

**SCOTTISH GOVERNMENT
RURAL AFFAIRS, FOOD AND ENVIRONMENT
PORTFOLIO**

**STRATEGIC RESEARCH PROGRAMME
1 April 2016 to 31 March 2021**

Submission

Theme 3 – Food, Health and Wellbeing

On behalf of

Biomathematics and Statistics Scotland
James Hutton Institute
Moredun Research Institute
Rowett Institute of Nutrition and Health
Scotland's Rural College

TENDERER DECLARATION

I the undersigned do hereby agree on the acceptance of the Tender for Grant Funding by the Scottish Ministers, to provide the work detailed in the Specification for the Strategic Research Programme 2016-2021.

This work will be undertaken in accordance with the principles of governance, quality, value for money and I accept that the Scottish Ministers reserves the right to withdraw funding should the outputs not meet the required standards. I confirm that the work will be completed at the prices entered in the Pricing Proposals and in accordance with the Scottish Government Conditions of Grant.

I the undersigned do hereby agree to abide by the requirements that each organisation is to have a structured data management and Intellectual Property plan in place; and to the Joint Code of Practice for Research as detailed in Schedules 2 – Annex D and 4.

I confirm that the tender as submitted is complete and that all the information contained within this is accurate. I agree to abide by this tender from **Noon on Thursday 30 April 2015** the date fixed for receiving tenders, until the Award of Grant.

Signature

Name

PROFESSOR PETER MORGAN

(BLOCK CAPITALS)

Designation

DIRECTOR ROWETT INSTITUTE OF NUTRITION AND HEALTH

List of Abbreviations

A - Activity
ABM - Agent Based Modelling
AGEs - Advanced Glycation End-Products
AHDB - Agriculture and Horticulture Development Board
AHRC - Arts and Humanities Research Council
AIDS - Almost Ideal Demand System
AMR - Antimicrobial Resistance
APHA - Animal and Plant Health Agency
APUC - Advanced Procurement for Universities & Colleges
BBSRC - Biotechnology and Biological Sciences Research Council
BioSS - Biomathematics and Statistics Scotland
BPC - British Potato Council
BSF - British Science Festival
CAFA - Culturally Appropriate Food Accessibility
CAMERAS - Co-ordinated Agenda for Marine, Environment & Rural Affairs Science
CAPIRE - Coordination Action on Implementation for Road Transport Electrification
CCAFS - Climate Change Adaptation & Food Security Initiative
CFA - Chilled Food Association
CFHS - Community Food & Health Scotland
CKEI - Centre for Knowledge Exchange and Impact
CNPA - Cairngorm National Park Authority
COE - Centre of Expertise
COSLA - Convention of Scottish Local Authorities
CoZEE - Cooperative of Zoonoses Experience and Expertise
CPP - Community Planning Partnerships
CRAT - Community Resilience Assessment Tool
CREW - Centre for Expertise on Water
CSGN - Central Scotland Green Network
cSRP - Current Strategic Programme
CVD - Cardio-Vascular Disease
cWP - Current Work Package
CxC - Centre of Expertise on Climate Exchange,
D - Deliverable
DALYS - Disability-adjusted life years
DEA - Network Data Envelopment Analysis
DEC - Directors Executive Committee
DEFRA - Department for Environment, Food and Rural Affairs
DEMOS - UK think tank
DERREG - Developing Europe's Rural Regions in the Era of Globalisation
DEVIL - Delivering Food Security on Limited Land
DFID - Department for International Development
DISCO - EU FP7 DISCOvery to products: A next generation pipeline for the sustainable generation of high-value plant products
DNA - deoxyribonucleic acid
DTAS - Development Trusts Association Scotland
EASI - Exact Affine Stone Index
EDORA - European Development Opportunities in Rural Areas
EFSA - European Food Safety Authority

EHFI - Experience of Household Food Insecurity
EPIC- Strategic Partnership Epidemiology, Population health and Infectious disease Control
ERANET - European Area Research Network
ESRC- Economic and Social Research Council
EU COST- European Cooperation in Science and Technology
EU - European Union
FAO - Food and Agriculture Organization of the United Nations
FCS - Forestry Commission Scotland
FDRC - Food, Drink and Rural Communities
FHIS - Food and Health Innovation Service
FSA - Food Standards Agency
FSS - Food Standards Scotland
GCMS - Gas Chromatography Mass Spectrometry
GHG - Greenhouse Gas
GHGE - Greenhouse Gas Emissions
GM - Genetically Modified
GMO - Genetically Modified Organism
GWAS - Genome-Wide Association Studies
HBC - Health Beneficial Component
HDC - Horticultural Development Company
HEI - Higher Education Institute
HFI - Household Food Insecurity
HGCA - Home Grown Cereals Authority
HO - Home Office
HPLC - High-Performance Liquid Chromatography
HPS - Health Protection Scotland
Hutton - James Hutton Institute
IBERS - The Institute of Biological, Environmental and Rural Sciences
ICT - Information and Communication Technology
ILSI - International Life Sciences Institute
INRA-ALISS - Institut National de Recherche Agronomique Alimentation et Sciences Sociales
ISO - International Organisation for Standardization
ITGF- Invitation to Tender for Grant Funding
JHI - The James Hutton Institute
JIC - John Innes Centre
JPI HDHL - Joint Programme Initiative; a Healthy Diet for a Healthy Lifestyle
JRF - Joseph Rowntree Foundation
KE - Knowledge Exchange
KEC - Knowledge Exchange Committee
KESL – Knowledge Exchange Sectorial Lead
KWP - Kantar World Panel
LC-MS - Liquid chromatography–mass spectrometry
LEES - Land Economy, Environment and Society (SRUC)
MACC - Marginal Abatement Cost Curve
MALDI - Matrix-assisted laser desorption/ionization
MRC - Medical Research Council
MRI - Moredun Research Institute
MRP - Main Research Provider

NAD - Nationwide Adenine Dinucleotide
NADP - Nicotinamide adenine dinucleotide phosphate
NDC - Non-Digestible Carbohydrates
NDNS - National Diet & Nutrition Survey
NERC - Natural Environmental Research Council
NFU - National Farmers Union
NFUS - National Farmers Union Scotland
NGO - Non-Governmental Organisation
NHS - National Health Service
NIAB - National Institute of Agricultural Botany
NIH - National Institutes of Health
NSIS - National Soil Inventory of Scotland
NSP - Non-Starch Polysaccharides
OECD - Organisation for Economic Co-operation & Development
PCR - Polymerase Chain Reaction
PE - Partial Equilibrium
PHD - Public Health Division
PHE - Public Health England
PI - Principal Investigator
QA - Quality Assurance
QMS - Quality Meat Scotland
qPCR - Quantitative Real-Time Polymerase Chain Reaction
RACCE - Rural Affairs, Climate Change & Environment Committee
RBGE - Royal Botanical Garden Edinburgh
RCUK - Research Councils United Kingdom
RD - Research Deliverable
REALITY - Rowett Energy Intake and Lifestyle Tool for You
REF - Research Excellence Framework
RESAS - Rural and Environment Science & Analytical Services
RHS - Royal Highland Show
RINH - Rowett Institute of Nutrition and Health
SACN - Scientific Advisory Committee for Nutrition
SAG – Strategic Advisory Group
SAOS- Scottish Agricultural Organisation Society Ltd.
SASA - Science and Advice for Scottish Agriculture
SCM - Structural Choice Modelling
SCVO - Scottish Council for Voluntary Organisations
SEGS - Social, Economic & Geographical Sciences Group
SEPA - Scottish Environmental Protection Agency
SERL - Scottish Escherichia Coli Reference Laboratory
SE - Scottish Enterprise-
SFC - Scottish Funding Council
SFD - Scotland Food & Drink
SFDF - Scottish Food and Drink Federation
SFPA - Scottish Fisheries Protection Authority
SFSA - Scottish Food Security Alliance
SG - Scottish Government
SHS - Scottish Household Survey
SIMD - Scottish Index of Multiple Deprivation
SIRA - Strategic Innovation and Research Agenda

SME - Small and Medium Enterprise
SNH - Scottish Natural Heritage
SNPs - Single Nucleotide polymorphisms
SPASE - Strategic Partnership for Animal Science Excellence
SPP - Scottish Primary Produce
SP - Strategic Partnership
SRDP - Scotland Rural Development Programme
SRP - Strategic Research Programme
SRPB - Strategic Research Programme Board
SRUC - Scotland's Rural College
SSSCDRL - Scottish Salmonella, Shigella and Clostridium difficile Reference Laboratory
STFA - Scottish Tenant Farmers Association
SUSDIET - Sustainable Diets in Europe
TIPSE - Territorial Dimension of Poverty & Social Exclusion in Europe
TMAO - trimethylamine oxide
TMA - trimethylamine
TSB – Technology Strategy Board
UN-COMTRADE - United Nations Commodity Trade Statistics Database
UoA - University of Aberdeen
VTEC - verocytotoxin producing *Escherichia coli*
WGS - Whole Genome Sequencing
WP - Work Package
WRAP - Waste and Resources Action Programme

Contents

Declaration	2
List of Abbreviations	3
Food, Health and Wellbeing Theme 3	8
Work Package 3.1 Improved Food and Drink Production	18
Research Deliverable 3.1.1 - Improving Primary Produce	28
Research Deliverable 3.1.2 - Improving Food and Drink Production	43
Research Deliverable 3.1.3 - Food Safety	57
Research Deliverable 3.1.4 - Preventing Food Waste	68
Work Package 3.2 Healthy Diets and Dietary Choice	81
Research Deliverable 3.2.1 - Importance of Healthy Diets	91
Research Deliverable 3.2.2 - Dietary Components of Healthy Diets and Their Effects	105
Research Deliverable 3.2.3 - Sustainability of Healthy Diets	117
Research Deliverable 3.2.4 - Food Culture and Dietary Choice	131
Work Package 3.3 Food Security	142
Research Deliverable 3.3.1 - Food Trade and Consumption	151
Research Deliverable 3.3.2 - Enhancing Food Security	163
Research Deliverable 3.3.3 - Local Food	177
Work Package 3.4 Communities and Wellbeing	188
Research Deliverable 3.4.1 - Demographic Change in Remote Areas	198
Research Deliverable 3.4.2 - Place-based Policy and Its Implications for Policy and Service Delivery	210
Research Deliverable 3.4.3 - Rural Landscape and Community Wellbeing	224
Research Deliverable 3.4.4 - Local Assets, Local Decisions and Community Resilience	238

Food, Health and Wellbeing - Theme 3

Executive Summary

The Food, Health and Wellbeing Theme includes a range of strategic research and knowledge exchange (KE) activities, designed to meet the requirements of many stakeholders in the public and private sectors as defined in the RESAS ITGF documentation. There is a pressing need for a joined up approach to address the paradox whereby the Scottish food and drink industry has rightfully gained a worldwide reputation for producing prestigious food, yet Scottish people are (in)famous for their poor diet. This poor diet contributes to public health concerns, in particular around non-communicable disease of dietary origin. In addition, while the food and drink industry is a key driver of the Scottish economy, its contribution to local rural economies remains unclear. The requirement to address the paradox of high rates of obesity, type 2 diabetes and CVD, while maintaining an economically important and sustainable food and drink industry with shorter supply chains to the Scottish population, and vibrant and resilient rural communities, forms the foundation of research in Theme 3. There are close links within and across the Strategic Research Programme (SRP) and its overarching Centre for Knowledge Exchange and Impact (CKEI), and also to other components of the RESAS funding portfolio including Centres of Expertise (CoEs) and Underpinning Capacity (UC) work in each institution.

Vision for Theme 3: The relationship between food and human health and wellbeing and rural communities is complex and multifaceted, involving many stakeholders from all sectors of society. The food supply chain stretches from rural communities, including primary production at the farm and local level, through to food processors, manufacturers and retailers, to reach consumers in localities throughout Scotland. Each of the end user groups and local communities in this interwoven supply chain have their own, often competing, viewpoints and priorities. The various priorities encompass many common themes such as economics, sustainability, health and societal awareness, although they also have the potential to generate discord. Thus while there are some things that most people will agree upon there are also issues where there are clear differences of opinion and priority which need to be addressed by policy makers and opinion formers seeking consensus and pragmatic solutions. How these different issues are tensioned ultimately determines how our food production system functions and performs in the context of global food trade and consumption, and how rural communities fare in a context of ongoing changes in the wider economy. For example, one area of broad agreement is that our food should be as healthy and safe as possible, yet levels of diet-related ill-health (e.g. obesity and its consequences, in particular) remain unacceptably high in Scotland. Overconsumption of certain types of food undoubtedly predisposes individuals to poor metabolic health, but where the responsibility for this situation lies is a clear area of tension – is this the responsibility of the food industry or the individual consumer, and how should policy makers manage the balance between societal and economic interests? Another example relates to the balance between producing food and drink for export and encouraging short food supply chains in Scotland. The former is important in ensuring economic growth at the macro level while short food supply networks can help achieve local rural development goals, can enhance community empowerment, and potentially address food insecurity issues at the micro, household level. Both of these - very

different examples - are explored within the theme.

At a fundamental level, the research in Theme 3 aims to provide the evidence base to help optimise interactions between different stakeholders so that Scotland can move towards a situation where a safe, healthy and sustainable food supply is available to all, and the food and wider environment encourages healthier choices and lifestyles, whilst supporting strong and resilient communities. **The vision** is therefore to undertake research that will inform the many stakeholders involved in food production, protection of human health and rural development about how economic and societal tensions can be minimised to the benefit of all concerned.

Over the next 5 years, we expect to identify new opportunities to enhance the healthiness, sustainability, safety and security of the foods that are available to the population of Scotland. These advances will be based on improvements and advances in, for example, crop breeding, the health credentials (bioactivity) of novel and existing diets and dietary components, mitigation of the risk of food-borne illnesses and diseases, and minimising food waste at all levels. We also expect to identify policies that can enhance rural community wellbeing and resilience in the context of wider social, political, economic and environmental change. Technological and process advances will be supported by clearer understanding of sustainable routes to market for new products, and by policy-relevant recommendations that will enhance food security at both national and household levels, including locally sourced foods, and that will take into account social and behavioural barriers to change at all levels, and particularly the impact of change on remote, rural communities and rural environments. Progress across the 5 years should make Scotland an exemplar for joined up thinking with research helping to address the food-health paradox and promote food security for the nation.

A1: Programme Governance

The overarching vision for the SRP is to support the Scottish Government's single purpose of sustainable economic growth by delivering excellent science and translating this into practice to protect our natural assets, promote productive and sustainable land management and rural economies, ensure a supply of safe, nutritious and affordable food, and enhance the health and wellbeing of our people and communities. The SRP involves six Main Research Providers (MRPs), a wide range of scientific disciplines, facilities and equipment, and important stakeholders in Scotland and further afield. To manage this complexity, we propose the following governance structure to provide vision and leadership in strategic science excellence, and maintain continual improvement in performance of activities funded and delivered through the SRP and the associated CoEs and Innovation Platforms.

1. The Strategic Research Programme Board (SRPB) convened by RESAS will oversee all scientific activities and impact from the SRP.
2. The Directors Executive Committee (DEC), comprising the Directors of each MRP, the KE Director, Programme Advisors, and DEC secretary, will provide top level management of the SRP and its KE, at all levels from RD through to CKEI.



3. A Strategic Advisory Group (SAG) convened by DEC with wide membership from scientific and stakeholder communities will advise DEC on strategic research and KE activities throughout the life of the SRP. This group will report to DEC and will be chaired by an independent member.

4. The Centre for Knowledge Exchange and Impact (CKEI) consisting of the KE Director, the two Programme Advisors, and five KE Sectorial leads (KESLs) covering the areas of food and drink, livestock, crops, environment, and communities, will coordinate KE activities across the SRP. The role of the KESLs will be to (a) interact with the SRP Themes, CoEs, Innovation Platforms and UC services, (b) coordinate engagement with stakeholders, and (c) help implement events and activities through the communications teams at each of the participating organisations. The CKEI will report to the DEC, and a KE Consultative Group will be used to advise on innovative KE approaches to maximise impact locally, regionally, nationally and internationally.

5. Theme Coordinators will coordinate all Theme activities and report to DEC. Management details specific to Theme 3 are given below.

6. Workpackage (WP) Coordinators in each Theme will coordinate Workpackage activities and report to their Theme Coordinator.

7. Research Deliverable (RD) Coordinators will coordinate Research Deliverable activities and report to their WP Coordinator.

Although not formally part of the structure, the CoEs are an important, policy-focused component of the portfolio supported by RESAS, and the SRP will be closely linked with the governance and management of the CoEs through their individual Directors.

The structure will facilitate the overall collating, synthesising and dissemination of information between the RDs, WPs, Themes, UC within each MRP, Innovation Platform projects, and the CKEI, to ensure integrated and responsive modes of working. Specific WP and RD coordinators will have a particular responsibility for developing integrative working among the MRPs in new areas of science. Throughout, an ethos of team working and collaboration will be fostered to implement an ambitious and far-reaching strategy for Scottish science and its KE.

Individuals have been identified for each of these roles for the first year of the SRP, although it is anticipated that these may change (subject to DEC approval) as the Programme develops. Rotation of managers may occur where the activities (e.g. at the RD, WP or Theme level) involve multiple major inputs from more than one MRP, or where significant changes have occurred.

Communications within the governance structure will be by a range of routes, including face-to-face meetings, video or teleconferencing, webinars, email and social media. The choice of approach will depend on geographical site, participant number and costs, and will attempt to minimise carbon emissions from travel while

maximising communication effectiveness. Meetings at the RD, WP and Theme levels, and with Innovation Platforms (and where requested, CoEs), will focus on the scientific excellence of current work, future opportunities linking with other scientific initiatives (especially within Scotland), and undertaking additional activities to deliver to the SG's Purpose of sustainable economic development. The meetings will be an opportunity for some of Scotland's most creative and innovative scientists to design and influence the future agendas for science delivering to the SRP vision. Meetings will also routinely assess delivery of scientific outputs and outcomes from the SRP to account for spend and demonstrate value. The division of time on science excellence/forward look compared to monitoring progress/delivery will be at least 50:50 at all levels and more likely to be 75:25 at the levels of Themes and WPs.

Roles and responsibilities of key individuals in the governance structure:

Members of DEC

1. Each Director, as a member of DEC, will be responsible for ensuring that the high quality of research is maintained and opportunities for more integrated and innovative working are embraced. Each Director will also identify and deliver corrective action in the event that issues affecting delivery have been identified by Theme Coordinators, the KE Director, or SAG.
2. The budgetary implications of issues identified by the Theme Coordinators or the KE Director will also be the responsibility of the relevant Director.

Programme Advisors

1. Assisting Theme Coordinators in identifying new opportunities or changes in policy foci, monitoring scientific progress within Themes and at SRP level.
2. Responsibility for overall coordination and oversight of the reporting process on behalf of DEC with designated MRP representatives for metrics.
3. Forming specific linkages, with KESLs, with RESAS Science Advisors.
4. Stakeholder engagement in liaison with the CKEI Director.
5. Identifying cross-Theme opportunities for both research and KE, through attendance at DEC meetings and membership of the CKEI core group.
6. Representation role for SRP at key KE events, liaising with the CKEI Director.

Theme Coordinator:

1. Identify ongoing opportunities to ensure the Theme Vision is realised and delivers to the overall SRP Vision.
2. As the principal point of contact with DEC and RESAS Science Advisors, assume overall responsibility for Theme development and co-ordination.
3. Chairing *Theme Management Group* (TMG) meetings, at least every 6 months.
4. Responsible for monitoring progress within the Theme against agreed and timetabled activities/deliverables/events, reporting to DEC and RESAS Science Advisors to inform when objectives are achieved and impact is realised.
5. Where necessary, reporting on problems with delivery of Theme to DEC and providing advice on contingency plans to address such issues.
6. As empowered by DEC, responsibility for implementing changes to Theme delivery/resource allocation.
7. Highlighting new opportunities for integration and added value within Theme or across the SRP, both in research and KE activity.
8. Represent Theme activities at key events and to RESAS, as appropriate.

WP Coordinator:

1. Identify ongoing opportunities to ensure the Theme Vision is realised.
2. Responsible for monitoring progress and KE activity within the WP against

- agreed and timetabled activities/deliverables/events and reporting to the TMG.
3. Organise and chair meetings of the *WP Management Group* (WPMG) consisting of RD leads, Theme Coordinator, and relevant Sectorial KE Leads.
 4. Organise WP meetings (all staff working in the WP will be invited), to review research progress and assessment of synergies across the WP portfolio.
 5. Coordinate the collation of material and reports in advance of annual reporting according to the reporting processes prescribed by RESAS.
 6. Discussing opportunities for, and delivery of, KE at the WP level with the Theme Coordinator and relevant KESLs, and contributing to decision-making on whether this activity might be escalated to either Theme or CKEI levels.
 7. Responsible for dealing with issues that have not been resolved at RD level.

RD Coordinator:

1. Identify ongoing opportunities to ensure the Theme Vision is realised.
2. Responsible for monitoring research progress within the RD against agreed and timetabled activities/deliverables/events and reporting to the WPMG.
3. Coordinate the collation of material and reports in advance of annual reporting according to the reporting processes prescribed by RESAS.
4. Responsible for dealing with issues arising at RD level.
5. Responsible for implementation of Data Management and IP Plan, and for dealing with issues arising at RD level.

A2: Theme

A2.1: Strategic Relevance (Plain English statement)

Research in Theme 3 addresses issues that are directly relevant to the SG, its policy priorities, the health of its population and the wellbeing of rural residents. Simultaneously tackling major public health concerns whilst maintaining growth in a sustainable food and drink industry is now high on the political agenda. This is exemplified by policy documents such as *Recipe for Success*, *Becoming a Good Food Nation*, *Supporting Healthy Choices* and the *Prevention of Obesity route map*, and the recent establishment of the *Scottish Food Commission*. Theme 3 research aims to help bridge the gap between public health policy and industry, addressing healthier food and drink production, what a healthy sustainable diet looks like, aspects of food security, and how behaviour change towards adoption of such diets can be encouraged. These issues variously influence the economic and social resilience of rural communities, which are the origin of primary food production.

