing yields.	Dr W.T.B. Thomas, JHI Link here - see page 24	Steps towards identifying climate-ready genetic variants of barley that can be used by commercial breeders.
Work Package 1.2 Potato Genetics	The adaptation-relevant output from this work package was: (i) the identification of tools to allow breeders to select crop varieties suitable for future climates in Scotland and to increase efficiency of water and fertiliser use in potato growing – important in preparing for reduced summer rainfall under climate change.	Dr G.J. Bryan, JHI Link here – see page 46	Steps towards making potato growing more climate resilient.

<p>Work Package 1.3 Soft Fruit Genetics And Pathology</p>	<p>The two adaptation-relevant outputs for this work package are: (i) the development of unique breeding material for raspberry and blackcurrant, some of which will be used to select material resilient to climate change; and (ii) consideration of the impact of climate change on crop health (e.g. aphids on raspberries) and the identification of future plant health risks.</p>	<p>Dr R.M. Brennan, JHI Link here – see page 75</p>	<p>Identification of climate-related risks to soft fruit crops; steps towards identifying climate-ready genetic variants of soft fruits.</p>
<p>Work Package 1.5 Potato diseases</p>	<p>This work package included a “Report on effects of climate change on pests and diseases with recommendations for future research” which considered the need to breed for resistance to new pests and diseases that may arise as a result of climate change. The report was submitted to RERAD.</p>	<p>Dr I Toth, JHI Link here - see page 107</p>	<p>Increased knowledge of climate-related risks to potato crops.</p>
<p>Work Package 2.1: Control of Viral Diseases of Livestock</p>	<p>This work addressed the control of important endemic viral diseases of livestock. It has increased knowledge with respect to virus variability, which will inform us in the future of the general applicability of specific control measures and will help to identify when new virus variants start to emerge.</p> <p>This work did not have a specific climate change or adaptation focus, but results will contribute to wider efforts to build resilience to climate impacts in the livestock sector.</p>	<p>Dr Colin McInnes, MRI Link here – see page 26</p>	<p>N/A</p>
<p>Work Package 2.2: Control of Bacterial Diseases of Livestock</p>	<p>The objective was to progress the development and implementation of control measures for endemic bacterial diseases of cattle, sheep and poultry. The research: 1) Improved diagnosis and controls for these diseases; and 2) Monitored agricultural trends in the incidence and prevalence of bacterial infections.</p> <p>This work did not have a specific climate change or adaptation focus, but results will contribute to wider efforts to build resilience to climate impacts in the livestock sector.</p>	<p>Professor David Smith, MRI Link here – see page 33</p>	<p>N/A</p>

<p>Work Package 2.3: Control Of Parasitic Diseases Of Livestock</p>	<p>This work addressed the need to maintain control over the parasitic diseases that are endemic in ruminants in Scotland. Although the work did not have a specific climate change or adaptation focus, the prevalence, spread and seasonality of these parasites are significantly affected by the prevailing climatic conditions. The work focused on improved diagnosis, novel vaccines and sustainable control strategies and results will help build resilience to climate impacts in the livestock sector.</p>	<p>Professor Dave Knox, MRI Link here – see page 41</p>	<p>N/A</p>
<p>Work Package 2.5: Livestock Genetics and Management for Product Quality and Sustainability</p>	<p>This work aimed to improve the financial viability and ‘environmental footprint’ of Scotland’s livestock sector. Outputs focused on 1) improving product quality, 2) designing sustainable livestock breeding programmes and 3) developing sustainable livestock production systems. This work did not have a specific climate change or adaptation focus, but results will contribute to wider efforts to build resilience to climate impacts in the livestock sector.</p>	<p>Professor Rainer Roehe, SAC Link here – see page 54</p>	<p>N/A</p>
<p>Work Package 3.3: Management of Soils to Enhance Function and Value</p>	<p>This included work on new modelling methods to predict the impacts of land use and climate change on soils and the consequences for soil functions. This work did not have an adaptation focus, but modelling how soils might respond to climate change will support other research.</p>	<p>Dr Rupert Hough, JHI. Link here – see page 60</p>	<p>N/A</p>
<p>Work Package 3.8: Multi-functional Land Use</p>	<p>This WP included the update of Land Capability for Agriculture and its incorporation in future land use change scenarios.</p>	<p>Iain Brown, JHI Link here – see page 137</p>	<p>See Section 2.</p>
<p>Strategic Research Programme 2011-16</p>			