Specific working arrangements for 'Food, Health and Wellbeing' Theme:

Theme 3 covers a wide range of research activity and has a diverse stakeholder base. The Theme has the following components (WPs), demonstrating this diversity:

- WP 3.1 – Improved food & drink production
- WP 3.2 – Healthy diets and dietary choice
- WP 3.3 – Food security
- WP 3.4 – Communities and wellbeing

This range of activity brings together researchers with complementary and interdisciplinary skills and expertise, within the RDs. The ambition is that, when brought together under the Theme and the SRP, the whole will be greater than the sum of the parts. The combined activity will be underpinned by strong links to the other Themes covering the whole food supply chain, from primary producer to consumer to local communities. The imperative to tackle the health and economic issues outlined above, in an integrated multidisciplinary approach, is recognised in

the Theme 3 proposal, which has been produced following consultation with relevant SG departments, most notably the *Public Health Directorate* and the *Food, Drink & Rural Communities Division*, and policy developers/advisors such as *Food Standards Scotland* (FSS). Discussions with these policy stakeholders have identified a clear commitment to closer working, building on established successes, such as the KE event – a workshop on *Behaviour Change* co-constructed between the cSRP (Theme 7: Healthy and Safe Diets) and the *Food, Drink & Rural Communities Division* in 2014. These interactions will help to maximise the impact of the research planned for Theme 3 and hence benefit SG and the taxpayer. Similarly, the expertise within Theme 3, currently accessed through platforms such as the *Food and Health Innovation Service*, provides the food and drink industry in Scotland with access to the science base required to help stimulate production of healthier products through reformulation and exploitation of novel crops and other nutritional resources. As outlined above, the Principal Investigators (PIs) within Theme 3 have a strong track record in KE with stakeholders, and are active in public engagement with research. This activity will be enhanced through the development of the CKEI and greater co-ordination of Theme 3 KE activities. Accordingly, engagement with end users of SG-funded research is planned over the course of the SRP, including those involved in policy, public, commercial and civil sectors.

A2.2: Theme-level management activities and structures:

A2.2.1: Coordination and management

Collaboration, coordination and networking within the Theme

Face-to-face DEC meetings involving the Theme Coordinators and the CKEI Director will be timetabled prior to SAG meetings (2 per annum). The meetings will be scheduled sufficiently in advance for DEC members to be able to assess and react to the information provided by the Theme Coordinators and the CKEI Director, and thereby support SAG in forming a strategic view. DEC will also have scheduled monthly meetings by video conference, which the Theme Coordinators will attend and contribute to, thereby allowing an appropriate oversight and integration of activities within the SRP. At the face-to-face DEC meetings prior to SAG, identification of new challenges, technological advances and opportunities for co-funding will be an important aspect. The Theme Coordinator will provide DEC with a summary of progress, including identification of any problems and potential solutions, but also highlighting opportunities for greater integration within and between Themes. The Programme Advisors, with their pan-SRP role, will also play an important part in identifying opportunities for greater integration across all activities. Information will be provided verbally, supported by audit information arising from WP/RD progress monitoring. Updates on KE at Theme level, thus incorporating information from WP and RD Coordinators, will be provided by the relevant Sectorial KE leads and by the Theme Coordinators, who will work closely with the CKEI Director. Individual WPs in Theme 3 have identified specific linkages with other Themes and reporting on these interactions will be a fixed agenda item at the biannual Theme meetings (see below). Discussions with other Theme Coordinators will identify specific topic meetings to be held with relevant PIs in the participating Themes. The Theme will be managed by a Theme Management Group, the core of which will include the Theme Coordinator, the WP Coordinators, and relevant Sectorial KE leads.

Theme Management Group Structure:

- Theme 3 Coordinator (Chair)
- Relevant Sectorial KE leads
- Theme 3 WP Coordinators
- MRP Theme 3 Representatives
- Programme Advisors
- RESAS Science Advisors

The Theme Management Group will be responsible for strategic direction and accountable for the delivery of outcomes (including KE), and will be the arbitrator where decisions within or between WPs are required but cannot be reached by other means. Where issues persist, the DEC will be the final arbitrator. The Theme Management Group will meet at least biannually and have the responsibility to:

1. Build a shared vision within and between the Themes and across the SRP
2. Provide overall co-ordination (financial, administrative, and intellectual);
3. Communicate with, and report to, the Programme secretariat;
4. Co-ordinate and ensure consistency and excellence in the science, and;
5. Communicate with and to a wider stakeholder community through integration with Sectorial KE Leads and with the CKEI.

WP Management Group Structure:

- WP Coordinator (Chair)
- RD Coordinators
- Each MRP nominated WP Representative
- Relevant Sectorial KE leads
- Programme Advisors
- RESAS Science Advisors

WP Coordinators will be expected to be pro-active in ensuring that opportunities for collaboration are exploited. Identifying these opportunities will be a fixed agenda item for the WP meetings. There will be an annual workshop for PIs, post-doctoral scientists and post-graduate students, where the emphasis will be on developing innovative approaches arising from trans/interdisciplinary linkages. This will include generation of new ideas for the 'Think Tank' – a mechanism for developing agenda-setting concepts from the RESAS programme (see CKEI tender). Annual workshops may be held jointly between WPs (e.g. WPs 3.2 and 3.3), and will be open to PIs working on related areas across the SRP to help identify cross-linking activities.

Collaboration and networking with wider science communities

Theme 3 research and the Impact and KE strategy described in A2.2.2 will engage stakeholders from a range of organisations such as FSS and CAMERAS partners. In response to feedback from stakeholders we will create bespoke KE structures, in collaboration with the Sectorial KE Leads, across WPs to simplify engagement and facilitate their interactions with researchers. These structures will produce regular reports of progress and outcomes, host regular KE events as detailed below, and will link closely with the indicative activities within the CKEI. The delivery of these will be refined in consultation with stakeholders throughout the programme.

Interaction with Underpinning Capacity

Theme 3 will interact with 5 of the components detailed in the Underpinning ITGF: 1. Support to policy; 2. Seedcorn funding; 4-6. Collections; 7. Biomathematical and statistical services; 10. Diagnostic test capacity. '**Support to policy**' is of particular importance. During the cSRP there has been major progress in relationship building with SG policy departments and other stakeholders, and discussions during the tender preparation have underlined enthusiasm for engagement. '**Maintaining and enhancing the science base in Scotland**' will see the use of seedcorn funding to support PhD training and other projects. '**Collections**' maintained by Underpinning Capacity Services funding will be used throughout the Theme such as large datasets and plant collections. '**Provision of Biomathematical & Statistical consultancy services**' will see BioSS staff continue collaborations with scientists throughout the MRPs.

Managing annual reporting

Annual reporting will conform to the processes and requirements detailed by RESAS. The production of metrics, progress reports and narratives will see the WP and Theme Management Groups working closely with the Programme Advisors. Metrics will be collated by each of the MRPs, and a SRP-wide database of outputs will be held by the CKEI and Programme Advisors. This will ensure that cross-Theme referencing is complete, consistent, and accurate. The progress of activities within each RD will be monitored routinely, with RD Coordinators providing the WP Coordinator with summaries of scientific progress, key outputs and reporting with respect to the proposed schedule. Updates will be provided at meetings of the Theme Management Group. This communication process will begin to identify narratives that are suitable and sufficiently developed to be included in the Theme level reporting. Accordingly, individuals will be identified to draft the details at the time of reporting. Final editorial responsibility for narratives and their submission will lie with the Theme Coordinator, acting on behalf of the Theme Management Group, and the relevant Programme Advisor. Progress will be assessed, classified (on schedule, slight delay, significant delay) and reported as described above. Key findings, activities and impacts will be collated into a WP level report for compilation into Theme level reporting. Each MRP will follow a QA system for its contribution to reporting, with ascending editorial responsibility of RD, WP and Theme Coordinator.

High impact narratives will be identified in the following areas:

- Policy relevant
- Industry/innovation
- Scientific excellence
- Leveraged external funding
- Collaboration and interdisciplinary working

Management of risks to delivery (Theme level)

A common risk management structure will be implemented across the SRP at Theme and WP levels with an iterative risk register. Risk management strategies for the WPs will link to and be a component of the Theme level risk management. At Theme and WP Management meetings the status of current risks will be assessed, and new emerging risks will be identified and added to the register. Mitigation strategies will be proposed, taking into account the research implications for cross programme links and external collaborations including implications for stakeholders.

Assessment will be agreed (e.g. tolerate, monitor, take action, including escalate), and the WP Management Group will update the Theme Management Group.

Risks at Theme level are included in the Table below, colour coded as follows:
RED – extremely likely to occur and would have a serious impact on delivery; must be escalated to Programme Advisors, who will report to DEC if appropriate.
AMBER – risks that could escalate if not effectively managed and monitored; monitor and provide updates to the Theme Management Group, with immediate escalation to Programme Advisors if re-assessed as red.
GREEN – low risks requiring minimal management, although monitoring is still required; manage and monitor, and if subsequently reassessed as amber, report to the Theme Management Group.

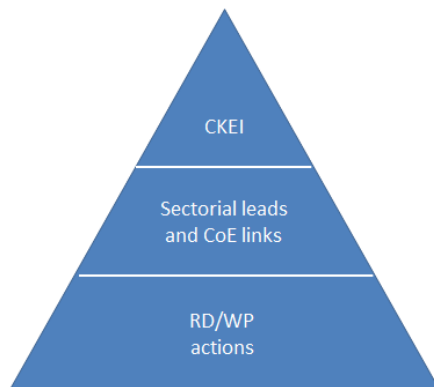
Risk Descriptor	Risk Assessment	Impact	Controls	Risk owner (e.g. RD, WP or KE Coordinator)
Significant reduction in budgets	MEDIUM	HIGH	RD content to be renegotiated with SG, and consequences agreed with partners	DEC
Staff turnover or long term absence due to ill-health	MEDIUM	LOW-HIGH	Identify early, discuss with RD/WP Groups – option to cover with existing staff or recruit – temporary/permanent	RD, WP, Theme Coordinator
Divergence in stakeholder and research priorities	LOW	LOW	RESAS, DEC, Advisory Group to help clarify interface between the commissioned research programme and stakeholder priorities	WP, Theme, KE Coordinator
Divergence in priorities and perspectives on optimal delivery between partner MRPs	LOW	MED-HIGH	Early identification of potential issues through discussions at <i>Theme Management Group</i> . Option to report to DEC for resolution.	RD, WP, Theme, Coordinator

Each of the MRP partners recognises that risk control is an integral part of good management and therefore is committed to achieving best practice with audited structures, procedures and protocols in place. Individual organisations are accredited to ISO9001 or ISO14001 standard, or working towards this. Key risks relate to communication failures and external factors affecting delivery. These risks will be controlled through the described management arrangements and risk ownership will focus on the Theme Management Group. The Theme Management Group will resolve any conflicts impartially and will communicate with both the partner organisations and RESAS on a regular basis to ensure responses to identified risks are proportionate and that problems are overcome. Conflicts that cannot be resolved at Theme level will be referred to the DEC for a decision.

2.2.2: Impact and Knowledge Exchange

MRPs are committed to a step change in the effectiveness of KE based in the RESAS research programme, to enable the research to have tangible benefit (impact) for a wide range of beneficiaries. As described in the KE tender document, the new KE Director and CKEI will provide leadership and guidance on best practice, QA, evaluation and training in support of all KE in the programme, whether delivered directly from the WP/RD or from the CKEI itself (see diagram). The conduit for KE from all parts of the SRP and MRPs will be the five, Sectorial KE Leads, specialising in Crops, Livestock, Food and Drink, Environment and Communities. These highly experienced and motivated individuals are already recognised by many important stakeholders within Scotland, and further afield, for their commitment to KE and to ensuring change and impact from research. The Sectorial KE Leads will attend Theme, WP and RD meetings as appropriate, and especially when these are

relevant to the immediate requirements for KE actions via the CKEI strategy. The SRP represents a core of strategic science in Scotland and links with the more applied CoEs and the HEI collaborative projects (at RD level) will ensure information and idea flow throughout the wider SG research portfolio. These science linkages and the CKEI will be used to maximise adoption and impact of SG funded research.



At RD and WP level (see below), KE will mainly be delivered through face-to-face meetings with stakeholders, building on existing relationships, and through a range of dissemination/media tools. Specific stakeholder events will be run to assist in the development of, and obtain feedback on, identified research outputs. Catch-up meetings with specific stakeholders by way of informal meetings or themed workshops will be a key feature,

At Theme level, the sectorial KE leads, who will also be part of the CKEI, will provide an integrating role, being able to pull together related strands of KE from the RDs and WPs not only from within Theme 3, but also other themes. This will provide more holistic and joined up KE and will form the basis for pan SRP activities/events at wider fora such as Food Matters Live and Vitafoods Europe, annual conferences and specialised events run by Scotland Food & Drink, the Food & Drink Federation (Scotland and UK), and new activities planned under the SF&D revised innovation delivery platform, as well as relevant public health conferences. The CKEI will provide an overarching KE strategy for the SRP, covering the research Themes and CoEs. Within this structure, the CoEs (CXC, CREW and EPIC) will synthesise relevant evidence from the SRP and other sources for use by the appropriate policy teams in policy development. The Theme will contribute to the proposed CKEI activities in a number of ways, including but not limited to the provision of material for the website, contributions to relevant international meetings, annual showcase events, training workshops and CPD events, and proposal of Think Tank topics.

Theme 3 encompasses research relevant to a wide range of stakeholders; these include SG policy teams such as the Public Health Division, Food, Drink and Rural Communities, and FSS, and policy stakeholders including Scotland Food and Drink, Scottish Food and Drink Federation, Scottish Enterprise, Scottish Natural Heritage, National Farmers Union, Community Planning Partnerships, etc. This diversity requires KE activity related to the Theme and its outputs to be handled carefully, with due consideration of the perspectives of the different stakeholders and the pressures under which they operate. Much has been learnt about navigating this path during the cSRP. We will look to increase the impact from the Theme by making effective connections that meet the topical demands of relevant policy teams, and facilitate innovation within the food and drink and agriculture industries.

Work package 3.1 Improved food & drink production

1. Overview

Food and drink production in Scotland is at the heart of this work package (WP) and the planned activities have been co-constructed with the appropriate stakeholders to deliver on the vision and aims of a range of Scottish policies; Recipe for Success, Becoming a Good Food Nation, Eating for Health: a Diet Action Plan for Scotland, Supporting Healthy Choices 2014, Scottish Rural Development Programme, Public Health etc. (Scotland) Act 2008, Towards Zero Waste & Scotland's Economic Strategy 2015. The planned activities span the Scottish food production pipeline from primary to secondary (processing), encompassing the need to ensure that the food available to the Scottish populace is desirable, nutritious, beneficial to health, safe, economically viable, sustainable and produced in an ethical manner. To deliver on these often conflicting attributes of food at the public & commercial sectorial and civil societal levels, a significant and aligned interdisciplinary research and translation effort is required across the Scottish food and drink production and supply chain. This planned research programme will build on the major findings, discoveries and technical advances achieved during the current strategic research programme, related to food, diet and health, and the food and drink strategic partnerships. Allied with this successful evidence-based delivery we will have an (inter)active portfolio of knowledge exchange activities appropriate for the diverse end users and stakeholders; policy, industry, academia, and consumers. These and work with the CKEI activities (e.g. Think Tank) and wider stakeholder interactions and partnerships assisted by the KE Sectorial Leads, will further link and integrate WP engagement with that other WPs across the SRP. By fostering interdisciplinarity, these linkages will also facilitate significant leverage for external grant income thereby positioning Scottish science as world leading whilst delivering local and national solutions.

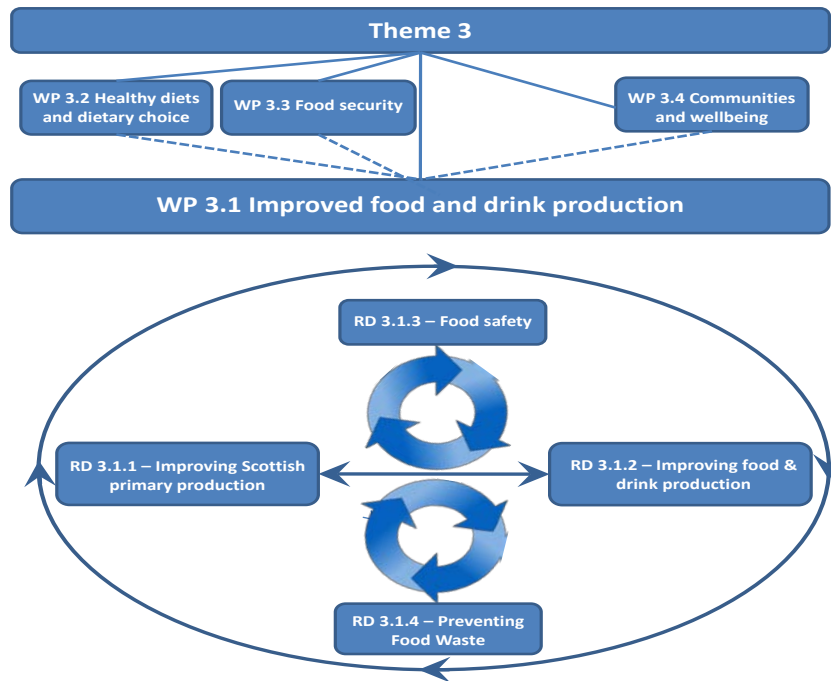
The key aims of Work Package 3.1 are therefore to contribute to a sustainable, healthy diet by improving the nutritional and health qualities, affordability, availability and sustainability of Scottish primary and processed food and drink through:

- The identification of the nutritious and health beneficial components in major, underused or emerging affordable and seasonal Scottish primary produce that would benefit from enhancement.
- The characterisation and development of strategies for improving the nutritive value and health benefits of processed foods.
- The development of technologies and strategies for the prevention, detection and eradication of food borne infections and related toxins with particular relevance for Scotland.
- The development of tools, techniques and best practice to allow the Scottish food and drink industry to reduce or valorise waste.
- Development of ethical principles, methodologies and standards across the food and drink supply chain that can help the sector in enhancing sustainability and expanding Scottish trade.

2. Coordination and management

The work package is interdisciplinary addressing common issues from different angles, aiming for synergies, optimal impact and efficacy. This approach means that collaboration, co-ordination and networking across, and within, the research portfolio and MRPs needs

to be well structured and managed. To this end, the WP Coordinator (Prof Derek Stewart, Hutton) will be responsible for the overall delivery of the collated WP activities. Each MRP has also assigned a WP representative to facilitate integration and PIs have been assigned as Coordinators responsible for the delivery of the five Research Deliverables (RDs) in WP 3.1. The interaction of the WP within Theme 3, the RDs within WP 3.1 and the levels at which they operate relative to each other is highlighted schematically below.



Coordinated management of the WP will use the WP and RD Coordinators (and BioSS and MRP Representatives) as the management team with invites to the Food, Health and Wellbeing Theme Coordinator, KE sectorial leads (CKEI) and appropriate Programme Advisor to ensure efficient and swift upward reporting. This group will meet biannually using available online collaboration facilities where possible to reduce transaction and carbon costs. RESAS science advisors will have a standing invite to these meetings to enable a rapid update on, and transfer of, progress, achievements and impact and for them to provide steering advice if warranted. These WP meetings will also deal with the administrative management issues (annual monitoring of progress against objectives for all RDs, facilitating resolution of problems, reporting of progress and exceptions to the Theme 3 Management Group) in accordance with arrangements outlined at Theme level. Importantly, the WP meetings will also discuss the on-going RD science against the backdrop of developments in the food and drink sectors, with KE sectorial lead support, as it relates to the WP and the development of (cross) WP and Theme level KE and planned outputs. This may be done through selected scientific presentations or workshops and sessions devoted to the discussion of emerging issues of scientific or policy relevance. Engagement with Scottish Government will take a combined Theme 3 and WP level approach to unlock the fuller benefits of the SRP by drawing out a more strategic view of the outputs, and to optimise impact and relevance with policy. These dialogues, embedded in the Theme 3 and WP 3.1 management and interaction workplans, will be an opportunity to update policy colleagues on the research at the RD level but in a WP, Theme and full SRP context. This will allow the policy representatives to see where the future planned research can aid policy development and/or delivery and

redesign where necessary.

This policy engagement will be informed by the planned stakeholder events, engagements and workshops at WP and Theme level. Minutes of WP meetings will be communicated to all staff in the WP and to other work package Coordinators to ensure joined up delivery across the WP and Theme, to develop synergy and ensure transparency to the researchers. The Programme Advisors will also have an important role in ensuring the joined up delivery and identifying new opportunities.

3. Collaboration, co-ordination and networking

As highlighted above, WP3.1 is interdisciplinary and for this to deliver effectively at all critical levels (strategic relevance, international scientific quality, value for money and with probity) there is a necessity to ensure that there is a vibrant, but not over burdensome, collaborative interchange of ideas and updates within and across the RDs, WPs and Themes to ensure strategic relevance. Furthermore, there is also a necessity for this collaborative interchange of ideas and updates to include the representatives from bodies such as CAMERAS or, more relevant for WP3.1, the industry leadership organisations Scotland Food and Drink and Scottish Food and Drink Federation, as well as Food Standards Scotland, Zero Waste Scotland and the Scottish Government Food and Drink and Rural Communities Division. Engagement with, and cross fertilisation between, the Scottish Government funded programmes (WPs, Themes, Centres and Innovation Platform projects where appropriate: See below) will utilise the scheduled programme of events identified in the CKEI, Theme(s) and WPs and management and interaction workplans with support from the KE sectorial leads. This will ensure that collaboration, co-ordination and networking are delivered on a value-added basis with a minimisation of stakeholder engagement meeting fatigue and associated costs.

At the RD-specific level it is essential that there is well-structured RD/WP/Theme/Central Collaboration, co-ordination and networking. For example, RD3.1.1 (see Table below) has primary production at the heart of its activities, consequently this will be impacted upon, and itself impact on, other parts of the programme as highlighted below. For example, WP1.2 (Water resources and flood risk management) will impact upon WP3.1 in terms of water supply whilst the activities in RD3.1.1. will reciprocate with regard to aspects of run off into water courses: the interaction here is circular. Similarly the outputs of RD 3.1.1 identifying enhanced production of nutritional and health beneficially relevant components in, for example, barley will then feedback to the RDs 2.1.1, 2 & 8 to guide future crop improvement and RD2.3.9 to ensure that the practises developed for production enhance or at the very least maintain the levels of these components. This is more fully expanded for RD3.1.1 as an exemplar and for the whole WP at a higher level in the table “Key WP3.1 impactful linkages within and across themes” and in the WP 3.1 RD documentation.

WP3.1 has a strong requirement for interaction with the Underpinning capacity across the MRPs. Specifically these are potato, barley and soft fruit collections and genetic sequence databases (Hutton), a responsive and reactive capacity to develop diagnostic tests (MRI) and biomathematical & statistical services (BioSS; see below). This will be managed by integration with the planned management and workshops identified in the WP3.1 management work plan (below).

RD3.1.1:	RD/WP/Theme/Centre Collaboration, co-ordination and networking
Impacted Upon	<p>Theme 1: Natural Assets; WP 1.2 RD1.2.3: Water environment resilience and adaptation to change; RD1.2.4: Effectiveness of water management;</p> <p>Theme 2: Productive and Sustainable Land Management and Rural Economies; WPs 2.1 & 2.3 RD2.1.1: Genetic diversity of crops: RD2.1.2: Crop genetic improvement; RD2.1.6: Integrated pest management; RD2.1.8: Novel crops: RD2.3.9: Integrated management systems; RD2.3.12: Increasing uptake of best practice</p> <p>Centre of Expertise for Climate Change</p>
Impacts On	<p>Theme 1; Natural Assets: WP 1.2 RD1.2.3: Water environment resilience and adaptation to change; RD1.2.4: Effectiveness of water management.</p> <p>Theme 3: Food Health and Wellbeing; WP 3.1-3 RD3.1.2: Improving food & drink production; RD3.1.3: Food safety; RD3.1.4: Preventing food waste; RD3.2.1: Importance of healthy diets; RD3.2.2: Dietary components of healthy diets and their effects; RD3.2.3: Sustainability of healthy diets; RD3.3.1: Food trade and consumption; RD3.3.2: Enhancing food security; RD3.3.3: Local food</p>

WP 3.1 management and interaction workplan

Programme Year	2016-17				2017-18				2018-19				2019-20				2020-21			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Activity																				
WP meetings																				
RD Meetings																				
¹ Stakeholder meetings and workshops																				
Underpinning and Centres engagement																				
Update and Progress reports																				

Key WP3.1 impactful linkages within and across themes.

¹ * - Here stakeholders include, but are not exclusive to, CAMERAS, industry, policy groups, end-users, NGOs, the public etc.

Theme 3: Food Health and Wellbeing			Theme 2: Productive and Sustainable Land Management and Rural Economies				Theme 1: Natural Assets
WP3.1: Improved Food and drink production	WP3.2: Healthy diets & dietary choice	WP3.3: Food security	WP2.1: Crop and grassland production and disease control	WP2.2: Livestock production, health, welfare & disease control	WP2.3: Agricultural systems and land management	WP2.4: Rural industries	WP1.2: Water resources and flood risk management
RD3.1.1: Improving Scottish primary production	RD3.2.1: Importance of healthy diets RD3.2.2: Dietary components of healthy diets and their effects RD3.2.3: Sustainability of healthy diets RD3.2.4: Food culture and dietary choice	RD3.3.1: Food trade and consumption RD3.3.2: Enhancing food security RD3.3.3: Local food	RD2.1.1: Genetic diversity of crops RD2.1.2: Crop genetic improvement RD2.1.6: Integrated pest management RD2.1.8: Novel crops	RD2.2.2: Evaluation of livestock health RD2.2.3: Disease mechanisms RD 2.2.4 &5: Novel diagnostic tools and vaccines RD2.2.6: Animal disease epidemiology	RD2.3.3: Disease threats in the environment RD2.3.8: Alternative approaches to sustainable land management RD2.3.9: Integrated management systems RD2.3.10: Using and sharing data across supply chains RD2.3.11: Trade-offs between productivity and sustainability RD2.3.12: Increasing uptake of best practice	RD2.4.2: Resilience of rural economies to key external drivers RD2.4.2: How rural economies can adapt to key external drivers RD2.4.3: Environmental sustainability and circularity of the rural economy	RD1.2.3: Water environment resilience and adaptation to change RD1.2.4: Effectiveness of water management
RD3.1.2: Improving food & drink production							
RD3.1.3: Food safety							
RD3.1.4: Preventing food waste							

The WP Coordinator and the PI leading the underpinning capacity plans for the target crops are located in the same MRP ensuring regular and fruitful collaboration and interaction. Furthermore there are common staff leading and/or delivering on the planned outputs of WP3.1 RDs and the underpinning capacity activities thereby further ensuring effective links to those resources will be made, maintained and managed. More specifically in WP3.1 the underpinning capacities interacted with are identified below and coded as identified in the Hutton UC submission and relate to the use of germplasm collections.

Funding for BioSS inputs of a collaborative or advisory nature will be provided as described at the Theme level through Underpinning Capacity Function 7, "Provision of Biomathematical & Statistical Consultancy Services". Management level inputs will be provided through identification of a BioSS Work Package Contact, who will be invited to work package level meetings and be involved in the preparation of annual reports and Knowledge Exchange activities. Although many interactions between staff in BioSS and the MRPs have a long history and function effectively, the nomination of a BioSS WP Contact will ensure that no scientist contributing to the work package is left without a BioSS contact point. In addition, the BioSS WP Contact will be well placed to maintain a watching brief over BioSS-MRP interactions in the work package and to identify gaps in coverage or other mismatches between resource and demand which will be discussed with the BioSS Theme Contact along with other appropriate managerial staff in BioSS and the MRPs.

4. Mechanisms for scientific networking, collaboration and exchange with scientists in the CAMERAS and wider science communities

All of the above cross collaborations will enhance the science and facilitate evidence based advice to policy whilst broader relevance to other policy and non-policy end points will be further enhanced by links to and interaction with groups such as SASA, Scotland Food and Drink Ltd, NFUS, Food Standards Scotland, CAMERAS and the more sectional bodies such as AHDB (including HDC, BPC and HGCA) and SAOS, industry associations (BOBMA, SFDF, Association of Scottish Shellfish Growers etc) and NGOs (The Nutrition Society, WRAP, Zero Waste Scotland). Engagement with these groups is likely to be initiated at RD level and may be elevated to WP or Theme level depending on its scope and linkage to other activity across the SRP. Where appropriate, representatives of these organisations will be invited to planned progress and update meetings, workshops or KE events at RD to CKEI level.

There are many areas within the Strategic Research Programme where synergies have been identified and these are identified below;

- RD 3.1.1: Climate change represents a potential threat and promise with regard to indigenous and non-indigenous pests/pathogens arising and broad changes in crop quality, affordability and consequently synergies in approaches will be sought with RDs 2.1.1/2/3/4/6 and the Centres of Climate Change and Plant Health. In addition, the exploitation of new and/or underutilized crops will need to interact closely with the Novel Crops aspects in RD 2.1.8 to develop synergies particularly with respect to crops as alternative protein sources. Furthermore, the plan to look at Scottish produce sustainability in terms of changes in health benefits and the opportunities for marketing will need the

outputs of RDs 3.2.2 and 2.3.8-12.

- RD 3.1.2: Clearly the plans and outputs of the primary produce research (RD3.1.1) are intimately linked to this RD in terms of health benefits, baselines for process based changes and the identification of specific beneficial endpoints such as reduced obesity and improved metabolic health. Furthermore, the planned research into improving the health benefits of food processing and the associated supply and demand for such food needs to be in part informed by the plans for crop improvement (RD2.1.1) and the development (RD2.3.8/9) and adoption of management practices (RD2.3.11/12).
- RD 3.1.3: Plans for food safety in terms of new or technical improvements in the prevention, detection and eradication of food-borne infections and the development of risk based analyses to deploy these needs to be tightly integrated with the research at the animal and production systems levels. With respect to livestock, this means synergies can be developed from the outputs of livestock health to prevention and epidemiology (RD2.2.2-6) and environmental disease threats (RD2.3.3). For crops, the implications of food safety in the supply chain will need to be aware of the plans in IPM (RD2.1.6) and the development (RD2.3.8/9) and adoption of management practices (RD2.3.11/12). All these areas will consider not just the contribution of pathogens but also AMR to food safety. Overarching and more strategic interaction will be needed with EPIC with regard to deployment strategies of the tools developed.
- RD 3.1.4: The food waste plans will iteratively develop on the advances derived in primary produce production and processing (RD3.1.1&2), crop improvement (RD2.1.1) and management systems (RD2.3.8-12). Research here will also need input from what defines a sustainable healthy diet (RD3.2.3) and how trade (RD3.3.1) and the development of short food supply chains (RD3.3.3) will influence outcomes.

5. Key risks to delivery as identified at a Work Package level and the means by which how these will be managed.

Within the WP we have an appropriate mix of highly experienced staff with a track record of successful delivery in the current and previous RESAS programmes and on major national and international externally funded research projects. These staff are also experienced at assessing and managing risks to delivery. WP3.1 will establish a risk register and the risk management strategies for the WP will be integrated with those at Theme level and the other linked WPs. Identified risks will be allocated; a risk descriptor; a risk assessment; an evaluation of the potential impact for the WP; a list of risk controls in place; a risk owner (RD coordinator, WP coordinator, Sectorial KE leads). Identified risks will be subject to regular review and update including recommendations for risk mitigation and a Management Committee assessment. Risks will be rated as red/high (likely to occur with a serious impact on delivery), orange/medium (potential to seriously impact on delivery if not effectively managed), or green/low (requires monitoring but minimal management). Exemplars of the Risk register for WP.31 are identified below:-

Risk Descriptor	Risk Assessment	Likelihood & Impact	Controls	Risk owner (e.g. RD coordinator, WP leader, KE coordinator)	Update including recommendations for risk mitigation	Management Committee assessment ²
Loss of key staff	Medium	Medium/Medium	Continued staff turnover and training	WP leader		
Failure of key equipment	Low	Low/Medium	Continued investment in capital equipment	RD Coordinator		

6. Impact and KE

This WP has a strong interdisciplinary theme underpinned by basic through to applied science and integrated approaches encompassing interwoven physical, natural and socioeconomic science(s). The proposed interdisciplinary approach will allow the design, testing, validation and transfer of food and drink production and processing systems in a sustainable, equitable and ethical manner. The lack of fundamental knowledge associated with some areas provides the opportunity to provide science understanding and drive forward the science agenda in a critical area. A high degree of interdisciplinarity is anticipated with work involving crops, food technology, shellfish, human nutrition, soil, livestock science and socio-economics. Given the multiple disciplines across physical, natural and socioeconomic sciences involved, this WP has the potential to be a successful interdisciplinary approach to improving food and drink production, within and across MRPs and with wider HEI and industry/consultancy colleagues. The adoption of this approach with great scientific depth and excellence in each discipline will ensure the delivery of high impact publications in the areas of primary and secondary production (RD3.1.1/2) and food safety (RD3.1.3) whilst the combination of primary production and food processing advances (RDs 3.1.1/2), and those in food waste and valorisation (RD 3.1.4) will form the basis of impactful case studies. Furthermore the overarching combination of decision support tools and strategies for the ethical production of food has the potential to also be of global relevance and will deliver both highly cited outputs and case studies.

The provision of knowledge in and the development of healthy, affordable, nutritious and sustainable food and drink from primary Scottish produce and using improved processing systems in an ethical manner will provide ample opportunity for innovation. Links to industry will provide opportunities to develop joint externally funded projects to further commercialise outputs from the programme. The development of novel tools to characterise primary produce, and associated food and drink, for health benefits has previously led (and will continue to lead) to a number of strong industry and NGO (e.g. Food Standards Scotland) collaborations. The new research will help develop the next generation of targets for sustainable food and drink improvement and the strategies to ensure these are produced sustainably, economically and that they can be accessed with equity by all socioeconomic groups. Further, work in this and linked WPs will have strong

² Management Committee may decide to either: 'tolerate', 'continue to monitor', 'take action' or 'escalate' the risk.

interactions with the funded AgriTech Centres for Innovation on crops, livestock and precision smart farming themes which the MRPs are core partners in.

All the areas identified will deliver to and are highly relevant for a global and EU food security agenda, and will be leveraged internationally for additional broader research. Via the identified scientists this RESAS funded research will therefore also be delivered on an international platform. Of particular importance here are the roles staff play on committees in (inter)national groups and funding bodies such as European Plant Science Organization, European Innovation Partnership – Agricultural Productivity and Sustainability, ILSI, BBSRC, SACN, Agritech-Innovate UK etc. Strong links to overseas collaborations within Europe, and wider afield, particularly in China, Australasia and the US, will be further built on to broaden the SRP-derived impact and existing relationships and collaborations. Much of Scottish produce (fresh and processed) has international markets (and competitors) and the health issues targeted are global, meaning that the improvements and enhancements planned here for food and drink need an international perspective and would benefit from international collaboration.

The highly collaborative nature of this package will fuel close cooperation on KE events, and link activity at an RD level with Theme-level activities and broader undertakings in the CKEI. These will include participation in key annual stakeholder focussed events (Food Matters Live, Edinburgh International Science Festival, Royal Highland Show, Potatoes in Practice, Cereals in Practice, Fruit for the Future, AHDB SFD/SFDF/Nutrition Society health and nutrition events). Target audiences include CAMERAS and agronomic, agricultural, food and drink companies targeted either directly or via intermediaries such as levy boards and commercial subsidiaries. KE partners include the food and drink leading body, Scotland Food and Drink Ltd, Food Standards Scotland, the related industry associations, environmental regulators, and policymakers such as Food, Drink and Rural Communities. In addition, work with the CKEI will include contributions from WP research and expertise into Think Tank projects.

KE activities to inform food safety and the translation of the new tools and technologies for their deployment will be developed in collaboration with national (FSS and FSA) and international (EFSA) bodies. Similarly, the interrelated activities of improving primary and processed Scottish produce, whilst reducing and/or valorising waste, will be done via co-constructed events and workshops with SFD, AHDB (e.g. at HGCA monitor farms) and food and drink associations.

Quality Assurance

The MRPs contributing to this Work Package are dedicated to achieving and maintaining the highest possible standards of quality in order to meet the requirements of their work and the needs of their internal and external customers. To achieve this they will:

- Comply with the requirements of the Joint Code of Practice (March 2012) for quality assurance and the BBSRC Statement on Safeguarding Good Scientific Practice.
- Operate a quality management system that meets the requirements of the ISO 9001:2008 and which is systematically maintained, reviewed and revised to ensure continuous improvement. The relevant Quality Management Systems, or equivalents, in each Institute include:

- Comply with the requirements of customers and official bodies – plan and develop standard work processes by means of Standard Operating Procedures, where required.
- Monitor quality performance through internal and external auditing relating to the pertaining ISO standard.
- Set quality objectives and targets.
- Allocate sufficient resources to achieve its quality objectives and targets within budgetary constraints.
- Obtain and act upon feedback from RESAS and stakeholders.
- Assign competent personnel to co-ordinate the quality management system.
- Develop competency through provision of training and communication.

Ethical and regulatory issues

Use of GM organisms is governed mainly by the Biological Agents and Modified Organisms (Contained Use) Regulations. Environmental protection is enacted through the Environmental Protection Act 1990 (and amended Scotland 2001), Genetically Modified Organisms (Risk Assessment) (Records and Exemptions) Regulations 1996 and the Genetically Modified Organisms (Deliberate Release and Risk Assessment – Amendment) Regulations 1997, and the Genetically Modified Organisms (Contained Use) Regulations 2014 ('the GMO (CU) Regulations'). Use of licensed plant pathogens and of imported soils and plant materials is governed by the Plant Health (Scotland) Order 2005, regulated by SASA for the Scottish Government. Use of animals for research is regulated by Animals (Scientific Procedures) Act 1986. All work using animals is done under authority of Project Licences issued by the Home Office after Ethical Review.

Research involving human subjects is subject to the relevant Research Ethics Committees of the MRPs, and, where appropriate, authorisations from Multi-Centre Research Ethics Committees. Studies may follow the British Sociological Association (BSA) Statement of Ethical Practice [http://www.britisoc.co.uk/new_site/index.php?area=equality&id=63]. Surveys undertaken as part of the research programme are subject to completion of the RESAS Research Approvals Proforma and subsequent clearance.

Contribution to the 3R's (reduction, refinement and replacement)

There is no work planned that will directly contribute to the 3Rs, although these are considered whenever a proposal using animals is put forward and when HO licences are being reviewed.

Sustainable Development

The Scottish MRPs associated with WP 3.1 have Environmental, IP and commercialisation policy statements which affirm that they are committed to preventing pollution, adopting and promoting environmental best practice in connection with operations and in support of sustainable and safe practices and that they will use the scientific outputs for sustainable development in the circular and bio economies.

Name of RD: 3.1.1 – Improving Primary Produce

Research aim and key drivers

Scotland has an extensive larder of nutritionally valuable animal and plant-derived products that can be grown, harvested, produced and processed to provide a healthy and sustainable diet. Evidence has accumulated suggesting that specific dietary constituents from plants and animals can prevent the onset and progression of socially and economically important chronic diseases (**e.g. cardiovascular disease, type 2 diabetes and obesity**). However innovative routes to increasing the intake of beneficial dietary components are required, especially those in at risk groups. Driven by the Scottish National Food and Drink Policies, A Recipe for Success (2009) and Becoming a Good Food Nation (2014), which aim to increase access to good quality food to improve Scotland's diet and food culture, **our work will focus on providing scientific evidence to deliver plant- and animal-based foods with superior nutritional qualities**, within a framework of reducing resource use, as well as examining barriers and opportunities for the farming and the food and drink industry to enhance consumer uptake of such foods. Stakeholders who have been consulted in the writing of this were: FSS, SFDF, NFUS, Seafood Scotland, SEAFISH, AHDB, HDC and HGCA and a range of relevant companies and SMEs.

Summary of the proposal

Building on the year of Food and Drink Scotland in 2015, we seek to examine and embed the science that can underpin the long-term sustainability, economic growth and societal value of Scottish food and drink. The quality of Scottish primary produce (SPP) is a critical attribute for Scottish producers as it differentiates their products in crowded markets and attracts premium prices. As a result, diverse types of SPP (from crops to shellfish) can be crucial for the sustainability of rural communities. The health benefits that these diverse types of SPP could contribute to the diet of Scottish consumers are also of key importance to the health, and wealth, of the nation.

Major advances in genetic and genomic resources (e.g. see RDs 2.1.1/2) for crops have provided further opportunities to control the quality of SPP, particularly in furthering our understanding of the accumulation of known health beneficial components (HBCs) in a range of crops and in fish, e.g. β -glucans in barley, polyphenols in berries, vitamin C in potatoes and vitamin D and other micronutrients in shellfish. Target primary produce in this RD includes soft fruits, barley and potatoes, crops which are key to the Scottish economy and rural communities, and where existing and developing genetic and genomic resources can be exploited. Understanding the effects of environment, location and more sustainable agronomic practices on HBC levels is important for consistent delivery of benefits. Understanding the barriers for the uptake of produce with healthier and more sustainable characteristics in supply chains, and consumers' demand for such healthier and sustainable produce, is crucial so that improved SPP can deliver these health benefits.

Current pressures for sustainable healthy diets (link to RD 3.2.3) require SPP to provide affordable products for the food and drink industries that meet these demanding criteria. The following Objectives [O1-8] address the aims of identifying novel or improved primary products with proven health benefit, grown under sustainable production systems, that have realistic potential for beneficial inclusion

in the food supply chain:

- Exploiting genetic variability and breeding strategies (potatoes [O1], barley [O3], soft fruit [O5])
- Evaluation of the potential of under-exploited species/varieties (barley, leafy green vegetables, root vegetables [O2])
- Improving product quality for health benefit (barley [O3], soft fruit [O5])
- Assessment of the impact of more sustainable farming on health promoting attributes of Scottish produce (potatoes, grain, oilseed and beans [O8])
- Characterising health-promoting properties of Scottish produce (shellfish [O4], soft fruit [O6])
- Assessing likely uptake of healthier sustainable produce by consumers and the supply chain (shellfish [O4], general produce [O7])

O1 - Exploiting genetic variation to increase potato Vitamin C content.

Despite their relatively modest content, potatoes represent the most significant source of vitamin C in the Scottish diet. As a result, the introduction of improved cultivars could provide meaningful and affordable impact on the vitamin C status of the Scottish population. Given that plasma vitamin C status is currently considered low/ marginal in half the population, enhanced potato vitamin C content could have a positive impact on Scottish public health. Cultivar to cultivar variability in tuber vitamin C content and the impact of storage/processing is well understood but no studies have characterised the genetic regulation of this trait. Initially we will establish if the genetic variation in vitamin C content is sufficiently robust to make the development of novel molecular markers, and then examine the deployment of these markers in breeding programmes.

Key deliverables D1.1. Determine extent to which genotypic factors control vitamin C content in potatoes (year 2) **D1.2.** Deploy genotypic screen for the potential identification of molecular markers of vitamin C content (year 5)

O2 - Learning from wild and underexploited plants: Nutritional information to inform crop breeding.

Work in the cSRP5.2 has shown that some wild and underexploited plant species are rich sources of phytochemicals. These are potential bioactives beneficial to health. Through modern breeding practice, which has favoured productivity and profit, this potential nutritional benefit may have been lost. The objective of this project is to re-evaluate the nutritional benefit of such wild and underexploited species. This will be achieved by investigating the phytochemical profiles of selected underutilised plant species relative to more intensively grown contemporary varieties. Human intervention studies will establish whether any improvement in phytochemical profile translates into enhanced benefits in terms of bioavailability and bioactivity. Alongside these studies, the role of growing conditions (location/soil quality) on phytochemical content and profiles of selected crops will be assessed. Ultimately the aim is to identify products with strong economic advantage for the agri-food sector.