<p>WP3.2 Rural land management and climate change</p>	<p>The research aims to improve the evidence base for Government by providing data on cost effectiveness of different technical solutions for mitigation or adaptation to climate change in Scottish rural land use, including arable, livestock, game and forestry systems across different scales. It aims inter alia, to develop relevant, effective and environmentally sustainable adaptation strategies for Scottish rural land use.</p>	<p>Eileen Wall and Anita Wreford, SAC Link here Christine Watson, SAC is the WP leader</p>	<p>See section 2.</p>
<p>WP 3.3 The soil, water & air interface and its response to climate and land use change</p>	<p>Research focusing on investigating key soil functions will provide a quantitative understanding of ecosystem processes at the soil, water, air interface, including how these are affected by changes such as climate change. The work will support wider research on the impacts of climate change on (livestock and) arable systems.</p>	<p>T Daniell, JHI Link here</p>	<p>N/A</p>
<p>WP 3.5 Optimising the delivery of multiple benefits from land use</p>	<p>The work assesses multi-functional land use and demands on land from different sectors. This work does not have a solely agriculture or adaptation focus, but it will be important in terms of progressing thinking on the rural economy as a whole and understanding and taking decisions about competing pressures on the land, including in the face of a changing climate.</p>	<p>Iain Brown, JHI Link here</p>	<p>N/A</p>
<p>WP 3.6 Understanding land managers' attitudes and behaviour towards the management of environmental assets and responding to climate change</p>	<p>The work sets out, inter alia, to understand how land managers' attitudes and decision making affects their responses to climate change, and to evaluate means of influencing land manager decision-making.</p>	<p>Nick Gotts; Anke Fischer; Lee-Ann Sutherland, JHI Link here</p>	<p>A Handbook on increasing 'regional sustainability of agriculture', which may have practical application if it explicitly includes adaptation (not due until 2014).</p>

<p>WP4.1 Adaptation to change in land-based and other rural industries</p>	<p>Define and map risks to existing farming systems. Extend the CC risk analysis to other rural industries and identify gaps in the adaptive capacity of rural industries and strategic interventions (information, technology, markets and regulation) that can be undertaken.</p> <p>The work is not explicitly linked to crops or livestock production, but lessons will be relevant to the agri sector.</p>	<p>Keith Matthews JHI, Alastair Stott, SAC</p> <p>Link here</p>	<p>N/A</p>
<p>WP 5.1 Assessment of Food Security, Efficiency and Sustainability of the Food Supply Chain in Scotland</p>	<p>This work package comprises two strands of work: the first strand aims to measure and identify opportunities for improving the sustainability and efficiency of selected food commodity supply chains (FCSC). The second strand of work aims to provide an analysis of the current and possible future situation for the supply and demand for food in Scotland, in order to provide an assessment of Scotland’s food security in the context of global issues including climate change.</p>	<p>Cesar Revoredo-Giha, SAC</p> <p>Link here</p>	<p>N/A</p>
<p>WP 5.2 Crops and horticultural plants with improved performance in terms of resource use and outputs</p>	<p>The purpose of the work is to generate the tools, technologies and information necessary to enable production of crop plant varieties with improved performance, whilst preserving the productivity that is required to maintain the food security which underpins the Scottish Economy.</p>	<p>David Marshall, JHI</p> <p>Link here</p>	<p>N/A</p>
<p>WP 5.3 Livestock with improved performance in terms of health, welfare, resource use and output</p>	<p>The work aims to support Scottish livestock production to contribute to reductions in GHG emissions whilst maintaining productive capability (system resilience) in the face of disruption, contributing to food security, improving human diet and health and meeting societal expectations with respect to animal health and welfare.</p>	<p>Mike Coffey, SAC</p> <p>Link here</p>	<p>Development of animal breeding tools to promote resilience to climate change.</p>

Wider research related to climate change and agriculture (not adaptation-focused) 2011-16		
<p>WP 3.1 Net Greenhouse Gas (GHG) response from Scottish soils and vegetation to a range of land use change options and climate change scenarios – improving the evidence base</p>	<p>It will contribute quantitative data to decrease uncertainties surrounding GHG emissions from soils and soil C changes from converting land use (e.g. reforestation and restoration of degraded peatlands)</p>	<p>Robin Matthews, JHI</p> <p>Link here</p>
<p>WP4.2 Developing a low carbon rural economy (LCRE)</p>	<p>Improved understanding of key behavioural changes required in rural businesses and households to achieve Low Carbon Rural Economy (LCRE) which will support reduced impact of climate change on rural Scotland.</p> <p>Development of Marginal Abatement Cost Curves for rural economy which will generate a selection of cost effective mitigation options and will reduce economic impacts of climate change mitigation on rural businesses.</p> <p>Greater understanding of importance of governance and institutional issues in relation to development of LCRE, which will lead to increased inclusion and engagement in Low Carbon rural futures, which sees rural communities and individuals as entrepreneurs for a LCRE.</p>	<p>Alan Renwick SAC, Nick Gotts, JHI</p> <p>Link here</p>