Key Deliverables: D2.1: Identification of plants with favourable nutritional profiles to inform future breeding strategies (year 2). **D2.2:** New nutritional data to inform dietary advice (year 5). **D2.3:** New plant-based ingredients to aid the food industry (year 5).

O3 - Improving barley quality for malt and as a health food. Barley grain (1,3;1,4)- β -glucan content has an established positive impact on human cardiovascular and gut health when consumed above certain levels. Arabinoxylans

also have a health claim related to glycaemic control. While current elite barleys have low levels of these fibre components, potentially more variation exists in wild and landrace material (link to O2). We aim to provide high β -glucan and/or arabinoxylan lines to give opportunities for the food industry to improve diet without changes in behaviour (a health by stealth approach), e.g. as partial wheat replacements in 'barley breads' or oat/barley porridges. Barley for beer and whisky has differing requirements and adjunct brewing requires high diastatic power (DP). Selection for malting quality has led to reduced variation in the structural genes for enzymes that contribute to DP and few elite varieties have high DP. Using contemporary genetic approaches, including searching existing next generation sequencing (NGS) datasets for allelic variation, we will gain a better understanding of the genomic regions crucial for this trait, potentially enabling the development of high DP varieties crucial for these industries.

Key deliverables: **D3.1.** Identify genes and natural or induced alleles responsible for high β -glucan/ arabinoxylan synthesis in barley grain (year 5) **D3.2.** Identify genes and natural or induced alleles responsible for high DP enzyme levels in specific barley germplasm (year 5).

O4 - Establishing the bioavailability and efficacy of vitamins and micronutrients in shellfish to improve nutritional status and health biomarkers. In the cSRP7.2, we established that consumption of two portions of Scottish salmon per week for 18 weeks improved nutritional status of omega-3 fatty acids and vitamin D, as well as cardiovascular health. Shellfish are a good source of omega-3 fatty acids, and cSRP studies indicated that some shellfish e.g. mussels, both a sustainable and affordable dietary option, contain significant levels of vitamin D metabolites. This project evaluates 1] levels of fatty acids and micronutrients in a range of shellfish, and assesses the influence of seasonality and provenance; 2] effects of shellfish consumption on bioavailability of vitamin D3 and its metabolites, omega-3 fatty acids and micronutrients as well as on markers of cardiovascular health; 3) whether increased knowledge about personal requirements could modulate behaviour w.r.t. shellfish consumption.

Key deliverables: **D4.1.** Evaluation of fatty acid and micronutrient composition of range of shellfish samples from different locations across the year (year 2). **D4.2.** Assessment of bioavailability of vitamins/micronutrients and omega-3 fatty acids from shellfish to improve nutrient status and reduce cardiovascular risk (year 3). **D4.3.** Identification of factors relating to personal requirements that influence consumer behaviour with respect to fish/shellfish consumption (year 5).

O5 - Improving soft fruit quality. Polyphenols in soft fruits may be health beneficial components (HBCs) affecting various disease processes, and their levels have become important quality criteria. Understanding the inheritance of HBCs will allow development of molecular markers that can accelerate breeding of new, improved varieties with altered polyphenol levels. In cSRP work, accumulation of polyphenols has been linked to specific areas of the genetic maps already constructed for particular soft fruit species. Season-on-season data from progeny sets grown in different environments/locations is required to remove confounding effects and confirm the position of these quantitative trait loci (QTL), which overlie the location of potentially novel genes that synthesise these HBCs, and thereby aid in their identification. A theoretical approach examining QTL networks will also be developed to provide greater understanding of the

relationships between biosynthetic pathways for these HBCs.

Key deliverables: **D5.1.** Establish environmental and seasonal variation in polyphenol composition in raspberry/blackcurrant progeny (year 4). **D5.2.** Develop tools to aid discovery of potential novel genes that influence polyphenol biosynthesis (year 5).

O6 – To identify soft fruit bio-actives promoters of metabolic health. Research in the cSRP, along with RINH and Hutton data, suggests that soft fruit contain bio-active phytochemicals, which decrease post-prandial glucose and reduce macronutrient uptake (e.g. lipids) *in vivo*. Soft fruit rich in these bio-actives may therefore influence nutritional strategies for improving glycaemic control (relevant to type 2 diabetes) and healthy weight management and obesity; two health issues which are particularly important and significant in Scotland. Identification of these bio-actives could inform the breeding of crop varieties with enhanced health benefits and offers opportunities to develop novel food/drink products. We propose to 1] identify these bio-actives and evaluate their mode of action, 2] determine the concentration of the bio-active required for effects, and 3] measure their potential to reduce risk of diabetes and support healthy weight management in humans.

Key deliverables: **D6.1.** Identify bio-actives with health benefits in Scottish soft-fruit (year 5). **D6.2.** Develop strategies for the enrichment of these bio-actives in primary produce and ultimately in food products (year 5).

O7 - Encouraging the marketing of healthy and environmentally sustainable Scottish produce. This socioeconomic work comprises two components: (1) the identification of the uptake of produce with healthier and more sustainable characteristics in the produce supply chains and (2) consumers' demand for produce that is healthier and sustainable (as without this, there can be no impact on health and sustainability). For (1) we will study the uptake by Scottish supply chain of healthier and/or more sustainable produce, considering amongst other aspects seasonality and affordability. For (2), we will investigate consumers' demand for healthier and more sustainable food products considering: (a) produce available in the market (using econometric methods with purchasing data) and (b) new produce (using economic experiments). The results should inform on market acceptance for work within the other objectives within the RD. (e.g. O1, O3, O5 and O7) and will complement work in O3, RD 3.1.2.

Key deliverables: **D7.1:** Paper identifying conflicts and power-relationships among stakeholders within Scottish produce supply chains (year 2). **D7.2:** Report on econometric results of the EASI demand model (year 2). **D7.3:** Report on alternative approaches to improve the uptake of produce with healthier and more sustainable characteristics (year 5). **D7.4:** Results of economic experiments on consumers' demand for new produce that is healthier and sustainable (year 5).

O8 - Effect of sustainable farming systems on HBC quality. The consequences of a shift from conventional practices toward more sustainable, low input alternatives on nutritional quality in crop species crucial to Scottish farming infrastructure/food production will be examined. This builds on cSRP3.3 (and the aligned SP) and uses produce from the Centre for Sustainable Cropping (supported by Underpinning Capacity) and links to RD 2.3.9. We will determine key quality parameters and levels of HBCs in specific varieties of some of Scotland's major crops (potato, wheat, barley and oilseed rape but also field bean) grown under conventional **or** sustainable, low input systems. As the crop rotation

completes over 5 years, confounding effects of year-on-year variation will be removed and the potential impacts/benefits of sustainable practices on HBCs revealed, especially when possible yield penalties are taken into account.

Key deliverables: **D8.1.** Define the effects of sustainable cropping on HBC levels (year 5). **D8.2.** Develop model for predicting shifts in crop quality due to reduced inputs under sustainable cropping (year 5)

Technical approach and detailed work plan

O1 - Exploiting genetic variation to increase potato Vitamin C content. Firstly, we will establish a BioSS-approved sampling protocol that accurately captures genetic variability (M1.1a; May 2016) and then define tuber-to-tuber, plant-to-plant and genotype-to-genotype variation in vitamin C content (M1.1b; March 2017). A subset of genotypes will be grown under different environmental conditions and retested to capture environmental variation in the trait (M1.2a; Dec 2017). Further, tubers will be stored under commercial conditions to establish genotypic variability of vitamin C content on storage (M.1.2b; Mar 2018). Thus over two years, we will confirm if the inter-genotypic variation is sufficiently robust compared to other factors to allow the effective screening of an elite suitable mapping population (the extensively genotyped diploid Tuberosum-Phureja cross) to develop putative molecular markers for tuber vitamin C content in later years.

O1.1 Establish variation in tuber vitamin C at the levels of individual tubers, plants and genotypes (March 2017). **O1.2** Examine variation due to effect of environment and under commercial storage conditions (March 2018)

O2 - Learning from wild and underexploited plants: Nutritional information to inform crop breeding. The macro-, micro- and non-nutrient (phytochemical) content of wild and underexploited crops will be investigated. This will include: 1. barley accessions, which have been bred from unexploited ancient/exotic lines found to be rich in soluble (e.g. β -glucan) & insoluble fibre, as well as important micronutrients (M2.1a; Sep 2016) and key phytochemicals (M2.1b; June 2017), 2. wild varieties of current domesticated crops (e.g. *Brassica* and *Daucus* sp.) rich in phytochemicals and micronutrient vitamins and minerals (M2.2a; Sep 2017) from seed collections at RBGE, which will be grown at several locations and 3. underutilised species high in protein (e.g. vetch, trefoil and clover) (M2.2b; Dec 2017). A combination of techniques, including several metabolomic LC-MS platforms, will be used to define the nutritional content of the various species. An acute randomised and controlled human intervention study will be undertaken to assess phytochemical and nutrient bioavailability and indices of postprandial health (e.g. anti-inflammatory, anti-genotoxicity, antioxidant function, glycaemic response) in response to selected wild/underexploited species. The study will start in year 2 (M2.3a; Aug 2017) and will be powered specifically to detect changes in metabolite bioavailability (M2.3b; Completed Mar 2018). As growing conditions can impact on nutrient quality of crops, studies of the effects of location/soil quality on the protein, phytochemical and micronutrients content of underutilised species will be initiated in year 2 (M2.4; Mar 2018). In later years, detailed studies of soil-plant-phytochemical interactions in controlled environmental growth studies will follow.

O2.1: Report on nutritional composition of selected barley accessions (Jun 2017), **O2.2:** Nutrient and phytochemical compositional analysis of wild, traditional and F1 hybrids of underutilised crops (Dec 2017), **O2.3:** Human intervention study to assess bioavailability/ bioactivity of phytochemicals in barley [Design/ recruitment; Aug 2017; complete March 2018) and **O2.4:** Impact of soil quality (Mar 2018).

O3 - Improving barley quality for malt and as a health food. Genes involved in the synthesis/hydrolysis of β -glucan and arabinoxylan, and their contribution to barley β -glucan and arabinoxylan content will be investigated. For β -glucan, we will focus initially on the *Cs1F* gene family (synthesis) and two genes (*HvG1b1* & *HvG1b2*) involved in β -glucan hydrolysis. For arabinoxylan, we will pursue a genetic approach combined with arabinoxylan measurements to identify loci controlling its abundance (M3.1a; Jan 2017). Similarly, we will approach high DP levels in varieties destined for adjunct brewing or distilling sectors. We will analyse specific populations in winter & spring germplasm pools to determine controlling factors influencing DP enzyme levels (limit dextrinase, α -amylase, β -amylase; M3.2a; Mar 2017). We aim to identify genes that are involved in synthesis and hydrolysis of these cell wall compounds (M3.1b; Feb 2018) and starch (M3.2b; Mar 2018), and validate using contemporary genetic approaches. We will mine existing NGS (genome & exome sequences and transcriptome) datasets from georeferenced wild, landrace and elite lines in our barley germplasm collection to understand gene family structure and gene expression patterns, and to catalogue available molecular diversity. In later years, we will exploit genome editing to knock out (KO) these genes for functional characterisation, and investigate the potential value of gene KO's *per se*. Advantageous new alleles could be incorporated into the breeding genepool, either directly by genome editing approaches via allele replacement (dependent on legislation) or by traditional marker-assisted introgression from donor accessions.

O3.1a Quantify β -glucan and arabinoxylan content in barley germplasm collection. **b** Identify accessions with favourable alleles for β -glucan and arabinoxylan content in NGS datasets. (**a** Nov 2016, **b** Feb 2018). **O3.2a** Quantify DP enzyme levels in barley germplasm collection. **b** Identify accessions from barley germplasm collection with favourable alleles for DP enzyme levels in NGS datasets (**a** Feb 2017, **b** Mar 2018).

O4 - Establishing the bioavailability and efficacy of shellfish to improve nutritional status and health biomarkers. Shellfish species (e.g. mussels, langoustine, lobster, scallop, crab and oysters) will be sampled across the year from geographically different producers in Scotland and analysed for omega-3 fatty acids, vitamins B & D, micronutrient composition and heavy metals to establish variability due to seasonality and provenance (spring to summer (M4.1a; Oct 2016) and autumn to winter (M4.1b; June 2017)). We will use this knowledge to investigate specific and robust health benefits associated with consumption of shellfish products (D4.1; Sep 2017). Ethical approval will be obtained for an intervention study (M4.2a; Aug 2017) in ~50 healthy subjects at risk of cardiovascular disease. This study will be powered to elucidate the effects of consumption of vitamin D-rich Scottish shellfish for 8 weeks, over winter, (trial completed, M4.2b; Mar 2018) on the bioavailability of vitamin D₃ (& metabolites), omega-3 fatty acids, iodine, selenium and B vitamins, as well as effects on established/emerging markers of cardiovascular health, compared with supplement and non-supplement control groups). Later, we will perform an observational personalised nutrition study in ~150 subjects. This will assess whether knowledge of an individual's key genes in fatty acid, vitamin D and selenium metabolism and their nutrient status, plus personalised advice on shellfish consumption, would encourage people to eat more shellfish, compared with a control group that only

get general advice on health benefits of shellfish consumption.

O4.1: Establish levels of vitamin D3 and metabolites, omega-3, and other key micronutrients in a range of Scottish shellfish products, depending on seasonality and provenance (June 2017). **O4.2:** Examine bioavailability and efficacy of key nutrients in selected Scottish shellfish to improve nutrient status and reduce cardiovascular risk (Mar 2018).

O5 - Improving soft fruit quality. The raspberry progeny set (Moy X Latham) is established in open field and under polytunnel-protected sites which differ greatly in temperature and conditions. Ripe fruits will be analysed for polyphenol composition (M5.1a; Mar 2017). A similar approach will be applied to the blackcurrant 9328 progeny set, grown at two separate locations (M5.1b; Dec 2017). This data will be modelled to develop enhanced linkage maps including QTLs for polyphenols that are consistent across years/locations (M5.2; Feb 2018). A complementary network modelling approach will be developed that examines the relationships between QTLs and metabolic pathways that can be inferred in mapping populations (M5.3; Mar 2018), involving both simulation studies and statistical analysis of metabolomic data obtained here and in cSRP7.2. Combining this data with transcriptomics-metabolomics correlations obtained during fruit development, as polyphenols show different patterns of accumulation, will further indicate candidate genes involved in specific polyphenol biosynthesis.

O5.1: Analyse polyphenol composition in raspberry (a) & blackcurrant (b) progeny (a Jan 2017, b Dec 2017). **O5.2:** Produce draft enhanced linkage maps including QTLs for polyphenols (Feb 2018). **O5.3:** Develop network modelling methods linking QTL/metabolomics data to infer metabolic pathways (Mar 2018).

O6 -To identify soft fruit bio-actives promoters of metabolic health. Primarily using human intervention studies, supported by cell culture and animal studies, we will identify the specific soft fruit bio-actives responsible for decreased post-prandial glucose and reduced nutrient uptake. The first human intervention study will measure effects on post-prandial glucose control. After ethical approval, 16 overweight/obese volunteers will be recruited (M6.1a; June 2016), randomised into 4 groups matched for BMI and age and given 200 g of blackcurrants (rich in anthocyanins) or green currants (which lack anthocyanins; composition confirmed at Hutton), followed by an oral glucose tolerance test with either glucose or Polycal carbohydrate. All interventions will be randomised and blinded in a cross-over design where the volunteers act as their own control (M6.1b, Jan 2017, trial completed). This will determine if anthocyanins are causing the changes in post-prandial glucose, and if these changes are due to 1] inhibition of α -glucosidase, the enzyme responsible for glucose release from carbohydrate, 2] inhibition of intestinal glucose absorption; or 3] effects on the incretin response [i.e. gastric inhibitory polypeptide (GIP)/glucagon-like peptide-1 (GLP-1); M6.3; Mar 2018]. Assuming a within-person spread of 10% (as noted in cSRP), 16 volunteers are needed to detect a change in postprandial glucose of 12% or more, with a power of 80% at 5% significance. The second human study will measure the ability of soft fruit to reduce lipid uptake. After ethical approval, 16 volunteers (M6.2a; Dec 2016) with strong risk factors for metabolic disease (e.g. obesity or diabetes) will consume high fat meals supplemented with or without blueberry extracts in a crossover design. Post-meal blood lipids and other physiological responses will be measured. (M6.2b, trial complete; Mar 2018) Outcomes will inform a later chronic

dietary intervention on blueberry extracts on weight management. Human studies will be supported by studies on intestinal/adipocyte cell lines treated with defined soft fruit extracts and plasma and urine from a cSRP human intervention study (M6.4; Mar 2018). We will measure indicators of lipid utilisation, incretin secretion by ELISA and expression of key signalling intermediates (e.g. FGF) by qPCR or Western blot, and activities of key enzymes (e.g. pancreatic lipase). A mouse study (M6.5; Mar 2018) will titrate the amount of blueberry extract required to reduce weight gain. 5 groups [n=9] will be fed control, or high fat diets supplemented with 10% (effective in cSRP), 5%, 1% or no blueberry extract. After 12 weeks, weight, body composition, energy intake and output will be measured. Tissues will be analysed for expression of genes, and intermediates of key metabolic signalling pathways. In years 3-5, a second mouse study will test efficacy of bioactives identified in cell line assays.

O6.1: Human intervention trial to identify the mechanism(s) by which soft fruit improve postprandial glucose (Jan 2017). **O6.2:** Human intervention trial to measure the impact of soft fruit extracts on nutrient uptake (Mar 2018). **O6.3:** Identify specific bio-actives that improve postprandial glucose (Mar 2018). **O6.4:** Identify bio-active soft fruit compounds in cell culture systems (Mar 2018). **O6.5:** Identify dose response of bio-actives for weight management (Mar 2018).

O7 - Encouraging the marketing of healthy and environmentally sustainable Scottish produce. The uptake of healthier and more environmentally sustainable products will be investigated in **specific supply chains** (e.g. barley, potatoes, soft fruit, dairy) by using the following approach: Kantar Worldpanel data and additional supply data (available from SG and FSS) will be used to establish the uptake of produce with the aforementioned characteristics within supply chains (M7.1a data preparation and initial analysis; Nov 2016). The Kantar dataset provides information of suppliers and retailers marketing the produce; therefore, it will allow us to study not only aspects such as seasonality but also affordability of those products by comparing their prices with alternative varieties (M7.1.b; Sep 2017). Based on these results, in later years, case studies will be selected to provide as in-depth analysis of reasons why some of the chains do not market those products and potential solutions to overcome those barriers. The **demand** of healthy/sustainable produce currently available in the Scottish market will be econometrically analysed using Kantar dataset for Scotland (2006-2013) and the novel Exact Affine Stone Index (EASI) demand system, due to its flexibility to represent preferences (M7.2a data preparation; Nov 2016 and M7.2b econometric analysis; Sep 2017). In later years, economic experiments will assess consumers' preferences and willingness to pay for new healthy/ sustainable food products.

O7.1: Identification of uptake of healthier and more environmentally sustainable products in Scottish supply chains (Mar 2018). **O7.2** Analysis of demand for healthy/sustainable produce in Scottish market (Mar 2018).

O8 - Effect of sustainable farming systems on HBC quality. For all crops, five varieties will be grown under conventional and sustainable practices. One industry standard variety per crop will provide a comparator to annual UK performance. Each year in the rotation, the crops will be assessed for industrially relevant quality criteria including specific HBC levels (Year 1-M8.1a; Sep 2016, 1b; Nov 2016, 1c; Feb 2017; Year 2-M8.2a; Sep 2017; 2b; Dec 2017; 2c; Mar 2018). For potato, cereals & beans – amino acids, sugar, protein, mineral and vitamins; oil seed rape

– fatty acid composition; cereals – alcohol yield; all crops – key anti-nutritional parameters. As well as carrying out this crop-appropriate quality phenotyping, we will use both targeted and untargeted metabolomic approaches to discern metabolic shifts underlying quality changes (M8.3; Feb 2018). Year on year data will be modelled to better understand changes due to sustainable practices that may influence health benefits (M8.4; Mar 2018).

O8.1 & O.2 Assess year on year variation in HBC levels between sustainable and conventional crops (March 2017, Feb 2018). **O8.3** Correlate metabolomic data with HBC compositional changes for each crop to better understand shifts in metabolism (Feb 2018). **O8.4** Draft report of effects of sustainable conditions on food quality (March 2018)

Key linkages, interdisciplinarity & collaboration: Many Objectives depend on genetic resources maintained through Underpinning Capacity. O1 uses the Tuberosum/Phureja mapping population, O3 relies on barley genotyping work and O5 uses elite berry progeny. O6 links with O5 and, through RD2.1.1, provides routes to bioactive-rich berry varieties. New germplasm populations developed and genotyped in RD2.1.1 O1-3 may be of value to O1, 3 & 5 in later years. Techniques developed in RD2.1.2 may be useful in years 3-5; gene pyramiding work in RD2.1.2 O1(i) could find application in O3. O1 may benefit from hierarchical model and gene editing work in O4 (iii+iv). O5 and O6 may benefit from advances in soft fruit genomics/ transcriptomics (O6.2 i+ii). O6 extends work with U. Dundee & the Marine Biodiscovery Centre; Aberdeen and may direct product development in RD 3.1.2. RD3.1.1 acts as a conduit for genetic advances in crop quality to 3.1.2. O2 integrates breeders, agri-ecologists, and health researchers from RINH/Hutton and RGE with potential social-economic involvement and uses barley germplasm from O3, and links to RDs 2.1.1, 2.1.8 and 3.1.2/ 3.2.2. Work linking soil quality and nutritional properties in O3 will provide background to work in WP.1.1 and feedback to work in RD 2.3.9 O4 links with SE work in O7. O7 links with RD2.1.1/2, 3.1.2, and 3.3.1. O8 provides specific quality data for integration with overall models of sustainable cropping developed in RD 2.3.9.

Added Scientific Value: Understanding how SPP accumulate enhanced levels of HBCs and the effects of sustainable agronomic practices, environmental, locational or seasonal factors on HBCs (e.g. shellfish, soft fruit, CSC work) are aligned with BBSRC and EU Horizon 2020 strategic priority areas in agriculture & food security, so opportunities for leveraged funding exist. Added value also comes from links with (e.g.) the International Barley sequencing consortium and the International Potato Centre. Collaborations with NIAB, IBERS, JIC, East Malling, and with Universities also extend our networks. RD scientists participate in EU COST actions (e.g. POSITIVE, human variability & plant food bioactive compounds) and the ERANET project “SUSDIET: Implementing sustainable diets in Europe”.

KE, Audiences and Impact: Our target audiences reflect stakeholders who have been consulted during RD development. We focus on primary producers, such as growers, plant breeders and other supply industries, but processors (i.e. brewers/distillers, potato and soft-fruit product manufacturers, seafood processors) and common interest organisations (e.g. NFU, Agriculture and Horticulture Development Board, Seafish, Seafood Scotland) are also major audiences. Impact from this RD may range from greater understanding of the effects of sustainable cropping on food quality, the major barriers to uptake of new healthier/sustainable produce or identification of bio-actives that influence metabolic diseases. Evidence

that supports the attainment of a health claim by the shellfish industry for vitamin D content may benefit producers (increased consumer uptake) and consumers (improved dietary information for their health). These outcomes could benefit to Scottish farming, processor industries and help maintain rural economies. As suitable genomic pipelines are available for potatoes, barley and soft fruits, this RD is well placed to translate research to new varieties/ products. It is envisaged this work will provide underpinning evidence relevant to in the food, drink and rural communities policy areas. We make best use of existing successful, stakeholder-focussed events [e.g. Cereals in Practice (KE1), Fruit for the Future (2)] to establish/ maintain early effective communication with our key audiences and retain their involvement, but will also use events relevant to specific producers [e.g. Scottish Society for Crop Research meetings (7)] and/or the public (e.g. EISF (5)). The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads will be responsible for delivering KE events and integrative activities across the Theme and wider areas (e.g. Food Security and Health). These will deliver greater impact and highlight the added value of SRP funding. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders (e.g. Seafood Scotland for shellfish/aquaculture industries) or be co-constructed with other RDs (e.g. RD3.1.2) to bring together the often linked interests of primary producers and processors. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

RESEARCH DELIVERABLE NUMBER: 3.1.1

Work planning and timetable for Year 1: Showing major milestones (M), deliverables (D), KE/impact events (KE); Reports to RESAS [R]) and their timing.

Year 1: 2016/17 Activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Establish variation in tuber vitamin C at the levels of individual tubers, plants and genotypes		M1.1a										M1.1b
O2.1 Report on nutritional composition of selected barley accessions.						M2.1a						
KE Events: Cereals in Practice				KE1								
O3.1a Quantify β -glucan and arabinoxylan content in barley germplasm collection										M3.1a		
O3.2a Quantify DP enzyme levels in barley germplasm collection												M3.2a
KE Events: Cereals in Practice				KE1								
O4.1 Establish levels of vitamin D3 & metabolites, omega-3, & other micronutrients in Scottish shellfish products, depending on seasonality & provenance							M4.1a					
O5.1 Analyse polyphenol composition in berry progeny												M5.1a
KE Events: Fruit for the Future				KE2								
O6.1 Human intervention trial on soft fruit & postprandial glucose			M6.1a							M6.1b		
KE Events: Public Open Evening												KE3
O6.2 Human intervention trial on									M6.			

soft fruit extracts & nutrient uptake									2a			
O7.1 Identification of uptake of healthier/ more environmentally sustainable products in Scottish supply chains								M7.1a				
O7.2 Analysis of demand for healthy/ sustainable produce in Scottish market								M7.2a				
O8.1 Assess year on year variation in HBC levels between sustainable & conventional crops Staggered harvests (a = cereals/oilseeds, b = potatoes, c = beans)						M8.1a		M8.1b			M8.1c	
KE Events: Cereals in Practice				KE1								
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.1.1

Work planning and timetable for Year 2: Showing major milestones (key research activities (A), deliverables (D), KE/impact events (E)) and their timing.

Year 2: 2017/18	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.2 Examine variation in vitamin C due to effect of environment (a) and under commercial storage conditions (b)									M1.2a			M1.2b D1.1
KE Events: Industry specific presentation						KE4						
O2.1 Report on nutritional composition of selected barley accessions			D2.1b									
O2.2 Nutrient and phytochemical analysis of wild, traditional and F1 hybrids of underutilised crops						M2.2a			M2.2b			
O2.3 Human intervention study to assess bioavailability & bioactivity of phytochemicals in barley					M2.3a							M2.3b
O2.4 Impact of soil quality on nutrient content of crops												M2.4
KE Events: Edinburgh International Science festival	KE5											
O3.1b. Identify accessions favourable alleles for β -glucan and arabinoxylan content in NGS datasets											M3.1b	
O3.2b Identify accessions with favourable alleles for DP enzyme levels in NGS datasets												M3.2b
KE Events: Cereals in Practice				KE6								
O4.1 Establish levels of vitamin D3 & metabolites, omega-3, & other key			M4.1b			D4.1						

micronutrients in a range of Scottish shellfish products, depending on seasonality & provenance													
O4.2 Examine bioavailability and efficacy of key nutrients in selected Scottish shellfish to improve nutrient status & reduce cardiovascular risk					M4.2 a								M4.2 b
O5.1b Analyse polyphenol composition in berry progeny										M5.1b			
O5.2 Produce draft enhanced linkage maps including QTLs for polyphenols												M5.2	
O5.3 Pilot network modelling methods linking QTL/ metabolomics to infer metabolic pathways													M5.3
KE Events: SSCR meeting				KE7									
O6.2 Human intervention trial on soft fruit extracts & nutrient uptake													M6.2 b
O6.3 Identify specific bio-actives that improve postprandial glucose													M6.3
KE Events: Fruit for the future					KE8								
O6.4 Identify bio-active soft fruit compounds in cell culture systems													M6.4
O6.5 Identify dose response of bio-actives for weight management													M6.5
KE Events: TechFest							KE9						
O7.1 Identification of uptake of healthier and more environmentally sustainable products in Scottish supply chains													D7.1
O7.2 Analysis of demand for healthy/sustainable produce in													D7.2

Scottish market												
O8.2 Assess year on year variation in HBC levels between sustainable and conventional crops (a, b, c)						M8.2a			M8.2b			M8.2c
O8.3 Correlate metabolomic data with HBC composition to better understand shifts in metabolism											M8.3	
O8.4 Draft report of effects of sustainable conditions on food quality												M8.4
KE Events: Potatoes in Practice					KE10							
Annual Report (Year 2)												R2

Name of RD: 3.1.2 Improving Food and Drink Production

Research aim and key drivers

Social, economic and cultural changes, particularly busy lifestyles, have led to changes in our diets including loss of cooking skills, with the majority of food we now consume being industrially processed in some way. Such food processing and reformulation converts primary animal and plant products into safe foods with longer shelf-lives allowing wider consumer choice all year round. However the pressure on processed food producers is to make a profit. Accordingly, there is a focus on foods which appeal to the customer in terms of taste, appearance and price. Such foods may not be compatible with the current health messages in key policy documents and legislature such as Recipe for Success-Becoming a Good Food Nation, Prevention of Obesity Routemap, Supporting Healthy Choices, the Food (Scotland) Bill and the UK Government Strategy for Agricultural Technologies. Therefore, a central question for public health nutrition is whether industrially processed foods can be reformulated to improve their healthiness. At the same time reformulation has to be acceptable to both manufacturers and consumers. Consequently, **the main driver** of this RD is to reformulate foods improving their healthiness while retaining consumer appeal and food manufacturer acceptability. To do this new opportunities for reformulation need to be established that will reduce the formation of detrimental components during processing, which can limit shelf-life and may be harmful to health, and increase health benefits by using natural products from novel and underexploited resources. Therefore, **the aims** of the RD are (1) to identify barriers to the acceptance of healthier reformulated products by both industry and the consumer (2) improve shelf-life, (3) assess and improve the nutritional and health value of reformulated foods, and (4) add value to waste from primary products by providing industry with additional usages for these waste streams.

The reformulation agenda described in this RD has been presented to and discussed with the Scottish Food and Drink Federation and the Interface Food and Drink Reformulation Common Interest Group.

Summary of the proposal

The pressure on the food industry to be profitable is perceived as incompatible with the production of healthy foods. The potential health consequences of industrially processed foods (e.g. obesity and related conditions) are concerning and often relate to excessive fat and sugar content, and inclusion of synthetic preservatives with no nutritional value. However, industrial food processing is a fact of life, improving food safety, and increasing availability and consumer choice. Innovation in food reformulation is also an important means of feeding an expanding population under the pressures of environmental change and limited resources. This research will examine the potential of changing processing methods to reduce the formation of harmful products and improve the availability of natural plant chemicals, which benefit health, in food. Products will be re-designed to have higher levels of healthy components (e.g. through enrichment in specific natural plant chemicals). An additional benefit of reformulation is that natural products may be retrievable from primary produce waste, including that rejected for direct sale, offering the potential to reduce food waste, which amounts to an annual loss of one third of food produced.

Research in food reformulation is required to maximise healthiness, improve shelf-life and sustainability of commonly processed foods (e.g. meat, dairy products, sauces and breads). However, successful implementation of such strategies requires understanding the reasons why, both food producers and consumers reject the uptake of new, healthier and sustainable food products.

This research will translate into new products of improved quality, healthiness and increased shelf-life. This technical innovation and product reformulation will be supported in this RD by the following research approaches:

- Assessment of likely uptake of innovations and developments across the supply chain and by consumers (O1, O2, O3)
- Improvement of the health profile and shelf-life of processed foods through the inclusion of natural bioactive products from novel or neglected food sources such as food waste streams (O2)
- Improvement of food product quality and safety by establishing the role of advanced glycation end-products (AGEs) in processed foods and the capacity of natural products to counter any negative health effects (O3)

The research will deliver several potential benefits to food manufacturers and consumers. These are to:

- Provide an indication of the impact on sustainability, efficiency and health of targeted improvements in food and drink products (O1, O3)
- Introduce more plant-based products into the food chain (O2, O3)
- Provide a data base of natural products/extracts/fractions which can be used during food processing and that will increase the healthiness of the product, facilitating informed ingredient choice (O2, O3)
- Improve product shelf-life (O2)
- Replace problematic synthetic additives/preservatives with products with improved health impact (O2)
- Identify bioactive components in waste streams improving sustainability and reducing food waste (O2)

O1 – Analysing the supply of and demand for healthy sustainable food products. This socioeconomic work has two aims: the first is to identify ways to improve the sustainability and health aspects of processed products and menus offered by food producers, manufacturers, caterers and retailers. The work will concentrate on supply chains of selected processed products, although it is envisaged that some of the key processed products will be those made of dairy, potatoes and soft fruit. This will be at two levels: macro (i.e. identifying the impact that competition, through new product development, has on what firms may adopt) and micro (i.e. the current uptake of products with high sustainability and health attributes). The second aim, since any impact on health requires consumer uptake of healthier products, will examine consumer preference for healthy and sustainable Scottish food products currently available in the market, as well as new and reformulated products with healthier and more sustainable characteristics. Both aims should provide an indication of the potential impact on sustainability, efficacy and health benefits of any improvements in food and drink products. The work complements studies on primary produce in RD 3.1.1, O7,

which also links with O2 and O3 in this RD and on decision making on farms studied in RDs 2.3.4 and 2.3.8.

Key deliverables: Analyses of selected food supply chains (O1.1) will produce: **D1.1:** Report on main effects of competition on firms' willingness to launch new reformulated products with healthy and sustainable traits (year 2). **D1.2:** Report on the uptake of healthy and sustainable processed products by the food industry (year 3). Demand analyses (O1.2) will generate: **D1.3:** Report on econometric results of the EASI demand model of healthy and sustainable food products currently available in the Scottish market (year 2). **D1.4:** Results of economic experiments on consumer demand for new produce that is healthier and sustainable, which will produce measures of willingness to pay. In addition, the work will report on the consequences of the introduction of healthier products. (year 5).

O2 – Investigate sources of natural products with bioactivities to produce novel foods or to reformulate processed foods with improved shelf-life and health benefits. Published research from the current SRP has shown that foods can be reformulated with plant materials rich in phytochemicals to improve their nutritional quality and/or shelf-life. This Hutton/RINH co-constructed project builds on this approach extending the search for bioactives to novel and underexploited food sources as well as primary produce destined for waste but identified as economically valid linking to RD 3.1.4. Emphasis will be on new dietary sources, rich in beneficial components, but will also investigate unexploited produce as novel sources of relevant bioactive components, including sources enriched in components with potential anti-inflammatory, anti-glycaemic, anti-obesity or lipid metabolism modulating effects as identified in O6 in RD 3.2.1. The research will benefit from recently available food technology expertise to produce pilot products with altered food structures. This will involve initial testing of reformulated products in simulated digestive systems, in the laboratory, prior to selection of extracts/products to be consumed by volunteers in human intervention studies. Sensory analysis will also be conducted on the reformulated products assessing consumer acceptability and determining practical feasibility for commercialisation. Through this research a data-base of natural products/extracts/fractions will be developed which can be used during food processing and engineering that will increase the healthiness of the product.

Key deliverables: **D2.1** Identification of most promising natural products for further study (year 1). **D2.2** Report on the characteristics, e.g. texture and flavour, of processed foods reformulated with natural products (year 2). **D2.3** Identification of suitable food compositions to deliver healthy bioactives (year 3). **D2.4** Report on outcome of human study utilising reformulated food (year 5).

O3 – Effect of advanced glycation end-products (AGEs) on food quality. Published work from the current SRP, and externally funded projects, has shown the presence of high levels of AGEs both in the circulation of overweight individuals and in processed foods, from which they are absorbed. AGEs result from the Maillard reaction; a chemical browning reaction between protein and sugar/fat. AGEs are a group of compounds, many of which are known to be detrimental to health. Conversely, some Maillard reaction products, formed from plant proteins, e.g bread crusts, are beneficial to health. Additionally, the

composition of milk (proteins, fats and sugars) may influence the formation of AGEs during processing whereas plant proteins are reported to be less susceptible to AGE formation.

Detrimental AGEs are found in high concentrations in dairy products, particularly those containing whey protein, a by-product of cheese making, processed under high-temperatures and frequently added to foods. AGEs are absorbed during digestion and may have unfavourable physical and mental effects. Evidence, shows that the Western diet, high in fat, sugar and AGEs, is associated with rapid impairments in memory. Restricting the intake of detrimental AGEs in the diets of diabetics leads to lower levels of inflammation and oxidative stress. The aims of this work are to: 1) clarify the specific contribution of AGEs to human nutrition in the context of a Western diet 2) investigate how food can be reformulated to avoid detrimental AGE formation during processing and 3) establish whether natural products can ameliorate any negative health effects of AGEs in processed foods linking to O2. This will result in the production of healthier foods and have positive economic and environmental consequences by adding value to low value or waste streams including whey protein from Scottish cheese-makers. As AGEs add to the colour and flavour of processed food, the impact of their reduction, along with fat and sugar, needs to be measured as a potential barrier to consumer acceptance linking to O1 and O2.

Key deliverables: **D3.1** Report on the analysis of AGEs in foods and the susceptibility of different proteins to form AGEs during processing (year 1). **D3.2** Report on the outcomes of human study investigating the short-term exposure to dietary AGEs (year 2). **D3.3** Report on the susceptibility of proteins from seasonal milk samples to form AGEs during processing (year 3). **D3.4** Establish whether reformulation and alternative processing can prevent the formation of AGEs in processed foods (year 4). **D3.5** Verification of the health benefits of foods reformulated with natural products identified in O2 (low AGEs) compared with traditionally processed foods (high AGEs) in a human intervention study (year 5).

Technical approach including detailed work plan

O1 – Analysing the supply and demand of healthy sustainable food products. An analysis of competition among processing firms will investigate the extent to which the increasing awareness of sustainability issues is making firms, in particular food categories, more willing to market products with healthy and sustainable attributes. This statistical analysis will be performed using Mintel's Global New Product Development, Kantar Worldpanel data and, where appropriate, data from the Scottish Government, from the Food Standards Scotland and the Office of National Statistics will also be considered. Mintel and Kantar data will be prepared for appropriate statistical analysis. Completion of Mintel data analysis will give rise to Milestone (M1.1) and Kantar data (M1.2).

To analyse the demand of healthy and sustainable food products currently available in the Scottish market, an econometric demand analysis will be carried out. Kantar Worldpanel dataset for Scotland covering the period 2006 to 2014 will be prepared for the analysis. In addition, Kantar data on trials/focus groups and from Defra's Family Food will be also considered and used as appropriate. Completion of this analysis will be Milestone (M1.3). The statistical demand

analysis will then be performed using the novel demand system EASI (Exact Affine Stone Index) due to its flexibility to represent preferences.

O1.1 Analysis of the interest of processing and retailing companies in launching products with healthy and sustainable attributes (March 2018). **O1.2.** Analysis of the demand of healthy and sustainable food products currently available in the Scottish market (November 2017).

O2 – Investigate sources of natural bioactive products to produce novel foods and reformulate processed foods to improve shelf-life and health benefits. The nutritional potential of a large number of Scottish natural products including agricultural and food waste streams remains unknown. Suitable local (e.g. honey) and underexploited Scottish foods (e.g. wild fruits and herbs) and agricultural and food processing by-products (e.g. oil seed and soft fruit waste, whisky/beer industry wastes, cereal brans and fruit/vegetable off-cuts) that show potential in human nutrition will be identified for further study. Functional ingredients from these sources will be isolated and characterised and the exploitation of the properties of these fractions in foods will be evaluated. Completion of this part of the work will result in Milestone (M2.1). Up to three products may be identified, and factors such as economic value and availability will be taken into consideration when making this selection (link to RD 3.1.4). These identified products will then be subjected to a detailed physico-chemical characterisation that will include measuring their physical, compositional, nutritional, antioxidant and chemical properties. Completion of this analysis will result in Milestone (M2.2). HPLC methods will be used to quantify molecular species indicative of the process of oxidation. Their phytochemical compositions will be established using the combined analytical techniques (GCMS, LCMSⁿ, HPLC etc) available at RINH and Hutton. Nutritional components will include carotenoids, polyphenols, proteins and soluble and insoluble fibres. The effect of processing/cooking method on the biodegradation/functionality of the nutrients in these products will also be investigated.

Product developmental work will be carried out which results in novel and reformulated foods with improved nutritional properties. Completion of product development will result in Milestone (M2.3). This will include the development of novel food matrices (e.g. through the use of complex emulsions) for producing new foods with beneficial nutritional properties, and reformulating existing foods (e.g. bread) for increasing their nutritional value. The potential of developing foods incorporating novel ingredients identified in M2.1 and M2.2 above will also be examined. Additionally work will be carried out to reformulate existing foods as nutritionally improved products that could be used for the amelioration of diet-induced chronic disease. This work will specifically focus on foods such as bread and ice cream. The developed novel foods and reformulations will undergo detailed characterisation for their physico-chemical attributes, sensory qualities and shelf-life. This will include assessing changes in stability (Turbiscan), viscosity and texture. Effects on shelf-life will be assessed by Rancimat. Bioaccessibility of the incorporated components will be evaluated using simulated digestion models, including potential gastric and intestinal formation of detrimental oxidation products including AGEs (link to O3; years 2-4).

The novel and reformulated food products that show most promise will then be tested in human intervention studies to assess their in vivo efficacy. Completion of the human study will provide Milestone (M2.4). The objective of the human studies would be to assess the bioavailability of the nutrients and physiological effects of the reformulated foods. Randomised controlled human intervention trials are considered the gold standard for evidence-based nutrition and public health policy. The human intervention trials will be initiated following power analysis by BioSS and review by the Human Studies Management Committee at RINH and the North of Scotland Research Ethics Committee. These human studies will be carried out under controlled conditions at the Human Nutrition unit of RINH. The reformulated foods will be tested on healthy and/or older overweight individuals (depending on the target group). In later years, consumer acceptance of pilot reformulated products will be evaluated in collaboration with O1.

O2.1 Identify novel sources and determine phytochemical content of material and suitability for reformulation (March 2017). **O2.2** Reformulation of processed foods to improve nutritional and health attributes (March 2018). **O2.3** Initiation of human intervention studies on reformulated products (Ongoing ends March 2019).

O3 – Effect of advanced glycation end-products (AGEs) on food quality.

The levels of a number of well characterised AGEs will be determined in a wide range of selected processed foods, particularly those recently introduced to the market, whose AGE content is currently unreported, limiting ourselves to up to 50 of the most commonly consumed products, particularly those containing high-levels of whey protein. These will be identified from both their ingredients, i.e. those high in protein, sugar and fat, and the processing methodologies used, i.e. prolonged heat treatment being most likely to produce AGEs. Completion of this part of the project will result in milestone (M3.1). Comparisons will be made between plant protein, potentially more resistant to the formation of AGEs, and animal derived protein after the most usual (heat treatment) and alternative (e.g. filtration) food processing techniques. Completion of this analysis will result in milestone (M3.2).

After identifying foods high in AGEs detrimental to health, a human short-term feeding study will be carried out using selected products with suitable controls (low-fat, sugar and AGEs). The study groups will be young, healthy adults and older, overweight, sedentary adults, who may be more susceptible to the effects of dietary AGEs. Exclusion criteria will include diagnosed type 2 diabetes, CVD and history of neurological abnormalities or current psycho-active or anti-inflammatory medication use. This will be a pilot study to assess/confirm the time frame of effects. It will focus particularly on behavioural and metabolic outcomes. The study will have a randomised crossover design and include an acute single meal challenge (high or low in AGEs) after an overnight fast before and after dietary intervention. Participants will be instructed to follow either a high or a low AGE diet for 4 weeks. Tests will be carried out at 0, 2, 4 and 6 hours after the test meal. Power calculations based on prior behavioural and metabolic test outcomes (e.g. glucose tolerance) indicate that sample sizes of 24 participants per experimental group will be required. The trial results will be subject to ongoing power analysis by BioSS. Review by the North of Scotland

Research Ethics Committee will be carried out prior to the trial. Also, habitual AGE intake, determined from dietary questionnaires, specifically designed for this purpose, taken at the start of the study, will be correlated with levels of circulating AGEs and outcomes such as inflammatory markers and glucose tolerance. Transcriptomic biomarkers of susceptibility to metabolic disease and acute response to dietary challenge will be measured. These tests will be developed building on CWP 7.2 work that has shown rapid changes in the transcriptome in response to diet and links to work in RD 3.2.2 (O6). Completion of the human study will provide milestone (M3.3).

The susceptibility of milk of different compositions, determined by season (summer vs. winter), supplied by SRUC, to form AGEs and other damaged proteins during processing will be investigated (O3.4). This work is directly linked to RD 2.3.1 (O3). These studies will continue into year 3.

Additionally in collaboration with O2 the effects of reformulation and alternative processing on the prevention of AGEs in processed foods will be investigated including verifying the health benefits of foods reformulated with natural products identified in O2 (low AGEs) compared with traditionally processed foods (high AGEs) in a human intervention study (years 3-5).

AGE content will be measured using commercially available ELISA kits, and for more uncommon AGEs, HPLC and MS techniques will be used. This data will provide an evidence base that will help inform ingredient choice, reformulation of current food products and the development of new ones. So far the industry interest in AGEs has been mainly from the perspective of food spoilage, flavour and texture, while the proposed approach would help ensure the production of relatively undamaged, healthy, premium quality food.

O3.1 Selection and analysis of processed foods for advanced glycation end products (AGEs) (September 2016). **O3.2** Test different plant and animal proteins for AGE formation under standard processing techniques (March 2017).

O3.3 Carry out human study to determine the consequences of AGE ingestion (March 2018). **O3.4** Analysis of AGE formation of Winter and Summer milk samples from SRUC (Ongoing ends March 2019).

Expertise

The personal expertise of the collaborators is also described in their CVs. RINH contributes experience in dietary intervention studies, cell based assay systems, gastric models, food processing and reformulation, shelf-life, markers of disease risk, dietary analysis, phytochemical analysis, measurement of damaged proteins in the diet and the circulation, *in vitro* assessment of biological effects of dietary damaged proteins, including AGEs.

Hutton adds internationally renowned expertise in phytochemical analysis, polysaccharide chemistry and access to elite plant germplasm and collections. Experience in smart extraction procedures will accelerate the discovery of active components from berries, cereals, novel crops and wastes essential for work in the co-constructed O2.

SRUC bring their expertise in understanding industrial organisation, food supply chain economics and econometrics in concert with experimental and behavioural economics, consumer analysis, consumers and producers' choice

behaviour.

Key linkages, interdisciplinarity & collaboration. The programme is integrated across four MRPs; RINH, Hutton, SRUC, and BioSS.

O1: This socioeconomic analysis complements the work in RD 3.1.1, which focuses on the demand of improved healthier produce with sustainable characteristics. This work also links to 2.3.4 (Sustainable Soil and Water Management) and 2.3.8 (Alternative Approaches to Sustainable Land Management). It also has links with ERANET-SUSDIET (Implementing sustainable diets in Europe).

O2: This research is central to the other objectives in the RD as it will examine the means to improve the health profile of processed foods by the incorporation of identified natural bioactives, linking to RDs 3.1.4 (Preventing Food Waste) and 3.2.1 (Importance of Healthy Diets). In addition there are natural and essential links to various other RDs. For example, identification of soft fruit components with novel health benefits in RD 3.1.1 (Improving Scottish Primary Production) (O6) and information on the heritability of these gene traits (O5) and RD 2.1.2 (Crop Genetic Improvements) could help guide work on reformulation. Materials and extracts will be made available for examination for reformulation from work carried out on food waste in RD 3.1.4 (Reducing Food Waste) (O7). Also fibres and useful carbohydrate sources will be provided from work in 3.2.2 (Dietary Components of Healthy Diets and their Effects) (O3). RD 2.1.8 (Novel Crops) will provide materials and helpful insights e.g. fibres from legumes and a review of Scottish flora diversity with bioactive potential (O2). Transcriptomic biomarkers of health will be in collaboration with RD 3.2.2 (O6) (Dietary Components of Healthy Diets and Their Effects).

O3 This project builds on compositional analysis of convenience foods and damaged proteins in the diet and circulation, conducted in the current SRP and through externally funded (TSB) research on whey proteins. Following on from this, dairy protein studies will link to work with SRUC RD 2.3.1 (Improvement of Livestock) and via this to RD 2.2.1 (Livestock, Genetic Improvement Tools) and RD 2.2.6 (Animal Disease Epidemiology). Linkages also exist between RD 3.1.3 (Food Safety) as improvements in processing will prevent the formation of potentially harmful products. The cognitive research approach in the human intervention study will be in collaboration with Dr Kevin Allan, University of Aberdeen. Transcriptomic biomarkers of health and cognitive ability as part of the human intervention study will be in collaboration with RD 3.2.2 (Dietary Components of Healthy Diets and Their Effects) (O3).

Added Scientific Value. This proposal represents a natural progression of current interests and expertise. The co-construction in O2, in this RD, cements previous relationships developed in the current SRP between RINH and Hutton. Hutton has been prominent in research on bioactives, with some extracted from natural products destined for waste, through both EU-funded collaborations and UK-funded research and studentships. RINH also has EU, UK and NIH funded work which focusses on the potential health benefits of plant bioactives. Moreover, several recent publications investigate how such natural products may be incorporated into the food matrix to improve shelf-life and health impact of processed foods.

The RD is well placed to translate the outcomes of this research to industry and

to products. Overall, the development of improved processed foods with confirmed health benefits (e.g. anti-obesity and diabetes) lends itself to leverage of funding from sources such as the EU and TSB Agritech or through direct interaction with companies. Also avoidance of shelf-life issues, replacement of synthetic food additives or reduction in formation of detrimental components such as AGEs is also eminently transferable. Hutton and RINH can depend on their established networks within the food industries and the experience of their commercial arms (James Hutton Ltd and University of Aberdeen Research and Innovation for RINH) to develop suitable consortia to leverage further funding and to deliver novel products.

Preventing AGE formation during food processing provides an opportunity for industry to develop foods with high health credentials targeted to key consumer groups such as seniors and the performance sports sectors where the impact of AGEs is most recognised. The work on AGEs has already attracted TSB funds on whey protein bioactives. Future funding in collaboration with the food industry will be sought to develop this work and augment the currently-funded BBSRC studentship on diet and cognition.

The analysis of barriers hampering the adoption of healthier and sustainable new processed products (either new or reformulated) will complement the work carried out in the ERANET project “SUSDIET: Implementing sustainable diets in Europe”, which is coordinated by INRA-ALISS (France) and encompasses 15 teams from 9 European countries. SRUC work in the project is funded by Defra.

KE, Audiences and Impact. This RD will feed information to KE activities at RD, WP, Theme levels and through RD, WP, and Theme Coordinators to the Centre for Knowledge Exchange and Impact (CKEI).

Industry is a key target audience for this co-constructed cross-MRP RD. The Agri-Food and food and drink industries, including brewers and distillers and food manufacturers, are major audiences for this research and scientists in the RD will continue to interact with individual SMEs and common interest bodies such as the Scottish Cold Pressed Rapeseed Group and the Interface Reformulation Common Interest Group, etc. Other important stakeholders include (e.g.) Scotland Food and Drink (SFDF), Food Standards Scotland (FSS), academia and the public.

As the RD delivers impact through evidence and methods to support the development of foods that have reduced formation of harmful AGEs, enhanced shelf-life, improved phytochemical composition, and information that leads to better understanding of barriers to uptake of improved products. Companies that have already shown interest through cSRP work, consultation activity and common interest groups will be engaged with throughout the programme. We will examine opportunities to co-construct specific joint industry relevant events e.g. with RD3.1.1 and Interface F&D KTN Fruit Common Interest Groups to highlight the synergy in our work and to bring together primary producers and processors. This may be through existing events or the development of new activities with specific industry groups to encourage further food industry involvement.

Under the auspices of CKEI, working with the relevant KE Sectorial Leads, RD scientists will contribute to centrally planned KE interactions on specific overarching and integrative issues. This may involve interaction with relevant SG Policy teams, e.g. Food, Drink & Rural Communities Division or FSS and also participation in major events, e.g. Royal Highland Show, Edinburgh International Science Festival, Food Matters Live (KE2, 3 and 4), relevant to our target audiences. In addition, we will continue to use online avenues such as the Theme 3 newsletter, videos, Hutton talking heads videos and participation in MOOCs (Massive Open Online Courses) through the University of Aberdeen. We shall continue to engage with the local public through new uses of existing events such as RINH nutrition and health outreach activities to schools, University of Aberdeen events at Mayfest (KE6), open days/evenings but also public talks and events, e.g. Café Scientifique events.

As the RD involves internationally-renowned scientists, the global scientific community will be an important audience. RD scientists will endeavour to publish in high impact journals, and contribute to national and international conferences, ensuring the SRP brand and SG investment is publicised and recognised.

RESEARCH DELIVERABLE NUMBER: 3.1.2

Work planning and timetable for Year 1: Please include major milestones: key research objectives (O), deliverables (D), KE/impact events (E) and their timing.

Year 1: 2016/17 Activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Analysis of the interest of processing and retailing companies in launching products with healthy and sustainable attributes									M1.1			
O1.2 Analysis of the demand of healthy and sustainable food products currently available in the Scottish market.												M1.3
KE activity - seminar						KE1						
O2.1 Identify novel sources and determine phytochemical content of material and suitability for reformulation						M2.1						M2.2 D2.1
KE events: Edinburgh Science Festival	KE2											
KE events: Food Matters Live								KE3				
O3.1 Selection and analysis of processed foods for advanced glycation end-products (AGEs)						M3.1						
O3.2 Test different plant and animal proteins for AGE formation under standard processing techniques												M3.2 D3.1
KE Events: Royal Highland Show			KE4									
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.1.2

Work planning and timetable for Year 2: Please include major milestones: key research objectives (O), deliverables (D), KE/impact events (E) and their timing.

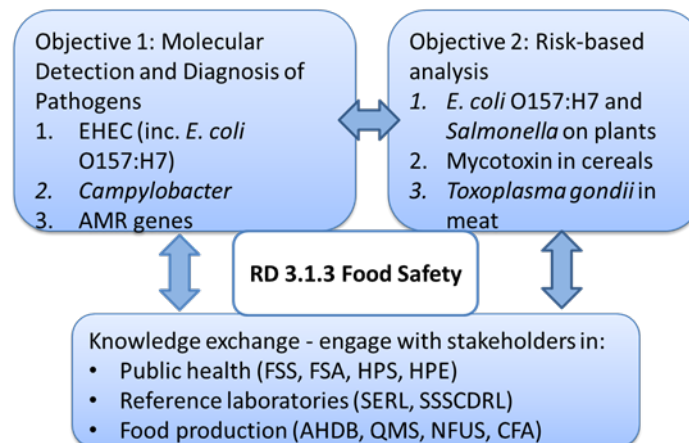
Year 2: 2017/18 Activity	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Analysis of the interest of processing and retailing companies in launching products with healthy and sustainable attributes			M1.2									D1.1
O1.2 Analysis of the demand of healthy and sustainable food products currently available in the Scottish market								D1.3				
KE event: seminar						KE5						
O2.2 Reformulation of processed foods to improve nutritional and health attributes						M2.3						D2.2
O2.3 Initiation of human intervention studies on reformulated products												M2.4
KE event: MayFest		KE6										
KE event: FHIS conference								KE7				
O3.3 Carry out human study to determine the consequences of AGE ingestion							M3.3					D3.2
O3.4 Analysis of AGE formation of Winter and Summer milk samples from SRUC												
KE Events: Open night for human study	KE8											
KE Events: Royal Highland Show			KE9									
Annual Report (Year 2)												R2

Name of RD: Food Safety (3.1.3)

Research aim and key drivers

Food safety and public health are recognised as critically important issues for Scottish food production (Scotland's National Food and Drink Policy, 2009). The Food Standards Agency estimate that in the UK, around 1m people *per annum* suffer foodborne illness, 20,000 of whom receive hospital treatment, and 500 cases result in death, with an economic cost of nearly £1.5bn. The emergence of new foodborne pathogens and the control of existing ones remains an important area for future research. Consultation with key stakeholders, including Food Standards Scotland (FSS) and industry highlighted the major areas of concern, including those with relevance to policy, such as the VTEC action plan and Acting on *Campylobacter* Together (ACT). As such, each of the systems under investigation addresses priority areas or emerging issues for the key stakeholder groups, primarily food and public health agencies and reference laboratories in Scotland and the UK (FSS / FSA, HPS / PHE). The focus of the work is on microbial contaminants of food, either directly or via toxins. The work will define risk factors and improve detection of the most important food-borne pathogens and toxins, and will examine the flow of antimicrobial resistance through the food and into the commensal microbiota, all of which will contribute to improved public health in Scotland through uptake by stakeholders in public health and the food industry.

Summary of the proposal:



The overarching aim of the work is Food Safety for issues that are relevant to Scotland, within the agricultural and rural setting. This will be achieved by carrying out research activities in two main areas: Molecular Detection and Diagnosis; and Risk-based Analysis, to provide technical improvements for detection or eradication of food-borne pathogens. In Scotland, the priority pathogens include VTEC and *Campylobacter*, and there is an emerging public health threat from anti-microbial resistance (AMR). Delivery of the outputs of the research will be disseminated through Knowledge Exchange events to public health and food service stakeholders.

Objective 1 - Molecular Detection and Diagnosis of Pathogens encompasses techniques for the detection of a number of stakeholder-identified priority pathogens. Verocytotoxigenic *Escherichia coli* (principally *E. coli* O157:H7), and *Campylobacter spp.* are well known as food-borne pathogens, and have environmental and animal health components, which means that they can be widespread in an agricultural setting. Food eaten raw, e.g. fruit and vegetables are a risk factor for VTEC, and

foodborne disease associations have knock-on economic impacts on Scottish horticultural production. For these pathogens, some sub-species types can be more prevalent or higher public health risk than others. Major technological advances in detection, e.g. whole genome sequencing, that have occurred in the last five years need to be appropriately assessed prior to exploitation. Rapid and accurate typing methods to distinguish pathogenic strains that are more prevalent or higher risk are critical for appropriate mitigation to be applied during outbreaks, but also relate to their epidemiology. This Objective aims to identify detection targets and techniques that are most appropriate to specific pathogens or genes (for AMR) and are able to discriminate higher risk isolates using cost and time efficient techniques. The work will include one of the most common food-borne pathogens in Scotland, *Campylobacter*, and a pathogen that often results in hospitalisation and mortality, VTEC.

- *Campylobacter* remain the commonest foodborne bacterial pathogen and its clinical incidence continues to increase. Furthermore, antimicrobial resistance is an emerging concern for this organism. Clinical incidence of *E. coli* O157:H7 is particularly high in Scotland compared to the rest of the UK. Work in the RESAS-funded Strategic Research Programme (SRP) 2011-2016 (WP3.1.3) and in Strategic Partnership for Animal Science Excellence (SPASE)) has developed new methods for rapidly and accurately identifying and typing VTEC; notably *E. coli* O157:H7 and has been piloted with *Campylobacter*. Current best practice methods for bacterial identification and typing involve a combination of phenotypic and genotypic tests, which takes 7 – 10 days; unacceptably long in the event of an outbreak. Whole genome sequencing (WGS) approaches offer unparalleled typing capability but computational and analytical requirements extend the time from sample receipt to strain characterisation. We have piloted a mass spectrometry (MS) method which can shorten the period from isolation to determination of lineage to several hours. WGS-based approaches will be compared against the novel, rapid and accurate MS method (MALDI) to determine applicability as an in-laboratory diagnostic tool, building on existing data for VTEC, and extending to *Campylobacter*.
- Food-borne bacteria are also associated with the carriage and spread of AMR genes, and there is increasing awareness of the impact of AMR on health, and of the role of environmental sources on AMR contamination and dissemination. The acquisition of large datasets and resources (from RD2.2.2, RD2.2.6 and HEI collaborations) provides an excellent unique opportunity to assess carriage of AMR genes, e.g. from existing *Campylobacter* genome datasets, the prevalence of the genes on a Scotland-wide scale using ruminant samples and the RESAS-funded National Soils Inventory of Scotland (NSIS 2), and finally to determine the potential flow of genes from the environment, through food, to human gut bacteria. This sub-objective brings together cross-MRP expertise to exploit their underpinning capacity (e.g. VM0526). The aim is to firstly assess and ultimately stop the flow of AMR genes through the food chain.

Key deliverables (years 1-2) Optimization of PCR-based screening method to detect target AMR genes (**D1.2a**); Feasibility of using MALDI for rapidly sub-typing VTEC (**D1.1a**); Report on incidence of AMR in food relative to AMR use in production (**D1.2b**); Assess the most important candidate control points for the spread of AMR (**D1.2c**). Additional deliverables (years 3-5) include roll-out of MALDI typing to other pathogens; determine the safety of food in terms of AMR by assessing the impact AMR carriage by foods/food-borne pathogens has on AMR within the commensal gut

microbiota, and the consequences for human health.

Objective 2 – Risk-based approaches. The aim of this Objective is to obtain, analyse and interpret robust enough data to inform stakeholders in public health and in agriculture of bacterial, toxin and parasite transmission into the food chain, so that appropriate measures and strategies can be implemented to mitigate the risk of food-borne illness and disease.

- Some crop species are now classed as high risk by retailers because of perceived and real elevated potential for microbial contamination, e.g. sprouted seeds; spring onions. The largest foodborne outbreak of VTEC in the UK was linked to soil-contaminated leeks and potatoes. Ongoing SRP work (cWP6.2.5) has shown differences in the colonisation potential of *E. coli* O157:H7 for different plant species, conferred by bacterial colonisation factors and plant factors. A systematic analysis of plant components that affect plant colonisation by the bacteria is now needed to address these factors. Outcomes, together with data obtained from RD2.3.3, will be used to rank plant species commonly grown in Scotland (and the UK), or imported for retail in Scotland, for their potential for contamination by food-borne pathogens, VTEC and *Salmonella enterica*.
- Fungal infestation and subsequent mycotoxin contamination pose a substantial problem to agricultural production systems. Climate change scenarios indicate a pole-ward migration of agricultural pests including mycotoxin-producing moulds into areas previously classed as low-risk, such as Scotland. *Fusarium* are the most common mycotoxigenic fungi in temperate climates of Europe. Plant breeding efforts to increase fungal resistance have sometimes been linked to increased production of 'masked mycotoxins' in agricultural crops. Recent RESAS funded work (cWP5.2 RD3SD7) shows that once ingested, masked mycotoxins enter the colon but can be released as free mycotoxins following degradation by the human gut microbiota. The maximum permitted levels of *Fusarium* mycotoxin in foods set by the EU Food Safety Authority do not currently include masked mycotoxins, although they are viewed as an emerging risk by the FSA. This project therefore aims to provide evidence on the presence and toxicological relevance of *Fusarium* mycotoxins and masked mycotoxins in primary production and commonly consumed cereal foods. The link between contamination levels in food and urinary exposure biomarkers will be studied from human intervention studies using cereal foods.
- *Toxoplasma gondii* is the most successful parasite worldwide, capable of infecting all warm blooded animals including humans. Infection occurs from the ingestion of oocysts, shed from infected cats or cysts in raw or undercooked meat (pork, lamb, beef and poultry). A primary infection during pregnancy in women may result in foetal death or other congenital anomalies. Ocular toxoplasmosis may lead to blindness in 25% of cases and most ocular cases are now attributed to acquired infection, therefore *T. gondii* poses a risk to all people, not just the developing foetus. Sensitive and discriminatory tools are now required in order to detect the parasite in food animals and prevent transmission into the food chain. The work will build on knowledge of aspects of the *T. gondii* life cycle in farm animals.

Key deliverables (years 1-2): Validate detection method and monitor mycotoxins and masked mycotoxins in Scottish cereals from year 1 (**D2.2a**) and year 2 (**D2.2c**); Estimate human exposure to mycotoxins through cereal foods and urinary biomarker analysis (**D2.2b**); Risk assessment and optimal sampling regime for accurate

diagnosis of *T. gondii* in food animals (**D2.3a**). Deliverables in years 3-5 will establish the risks of microbial contamination entering the food chain through fresh plant produce and commercial meats and establish the fate of masked mycotoxins in the gut.

Technical approach

Objective 1 Molecular Detection and Diagnosis of Pathogens

O1.1 Rapid identification and typing system for high public health risk organisms including major foodborne pathogens.

Method validation will be first completed for VTEC, by comparing strain differentiation (typing) obtained through currently accepted “gold standard” of WGS with MALDI, and rolled out to other high priority pathogens *Campylobacter* as well as initiate assessment for application to AMR bacterial strains.

Detailed Work-plan Year 1: 1. Comparison of VTEC strains (up to 200) representing the known genotypic and phenotypic divergence of *E. coli* O157 by MALDI (with BioSS); 2. The current panel of 100 VTEC isolates will be supplemented with additional, fully sequenced isolates; phylogenetic structures obtained by MALDI and by WGS will be compared to assess matches with currently recognised lineages (related to both routine diagnostics and to public health risk) (M1.1a). Predictive modelling will assess assignment of “unknowns” to defined clades.

Year 2: Adopt MALDI approach for *Campylobacter*: the pilot data set for *Campylobacter* will be extended for phenotype-genotype comparisons (M1.1b). Report on the feasibility and practicality of rolling out a typing system to support public health decision making (D1.1a). The end of year 2 is a critical decision point defining which of these topics could be rolled out as a routine decision support tool. It is anticipated that work in years 3-5 will involve further study of AMR bacterial strains and will define strain-specifying biomarkers using combined Omics approaches.

O1.2a AMR in foodstuffs and foodborne pathogens

The presence of AMR genes on foodstuffs eaten raw or minimally processed, and relevant to Scottish production and retail will be assessed, comparing those from different production methods (collated in O2.1). *Campylobacter* isolates from different sources (farms; retail) will be screened by growth studies and genome screening for the presence of specific resistance genes, to assess whether tracking specific genes could be used to monitor flow through the environment. Historic and ruminant samples (RD2.2.6, determined by work in RD2.2.2) will be included to assess the prevalence, persistence and spread of wild type and novel genes. These data will be built into the gene flow model to investigate the effects of specific changes in farming practice, including the impact of different composting pre-treatments on the carriage of AMR from manure.

Detailed Work-plan Years 1-2: 1. Determine optimal PCR-based screening method to detect target AMR genes (D1.2a); 2. Screen different foodstuffs and ruminant samples for the presence of AMR (from O2.1 and RD2.2.6 O4) (M1.2a); report on the incidence of AMR in foods relative to AMR use in food production (D1.2b).

Beyond years 1-2, the work will be continued by: Analysis of existing whole genome sequences of *Campylobacter* (**HEI project bid #3**, also FSS-funded work) and VTEC (RD2.2.2, RD2.2.6) for the presence of known and novel AMR genes; Apply information obtained from the screening of the NSIS-v2 soils (RD2.2.6), ruminant samples, and on-farm soil/manure sampling and analysis (RD2.2.6) to the gene flow model to estimate flow of AMR through the environment.

O1.2b AMR gene transfer

AMR work involves a 2-phase approach: In phase 1 a systems model of a simplified farm to fork system will be developed using existing and new data, and expert opinion to explore and identify the main points of intervention for the control of AMR transfer. Due to data limitations on AMR, a Bayesian Network (BN) approach will be used to integrate both 'hard' and 'soft' data, and expert opinion, whilst explicitly handling uncertainty. In phase 2 experimental procedures will investigate potential points of intervention identified using the BN in more detail to determine whether one can 'break the flow' of AMR gene transfer (within RD2.2.6). Data collected from RD2.2.2 and 2.2.6 on the carriage of AMR genes (and bacteria) from soil, manures and water courses in pristine environments and around farms; samples from foodstuffs; ruminants; and from foodborne pathogens (this RD) will be used to inform the model and assess the relative impacts of the possible environmental sources on AMR contamination and dissemination.

In parallel, the role of different selective pressures and bacterial gene transfer on the spread and evolution of AMR, both in the gut and in the environment, will be tested in model systems. Specific bacterial mating strategies will determine whether the formation of novel, highly resistant, mosaic AMR genes can be forced under experimental conditions. Any genes conferring a higher level of resistance will be sequenced and compared to those identified in the bacterial genome pool.

Detailed Work-plan Year 1-2: Develop conceptual model(s) of AMR transfer within a specific farm system and associated food chain using farm-scale data (RD2.2.6). The model(s) will be based on the three contrasting livestock systems, (i) intensive conventional lowland beef/sheep production, (ii) organic animal production, (iii) systems where animals are primarily housed indoors (e.g. intensive dairy, poultry or pig units) (M1.3b). Define the relationships within the conceptual model using conditional probability, built using 'hard' data (RDs 2.2.2, 2.2.6) and other sources, i.e. published, questionnaire data, numerical models output, and expert opinion. Run model and validate outcomes using expected results for given scenarios (M1.3c). Analyse network to determine the most important drivers in the system. Assess the most important drivers as candidate critical control points for the AMR spread here and in RD2.2.6 (D1.3c). Beyond years 1-2, the work will investigate gene transfer between incoming food-borne bacteria and bacteria resident in human gut in fermentor models, +/- the application of antibiotic and heavy metal selective pressures; conjugative matings between cultures of *Campylobacter* harbouring distinct tetracycline resistance genes, selecting for increased bacterial resistance; sequence novel genes from transconjugants and compare the sequences with the known genome pool. Collated data of gene transfer under different conditions in the lab with the incidence of AMR in farms and foodstuffs, subjected to variable AMR exposure, will contribute towards optimisation of the balance between AMR use for livestock health and onward flow through the food chain via zoonotic pathogens into the human gut microbiota.

Objective 2 Risk-based analysis

O2.1 Appraisal of *E. coli* O157:H7 and *Salmonella* interactions with plant produce to assign risk.

Biochemistry approaches will be used (GC-MS; HPLC; glycan screening) to detect components in ready-to-eat salad vegetables that promote colonisation and growth of food-borne pathogens, such as monosaccharides used for bacterial metabolism, or polysaccharides & glycoproteins that are targets for bacterial colonisation factors.

Detailed Work-plan Years 1-2: 1. Metabolite analysis of will be undertaken on plants eaten raw or minimally processed, and relevant to Scottish production & retail (M2.1a); 2. Components that promote growth and colonisation of VTEC and *S. enterica* will be identified in microbiology assays (Year 2+, M2.1b).

Beyond years 1-2, the work will be continued to form a ranked list of plant species based on 'diagnostic compounds' that promote bacterial colonisation. This will allow increased quantitative risk analysis for microbial contamination of fresh produce.

O2.2 Mycotoxins and masked mycotoxins. An established state-of-the-art LC-MS/MS method (cWP5.2 SD7) to monitor the major *Fusarium* mycotoxins will be further developed to incorporate masked mycotoxins. Method performance will be in accordance EC Regulation No 401/2006 (sampling and analysis for mycotoxins in foodstuffs). Mycotoxins and masked mycotoxins will be monitored in Scottish cereals (wheat, oats and barley), collected by SRUC in collaboration with SASA and Independent Crop Consultants (RD2.1.4) over the 5 year programme. For the first time, mycotoxin occurrence and fungal species prevalence will be linked to Scottish growth conditions (temperature, precipitation). Secondly, carry-over of mycotoxins and masked mycotoxins into food products will be assessed in wheat, oat and barley foods. Cereal foods including breads, breakfast cereals and pasta have been collected from a cereal-based human dietary intervention study carried out at RINH (under the RESAS food and drink partnership) and co-contamination with numerous *Fusarium* mycotoxins will be assessed. Corresponding urine samples have been collected from volunteers participating in this study to allow mycotoxin exposure assessment using urinary biomarkers.

Detailed Work-plan Year 1: 1. Validate detection method for mycotoxins and masked mycotoxins in cereals and monitor their occurrence in Scottish cereals from year 1 growth season (D2.2a). **Year 2:** 1. Estimate human mycotoxin exposure through analysis of cereal foods and urinary exposure biomarkers (D2.2b). 2. Monitor mycotoxins and masked mycotoxins in Scottish cereals from year 2 growth season (D2.2c). Beyond years 1-2 the monitoring of mycotoxins and masked mycotoxins Scottish cereals will continue to year 5 to assess fluctuation over several growth seasons.

O2.3 The risk of *Toxoplasma gondii* in meat. A recent report by the European Food Safety Authority recommended that data collection on surveillance and monitoring of *T. gondii* in animals and foodstuffs for human consumption must improve in order to better evaluate the disease burden of toxoplasmosis in member states. In addition, molecular genotyping techniques should be further developed to allow fingerprinting suitable to trace circulation of strains and source attribution in outbreaks. This work aims to develop detection techniques so that data on the prevalence of viable *T. gondii* tissue cysts or genotype information in meat destined for human consumption can be obtained, not currently available in Scotland.

Detailed Workplan Years 1-2: Sensitive detection and molecular typing tools will be evaluated to determine presence of *T. gondii* in food animals (M2.3a); Optimisation of detection and typing will then allow predilection sites for *T. gondii* cysts in food animals (cattle) to be determined from different tissue samples, thus enabling risk assessment and optimal sampling regime for accurate diagnosis (D2.3a).

Following the optimisation of the molecular detection methods for *T. gondii* and investigations of the anatomical distribution of the parasite in food animals in the first 2 years, these methods and knowledge will be applied to investigate the risk of *T. gondii* entering the human food chain in commercially available meat samples.

Expertise

Please refer to CVs for individual personnel. All work will conform with regulations for use of GMOs (the Genetically Modified Organisms (Risk Assessment) (Records and Exemptions) Regulations 1996 and the GMO (Deliberate Release and Amendment) Regulations 1997); any plant pathogens/imported soils/plant materials is governed by the Plant Health (Scotland) Order 2005, regulated by SASA.

Key linkages, interdisciplinarity & collaboration

Key examples include:

1. The antimicrobial resistance (AMR) work is a cross-Theme initiative within the SRP, explicitly linking Themes 2 and 3. Work from RD2.2.6 and RD2.2.2 for National-scale screening of the NSIS 2 soils archive will inform the work, described above. It also links to EPIC (CoE on Epidemiology, Population health and Infectious disease Control)) as part of the translation of environmental aspects of animal disease for land managers and has relevance to the CoE ClimateXChange.
2. Mycotoxin contamination in Scottish cereals will be monitored during years 1-5 in samples provided by SRUC and linked to fungal species identity and quantity (SRUC RD2.1.4 O2, while analysis of mycotoxins in human samples will make use of samples obtained in RD 3.2.2 for cereal intake.
3. Data obtained from RD2.3.3 (Disease threats in the environment) on *E. coli* O157 genes involved in plant colonisation (SD2.6) complements Obj. 2.1 and together, the data will contribute to delivery of risk analysis of microbial contamination of produce.
4. CAMERAS partners and related: Established relationships exist with FSS and the FSA, as current grantees (e.g. for VTEC; mycotoxin) and/or from expertise provision, and with QMS and SEPA as grantees. Food surveillance data in Scotland (from FSS) will be used to assess the relevance of pathogens/toxins under investigation during the course of the work. Close partnership with HEIs provides access to bacterial isolates: the Roslin Institute for veterinary and clinical pathogenic VTEC (Obj. 2.1); Aberdeen university for *Campylobacter* genome sequences (Obj. 1.3), enhanced by a proposed **HEI-partnership bid #3 with Aberdeen and Edinburgh universities, 'A systems-wide approach to the control of *Campylobacter* in the food chain: exploiting genetic variation'**. BioSS will be actively involved in the genomic analysis with software development and training and in provision of statistical advice.

Added Scientific Value

The work is complementary to a current FSA funded project on **Mycotoxins** 'Evaluation of masked mycotoxins in foods and their release and uptake in the gut'.

Work on ***E. coli* O157:H7** complements that done by collaborators (Roslin Institute; U. Galway; IFR) and an ongoing FSA-funded project to N. Holden on the relevance of internalised VTEC in produce plants.

AMR: This work primarily complements that done by collaborators at the University of Aberdeen and it is the intention to submit an aligned proposal(s) on this aspect to BBSRC in order to inform a more detailed analysis of co-selection of AMR genes with genes coding for other traits that provide adaptations to other environmental stresses such as heavy metals or detergents.

Development of surveillance capacity in Scotland: methodological aspects of this work are aligned to a RESAS Innovation proposal in collaboration with FSS and the Association of Public Analysts looking to develop more streamlined and cost effective testing and monitoring of meat and meat products; specifically with the aim of detecting deliberate substitution.

KE, Audiences and Impact:

Audience: Knowledge Exchange is critical to ensure that the best solutions are put

in place to mitigate the risk of food-borne illness. The aim is to ensure that the research data are best used to benefit public health and agriculture in Scotland. Common and specific KE events will be organised on an annual basis. This RD is an excellent example of the work informing and being informed by key stakeholder groups, e.g. FSS. Consultation will be maintained with stakeholders with a vested interest in public health, agriculture and production, and who list the pathogens and toxins as priority areas. One aspect that was raised in consultation with stakeholders was that successful take-up of recommendations from the science by end-users (e.g. farmers) requires active engagement, often facilitated by non-governmental agencies. Therefore, KE audiences involved in farming crops and animals, as well as policy-makers, commercial food producers and retail, will be targeted for engagement via the new CKEI and the appropriate KE Sectorial Leads. Stakeholders include:

- Public health - FSS and FSA (UK-wide), HPS and HPE, SEPA
- Reference and testing laboratories - SERL, SSSCDRL
- Levy boards - AHDB and QMS
- Producers – NFUS, CFA, QMS, Moredun Foundation.

This will be accomplished through various KE events including scheduled conferences, workshops and technical seminars. We will work closely with FSS / FSA, as the key stakeholders, benefitting from their established relationship with primary and secondary producers e.g. for events such as the AHDB Beef & Lamb meat chain information flow workshop (02/06/2015). The aim is to participate in a relevant group or topic workshop event at least annually.

- The MRPs have an excellent record of end-user engagement events: MRI frequently take part in events such as the Beef Expo and National Sheep event; Hutton organize grower and producer events (e.g. Potatoes in Practice) and participate in technical seminars for the AHDB; RINH organise and take part in multiple public engagement events, e.g. Open Evenings, the Produce Market, Café Scientific. Previously cross-MRP-led workshops and events have been successful in bringing stakeholders together with scientists and policy makers (e.g. CoZEE workshop Nov 2014, Dundee, was driven by FSA & HPS to discuss genome sequencing in surveillance, tracking and diagnostics for zoonoses). Each of these activities and forums can be used as a platform for engagement with primary and secondary producers, and the public for Food Safety.
- Outcomes will be made accessible to RESAS and SG through CAMERAS and the new KE and Impact facility. The outcomes will also be publicised to the wider public e.g through annual Science festivals, RHS (June), BSF (Sept), Dundee Food and Flower festival (August). The outcomes will be disseminated to the scientific community through scientific papers and targeted conferences and workshops (e.g. VTEC 2018, International Association of Food Protection).

Impact: The inter-disciplinary capabilities provided by contributing MRPs offer the means towards mitigating public health risk, originating in agricultural systems and environments. Our integrative approach will provide a robust evidence base to support RESAS input into decision-making for policy development to mitigate public health risks. We will accomplish this principally through engagement with stakeholders, who are able to influence policy and implement the recommendations at the grassroots level. Ultimately, effectiveness of the RD outcomes will be measured by their implementation at the stakeholder and policy level, or within the commercial sector for producers.

- The aim is to reduce food-borne illness by providing appropriate resources, e.g. rapid sub-species typing of *E. coli* O157:H7; diagnostic tools to better understand *Campylobacter* host association and transmission, which can be used by a wide variety of end-users, e.g. reference laboratories, public health boards, commercial organisations. Data that feeds into risk analysis will be provided for *E. coli* O157:H7 and Mycotoxin, most likely in the form of advisory documents e.g. AHDB datasheets for producers, or FSA advice to the general public and health authorities.
- AMR is recognised as an international priority area and the work will align with the UK Five Year Antimicrobial Resistance strategy, impacting multiple partners in public health and food production, e.g. in meat primary production.
- *Toxoplasma gondii* as emerged as one of the most important food-borne pathogens globally from new studies looking at disability adjusted life years (DALYS). Our surveillance of the parasite in food producing animals will contribute to the need for prevalence studies in food animals to help determine the risk of transmission of *T. gondii*, highlighted by FSA and EFSA.

RESEARCH DELIVERABLE NUMBER: 3.1.3

Work planning and timetable for Year 1: Key milestones (M), deliverables (D) and KE/impact events (KE) are listed.

Year 1: 2016/17 Activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 MALDI comparisons for VTEC isolates												M1.1a
O1.2a Design PCR-based screening method for AMR genes; report							D1.2a					
O1.2b Develop conceptual models										M1.2b		
O2.1 Metabolite analysis of RTE plants												M2.1a
O2.2 Validate method and monitor mycotoxins and masked mycotoxins from year 1												D2.2a
O2.3 Evaluate <i>T gondii</i> tools									M2.3a			
KE events: e.g. RHS (Aug 2016)					KE1							
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.1.3

Work planning and timetable for Year 2: Key milestones (M), deliverables (D) and KE/impact events (KE) are listed.

Year 2: 2017/18 Activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 MALDI assessment for <i>Campylobacter</i>										M1.1b		
O1.1 Report on feasibility of rolling-out of MALDI												D1.1a
O1.2a Assess prevalence of AMR genes in food, ruminant & pig and report on incidence						M1.2a	D1.2b					
O1.2b AMR scenario analysis; Define drivers for AMR control points										M1.2c		D1.2c
O2.1 Bacterial assays under different metabolite regimes												M2.1b
O2.2 Estimate human exposure to mycotoxins, and report on												D2.2b
O2.2 Monitor mycotoxins and masked mycotoxins from year 2												D2.2c
O2.3 <i>T gondii</i> sites in food animals		D2.3a										
KE event: e.g CoZEE workshop								KE2				
Annual Report (Year 2)												R2

Name of RD: 3.1.4 - Preventing food waste

Research aim & key drivers

Wider question. Roughly one-third of the edible parts of food produced for human consumption gets lost or wasted globally. More specifically up to 50% of edible food is wasted in the European Union (EU) households, supermarkets, restaurants & along the food supply chain every year, despite 79 million EU citizens living beneath the poverty line & 16 million depending on food aid from charitable institutions. Currently 89 million tonnes of food (i.e. 179 kg per capita) per annum is wasted in the EU & this is projected to increase by 40% by 2020 if no action is taken. Food waste collection & disposal costs for Scottish councils amount to £85 million per year. 570,000 tonnes of food & drink per year is wasted by Scottish households whilst at the farm level the primary losses vary according to crop & for potato are estimated to average ~20% with analogous losses for other crops, but much less so for livestock. In the current environment of increasing global population & climate change pressures on agricultural production, food security demands action on several fronts & identifying efficient means of reducing crop-to-food waste across the supply chain is essential.

Key drivers. There is an acknowledged need to assess food waste & identify ways of reducing it at different levels – primary & secondary production, processing, retailing, consumption & society - which form the key drivers for this research.

Addressing the problem. The aim of the proposal is to undertake an assessment of food waste along main Scottish food supply chains (e.g. dairy, potatoes & fruits) & consumption in Scotland, & to provide coherent & robust strategies to reduce waste across the chain. Also, where waste cannot be reduced identify valorisation routes for coproduct/income generation. The analysis will identify good practice supply chains (where high resource efficiency exists up to the factory gate).

Industry. The research will identify opportunities for innovation & collaboration acceptable to the private sector including the farming sector. The proposed research will identify determinants of firms' absorptive capacity for transfer of innovative knowledge over short, mid & long term timescales from other firms, & how firms collaborate in the creation & transfer of innovation *re* food waste reduction techniques. Opportunities to recognise value in waste via coproduct generation will be explored.

Consumers. At demand level, the research will identify opportunities for waste reduction acceptable to consumers. The research will include an analysis of consumers/public perceptions & behaviours as regards ranking/uptake of waste reduction methods, which will include waste reduction innovations identified in the supply analysis (i.e. producers, processors, retailers, food caterers & services, & waste management sector).

Society. The research will identify opportunities for waste reduction & valorisation that provide net benefits to society. The research will assess the environmental & social sustainability of waste reduction beyond food supply chains. The work will simulate waste reduction & reuse strategies at different stages of the food supply chains & estimate their impacts on environment (e.g. GHG emissions) & social sustainability (e.g. employment opportunities due to innovation creation in waste reduction; welfare gains due to lower food waste at household level).

Stakeholders consulted in developing this proposal & selecting case studies. The current proposal is based on evidence of work having been done in Scotland & elsewhere. Discussions have been undertaken with all actors in the sector. These include Waste & Resources Action Programme (WRAP), Zero Waste Scotland

(ZWS), National Farmers Union Scotland (NFUS), RESAS, Scotland Food & Drink (SFD) Ltd, Agriculture & Horticultural Development Board (AHDB) & more specific crop associations & bodies, e.g. British Oat & Barley Milling Association.

Stakeholders will be consulted throughout project life in a co-construction process, & thus the proposal shows from the start a structure flexible enough to accommodate easily to change, e.g. the forthcoming legislative changes around food waste for businesses mentioned in the ongoing Circular Economy consultation document. As regards the latter, aspects of research such as timing & focus of in-depth interviews may change in light of the consultation outcomes.

Summary of the proposal

Objectives. The proposal answers fully the ITGF requirements for RD 3.1.4. The aim of the proposal is to undertake an assessment of food waste along main Scottish food supply chains (e.g. dairy, potatoes & fruits) & consumption in Scotland. The research will estimate the waste performance of firms along food supply chains & allow comparison of firms based on their waste performance & identify best performers & waste hotspots. The work will identify technically feasible & cost-effective waste mitigation measures together with potential opportunities & barriers to their uptake. Allied to this, case studies will be undertaken at the primary production end to demonstrate how “better” or more adapted raw materials going into the supply chain can maximise waste reduction across the chain. Also where losses are consistent & not amenable to reduction (e.g. selected crop production) case studies for waste valorisation will be established to identify coproduct development & alternative revenue streams for the stakeholders.

Major activities/specific objectives are:

- Estimate the waste performance of firms along food supply chains & identify the most waste efficient ones & the poorest performers (waste hotspots).
- Estimate the efficiency of waste reduction of firms along food supply chains based on their capacity to adopt cost effective waste mitigation measures.
- Analyse the transfer of innovation from academia to industry & between firms along food supply chains towards increased resource use efficiency & waste reduction.
- Analyse public/consumer uptake of waste reduction methods.
- Estimate the environmental & social impacts of food waste reduction beyond food supply chains.
- Develop case studies at the primary production level where innovation in primary production can maximise waste reduction across the supply chain.
- In sectors where waste is known, but strategies to reduce it are less tractable, develop case studies for waste valorisation.

Research already undertaken in this area. At the socio-economic level the proposal will use & develop established methodologies & create new data, whilst the case studies for waste reduction &/or valorisation will need experimental work to validate the approach in co-construction with industry. There is a recognised lack of knowledge on the topic & therefore this interdisciplinary research will advance the state-of-the-art & align, but not duplicate, the efforts of WRAP, ZWS, etc. Indeed the effort on waste valorisation & supply chain value enhancement resonates with the EU strategic vision as outlined in Strategic Innovation & Research Agenda Bio-based & Renewable Industries for Development & Growth in Europe. Here progress beyond the state-of-the-art consists of:

- Development of established methodologies (collaborative innovation games,

partial equilibrium [PE] models) & more recently established methods (network data envelopment analysis [DEA], structural choice modelling, learning games).

- Application of developed methodologies to a novel context (efficiency of waste reduction along food supply chains).
- Creation of new databases.
- Creation of functional case studies to deal with waste reduction at source & the valorisation of intractable waste streams for added value & benefit.

Track record of researchers. The combined expertise available in the team ensures a full coverage of the work required by the ITGF for this RD. The research builds on existing work of the proposed team. The team has expertise in both the proposed topic (waste efficiency & reuse) & proposed methodologies (efficiency modelling, life cycle analysis, behavioural economics techniques – game theory & structural choice modelling, equilibrium simulation modelling, crop manipulation, waste compositional analysis & food & drink process technology manipulation). SRUC currently has a RESAS Underpinning Capacity-funded PhD studentship analysing the impact of information on food waste in the dairy supply chain in Scotland, whose findings will feed into proposed research. The composition of the team, socio-economists & natural scientists ensures the interdisciplinarity required by the ITGF for this RD. SRUC & Hutton have collaborated successfully in many projects including the current Strategic Research Programme (cSRP).

Key deliverables

O1. Management & communication & dissemination activities (Apr 2016-Mar 2021)

O1.1. Project meetings, stakeholders workshops & reports (Apr 2016-Mar 2018)

D1.1 Kick-off meeting & preparation of detailed Communication & Dissemination Plan (Apr 2016); D1.2a,b,c,d Biannual project meetings (Sep 2016, Feb 2017, Sep 2017 & Feb 2018); D1.3a,b End-of-year reports & policy summaries (Feb 2017 & Feb 2018); KE1a,b Annual stakeholders' workshops including engagement with NFUS & SFD Ltd on the progress to reduce primary production waste & develop valorisation strategies for consistent waste streams (Mar 2017 & Mar 2018)

O1.2. KE & project outputs

D1.4a,b Policy briefings (Feb 2017 & Feb 2018); D1.5a,b Peer-review article submissions (May 2017 & Mar 2018); KE2a,b,c Presentations at public (Royal Highland Show, Science Festival) & academic conferences (Mar 2017, Jun 2017 & Aug 2017)

O2. Efficiency of waste reduction - supply chain analysis (Apr 2016-Sep 2018)

O2.1. Secondary data collection (Apr 2016-Mar 2017)

M2.1 Complete secondary data collection (Nov 2016)

D2.1 Literature review report (Mar 2017)

O2.2. In-depth interviews with producers, processors, retailers (Oct 2016-Sep 2017) (repeated in year 5 - longitudinal study)

M2.2 Complete primary data collection (Jun 2017)

D2.2 Database & report (Sep 2017)

O2.3. Structured survey of producers, processors, retailers (Apr 2017-Sep 2017) (repeated in year 5 - longitudinal study)

M2.3 Complete survey data collection (Jun 2017)

D2.3 Database & report (Sep 2017 & year 5)

O2.4. Life cycle analysis (LCA) (Apr 2017-Sep 2018)

D2.4a Complete development of LCA model (Jun 2018)

D2.4b Peer review paper submission (Sep 2018)

O2.5. Network DEA (Apr 2017-Sep 2018)

D2.5a Complete development of DEA model (Jun 2018)

D2.5b Peer review paper submission (Sep 2018)

O3. Cost-effective waste mitigation measures (Apr 2016-Sep 2018)

O3.1. Secondary data collection (Apr 2016-Mar 2017)

M3.1 Complete secondary data collection (Nov 2016)

D3.1 Literature review report (Mar 2017)

O3.2. In-depth interviews with producers, processors, retailers (Oct 2016-Sep 2017) (repeat in yr 5 - longitudinal study). Combined data collection effort with O1.2.

M3.2 Complete primary data collection (Jun 2017)

D3.2 Database & report (Sep 2017)

O3.3. Structured survey of producers, processors, retailers (Apr 2017-Sep 2017) (repeated in yr 5 - longitudinal study). Combined data collection with SO1.3.

M3.3 Complete survey data collection (Jun 2017)

D3.3 Database & report (Sep 2017 & year 5)

O3.4. Marginal Abatement Cost Curve (MACC) analysis (Apr 2017-Sep 2018)

D3.4a Complete development of MACC model (Jun 2018)

D3.4b Peer review paper submission (Sep 2018)

O3.5. Network DEA (Apr 2017-Sep 2018)

D3.5a Complete development of DEA model (Jun 2018)

D3.5b Peer review paper submission (Sep 2018)

O4. Innovation & collaboration - behavioural analysis (Apr 2017-Dec 2018)

O4.1. Literature review (Apr 2017-Oct 2017)

M4.1 Complete literature review (Jul 2017)

D4.1 Literature review report (Oct 2017)

O4.2. Behavioural experiment with producers, processors, retailers (Jan 2018-Jun 2018)

M4.2 Complete experimental data collection (Mar 2018)

D4.2 Database & report (Jun 2018)

O4.3. Behavioural game theory analysis (Apr 2018-Dec 2018)

D4.3a Development of game theory models (Sep 2018)

D4.3b Peer review paper submission (Dec 2018)

O5. Food waste at household level - behavioural analysis (Apr 2016-Sep 2018)

O5.1. Literature review (Apr 2016-Oct 2016)

M5.1 Completion of literature review (Jul 2016)

D5.1 Literature review report (Oct 2016)

O5.2. In-depth interviews & consumer survey (Apr 2017-Sep 2017)

M5.2 Complete in-depth interviews & survey data collection (Jun 2017)

D5.2 Database & report (Sep 2017)

O5.3. Structural choice modelling (SCM) analysis (Oct 2017-Sep 2018)

D5.3a Complete development of SCM model (Jun 2018)

D5.3b Peer review paper submission (Sep 2018)

O6. Environmental & social effects (Jan 2018-Mar 2021)

O6.1. Secondary data collection & results from O1-O4 (Jan 2018-Sep 2019)

M6.1 Complete secondary data collection (Jul 2018)

D6.1 Database & report (Sep 2019)

O6.2. PE models (Oct 2019-Mar 2021)

D6.2a Complete development of PE models (Oct 2020)

D6.2b Peer review paper submission (Mar 2021)

O7. Waste reduction at source – enhanced benefits through the supply chain
(Apr 2016-Mar 2021)

O7.1 Develop an exemplar case study for primary source waste reduction in the potato supply chain (Apr 2016-Mar 2021)

M7.1 Construct design for optimised potato quality & reduced wastage in industry-relevant potato variety (Aug 2016)

M7.2 Complete transformation process using constructs from M6.1, including selection of 10-20 positive independent lines per construct (Dec 2016)

M7.3 Confirm CRISPR events (Feb 2017)

M7.4 Propagation of 1st generation lines identified in M6.2 & M6.3 for phenotypic analyses (Aug 2017)

D7.1 Complete assessment of phenotypic modifications in first generation stored tubers (gene expression, enzyme activities, metabolite levels [sugars, amino acids], bruise control, fry colour & acrylamide-forming potential) (Aug 2018)

D7.2 Line selection for second generation tuber propagation (Aug 2018)

M7.5 Propagation & harvest of select 2nd generation lines (Mar 2019)

D7.3 Complete analyses of phenotypic stability & other aspects of quality & agronomic performance e.g. yield, dry matter, levels of key nutrients & anti-nutrients (Aug 2020)

D7.4 Final report & dissemination of data (Mar 2021)

O8 Waste not want not: the valorisation of consistent waste streams in the food & drink supply chains (Apr 2016-Mar 2021)

O8.1 A review of the existing primary & secondary production waste streams & their potential for exploitation (Apr 2016–Dec 2016)

M8.1 Collate data on primary & secondary production waste streams (Oct 2016)

D8.1 Completion of review (Dec 2016)

O8.2 Development of case studies to valorise primary & secondary production waste streams (Dec 2017-Mar 2021)

M8.2 Identify & timeline case studies from the waste review (Jan 2017)

D8.2 A plan for the valorisation of selected Scottish primary & secondary production waste (Feb 2017)

M8.3 Develop the potential of primary production wastes (rapeseed, soft fruit & cereal sectors) waste for food & non-food uses (Jan 2019)

D8.3 Deliver strategies for primary production waste valorisation, utilisation & exploitation (Jan 2019)

KE8.1 Consult with stakeholder groups regarding developing the potential of secondary production waste for food & non-food uses via a workshop (Jan 2019)

M8.4 Develop the potential of primary production wastes (fruit, potato & cereals) waste for food & non-food uses (Jan 2021)

D8.4 Deliver strategies for secondary production waste valorisation, utilisation & exploitation (Jan 2021)

Technical approach & detailed work plan

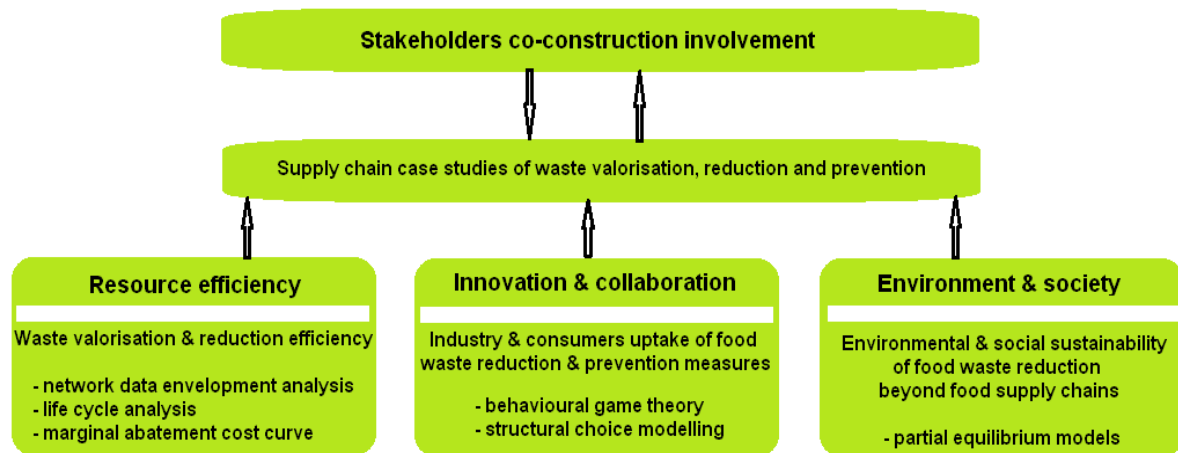


Figure 1. Diagram of research aims & technical approaches

Primary data collection (Apr 2016-Mar 2021): longitudinal survey of 500 producers, processors, retailers; experiment with 150 producers, processors, retailers; 10-20 in-depth interviews with consumers; survey of 500 consumers; 50 in-depth interviews with producers, processors, retailers (longitudinal study). Data collection during the first two years is detailed in the work plan & Gantt chart.

O2 - Efficiency of waste reduction - supply chain analysis. The research will estimate the waste performance of firms along food supply chains & identify the most waste efficient ones. Analysis will involve LCA or green accounting to estimate waste along food supply chains & identify waste hotspots. Overall waste performance will be analysed using network DEA models with desirable & undesirable outputs, which allow comparison of firms along food supply chains based on their waste performance & identify best & worst performers & waste hotspots. Data will be collected from secondary data sources, in-depth interviews & surveys.

O2.1. Secondary data collection (Mar 2017)

O2.2. In-depth interviews with producers, processors & retailers (collaboration with RD 2.4.3) (Sep 2017)

O2.3. Structured survey of producers, processors & retailers (Sep 2017)

O2.4. LCA (collaboration with RD 2.4.3) (Sep 2018)

O2.5. Network DEA (Sep 2018)

O3 - Cost-effective waste mitigation measures. Technically feasible & cost-effective waste mitigation measures together with potential opportunities & barriers to their uptake will be identified based on literature & discussion with a range of industry & policy stakeholders. Costs & benefits of waste reduction measures will be estimated using MACC analysis. Network DEA models will be used to estimate the efficiency of waste reduction of firms along food supply chains based on their capacity to adopt cost-effective waste mitigation measures.

O3.1. Secondary data collection (Mar 2017)

O3.2. In-depth interviews with producers, processors & retailers (collaboration with RD 2.4.3) (Sep 2017)

O3.3. Structured survey of producers, processors & retailers (Sep 2017)

O3.4. MACC analysis (collaboration with RD 2.4.3) (Sep 2018)

O3.5. Network DEA (Sep 2018)

O4 - Innovation & collaboration - behavioural analysis. We will identify opportunities for innovation & collaboration acceptable to the private sector. These will be analysed using behavioural game theory techniques. Analysis will consist of (1) learning models to analyse determinants of firms' absorptive capacity for transfer of innovative knowledge from other firms (& academia), & (2) game interaction models & institutional game theory models to analyse collaborative innovation, i.e. how firms collaborate in the creation & transfer of innovation *re* food waste reduction techniques. Data to be collected via in-depth interviews & economic experiments.

O4.1. Literature review (Oct 2017)

O4.2. Behavioural experiment with producers, processors & retailers (Mar 2018)

O4.3. Behavioural game theory analysis (Dec 2018)

O5 - Food waste at household level - behavioural analysis. The research will identify opportunities for waste reduction acceptable to consumers. The research will include an analysis of consumers/public perceptions & behaviours as regards ranking/uptake of waste reduction methods, which will include waste reduction innovations identified in the supply analysis (i.e. producers, processors, retailers & caterers). The consumer analysis will use the novel SCM, which combines choice experiments with behavioural economics techniques (structural equation modelling) & provides a deeper understanding of both the uptake of specific waste reduction measures & the drivers & barriers that influence consumers' waste reduction behaviours. Data collection will involve in-depth interviews (potentially focusing on a specific case study, e.g. catering/eating out), based on which we will build a structured questionnaire survey. The findings from the consumer analysis will feed back into the supply chain to improve impact as they will refine the second stage of longitudinal in-depth interviews & survey with producers, processors, retailers & the subsequent analysis & KE with stakeholders.

O5.1. Literature review (Oct 2016)

O5.2. In-depth interviews & consumer survey (Sep 2017)

O5.3. SCM analysis (Sep 2018)

O6 - Environmental & social effects. The research will identify opportunities for waste reduction that provide net benefits to society. The research will assess the environmental & social sustainability of waste reduction beyond food supply chains using economic simulation modelling such as PE models. Modelling scenarios will simulate waste reduction strategies at different stages of the food supply chains & estimate their impacts on environment (e.g. GHG emissions) & social sustainability (e.g. employment opportunities due to innovation creation in waste reduction; welfare gains due to lower food waste at household level, the role of women in reducing food loss & waste). Data will be collected from secondary sources & from the other stages of research, i.e. results of network DEA of waste performance, the case studies (O6.1 & O7.2) & of behavioural analyses at supply & consumption level.

O6.1. Secondary data collection & results from O1-O4 (Jan 2018-Sep 2019)

O6.2. PE models (Oct 2019-Mar 2021)

O7 - Waste reduction at source – enhanced benefits through the supply chain. The research will build on advances made in the cSRP & other RESAS supported funding schemes that have targeted primary production approaches to maintaining crop quality (reduced waste). In potato production ~£50 million lost product per annum is attributed to discards as a result of internal bruising, whilst rejection of tubers (pre & post storage) due to elevated sugar content & poor fry colour has a significant impact on the economics, level of waste & competitiveness of the supply chain. It is proposed to use rapidly emerging, highly targeted, EFSA-recognised molecular breeding technologies to target the genes known to be responsible for regulating the bruise & high sugar traits & take the first steps towards crops with significantly improved supply chain resilience & reduced waste. The case study will be interdisciplinary (hard & socio-economic sciences) with the experimental developments informing on the potential for waste reduction & the impact this would have at each point in the supply chain with respect to costs, waste & biomass management, logistics etc.

O7.1 Develop an exemplar case study for primary source waste reduction in the potato supply chain (Apr 2016-Mar 2021)

O8 - Waste not want not: The valorisation of consistent waste streams in the food & drink supply chains. Inherent in all food & drink production systems is a level of waste that cannot be reduced to zero due to factors such as seasonal production, environmental variability, market changes etc. This necessitates alternative uses for the waste that maximise value: waste valorisation. Initially the major & minor Scottish crop waste streams will be reviewed & then prioritised in terms of exploitation potential for different sectors: sustainable ingredients, additives, shelf life extenders, non-food etc. Once completed, case studies will be initiated via consultation with stakeholders (e.g. SFD Ltd, ZWS) & being cognisant of the Scottish Government Circular Economy to develop the concept & assess viability & impact at the production level & also on the end use sector(s). Preliminary research & industrial interaction has identified waste streams from the rapeseed, soft fruit & cereal sectors (primary production & processing) as being potentially valuable with respect to coproduct development.

O8.1 A review of the existing primary & secondary production waste streams & their potential for exploitation (Oct 2016)

O8.2 Development of case studies (two max) to valorise primary & secondary production waste streams (Mar 2018)

Key linkages, interdisciplinary & collaboration:

SRUC & Hutton are the only MRPs involved in RD 3.1.4 (with underpinning contribution from BioSS), however they fully cover the socio-economic & natural science requirements of the ITGF for this RD. SRUC & Hutton are present also in other areas of work & this will ensure strong linkages with:

- WP 2.1 (RD 2.1.6 'Integrated pest management'; RDs 2.1.1 & 2.1.2 'Genetic diversity of crops & crop genetic improvement'; RD 2.1.8 'Novel crops' (specifically SD 'Developing commercial potential of Scottish native flora'): Feed into the proposed work in terms of crop production & quality.
- WP 2.3 (RD 2.3.9 'Integrated management systems'; RD 2.3.12. 'Increasing uptake of best practice'): The outputs of new & adopted (best practice) systems will impact on waste streams & alternative uses in RD 3.1.4.
- WP 2.4 (RD 2.4.2 'How rural economies can adapt to key external drivers'; RD 2.4.3 'Environmental sustainability & circularity of the rural economy'): Data

collection in this RD will include information on farm waste & feed into RD 3.1.4.

- WP 3.1 (RD 3.1.1 'Improving Scottish primary production'; RD 3.1.2 'Improving food & drink production'; RD 3.1.3 'Food safety') & WP 3.2 (RD 3.2.2 'Dietary components of healthy diets & their effects'): The primary & secondary production chains may have altered waste stream, which impacts on the plans of RD 3.1.4.

Added Scientific Value:

Waste along food supply chains 'from farm to fork' is poorly documented & the existing information is scarce & unstructured reflecting a piecemeal approach to research funding & a lack of "*joined up thinking*" that this research will serve to address. There have been limited attempts at estimating waste &/or food losses at production or processing levels, & some basic analysis of public attitudes towards food waste have been undertaken but not in the coherent manner planned here.

This project is innovative since it plans to fill the current knowledge gap & provide recommendations on how best to improve efficiency of waste reduction &/or valorisation at levels of supply & demand for a number of key Scottish supply chains. A coherent methodological framework will be developed & estimated for a number of the main Scottish food supply chains in a 'farm to fork' approach. The framework will involve innovatively combining economic & behavioural techniques, yielding an accurate & realistic assessment of food waste reduction efficiency & behaviours. Furthermore, by targeted case studies co-constructed with stakeholders to both develop strategies for reduction at source & to add value to waste, the research adopts a Circular Economy approach: a current Scottish Government priority.

KE, Audiences & Impact:

KE. Stakeholders' involvement from the beginning of the research in a co-construction process will ensure actual knowledge exchange with industry & policy makers. They will be involved in shaping the research at every stage (e.g. identification of high waste areas, identification of measures to prevent, reduce &/or valorise food waste, participation in behavioural games & surveys), & the research will progress in repeated knowledge exchange loops. The KE plan is detailed in O1. Management & communication & dissemination activities & the Gantt charts.

Audiences. The project outputs will be targeted at all stakeholders involved: policy makers, industry (farmers, processors & retailers), public, & academia:

- *Policy makers* (RESAS) - will be provided with a clear assessment of the waste situation in the Scottish food & drink industries relevant for both the industry & public, on which appropriate waste reduction policy & support can be constructed.
- *Industry stakeholders* (e.g. NFUS, SFD Ltd, The Potato Council, AHDB) - will be provided with clear information on strategies for, & costs & benefits of using waste reduction methods, which have considered all aspects of efficiency, i.e. production, economic, environmental & social performance indicators. Selected case studies will highlight the potential of waste reduction at source & the potential of waste valorisation in scenarios where reduction is limited. Stakeholders are involved throughout the project in a co-construction process ensuring continuous KE. Moreover, findings from the consumer analysis will feed back into the supply chain through refining the second stage of longitudinal in-depth interviews & survey & subsequent analysis & KE with stakeholders.
- *The public* - indirectly through policy measures, will be provided with clear guidelines on food waste reduction measures at household level.

- *Academia* - will be provided with research outputs from a novel methodological framework operation a Circular Economy ethos; both reducing & valorising waste.

The communication & dissemination plan will include:

- Under the auspices of CKEI and the relevant KE Sectorial Leads, RD scientists will contribute to centrally planned KE interactions on specific over-arching issues with relevant SG Policy teams.
- KE with stakeholders (funders/policy makers): (preliminary) results of the research support advice on possible interventions (e.g. within SRDP) to ensure that opportunities are explored. Stakeholders are firmly part of the research co-construction process.
- Knowledge transfer to stakeholders (funders/policy makers; industry): three workshops to present project intermediate/final results as well as at the major Centre for Knowledge Exchange and Impact (CKEI) events; presentation at policy briefings & project meetings (bi-annual).
- Knowledge transfer to academia: 10 publications in peer-review journals; eight presentations at national & international conferences; contribution to academia blogs such as 'The Conversation'.
- Knowledge transfer to public: presentations at public events such as Royal Highland Show, Edinburgh Science Festival, school talks & key CKEI events.

Impact

- **ITGF expected impact.** The proposal answers fully the ITGF requirements for RD 3.1.4., & is fully expected to generate the impact required in the ITGF. It is interdisciplinary with socio-economic ITGF requirements answered by SRUC & the natural science ITGF requirements covered by Hutton & SRUC.
- **Industry impact.** The research proposed will have a strong impact with industry given their co-construction involvement in this work. This will ensure that outputs find their way into implementation at industry level yielding food waste reduction, valorisation & economic growth. With longitudinal data to be collected, the research will analyse potential evidence of behavioural change during project lifetime & contribute to REF impact case studies & positive economic growth.
- **Academic impact.** The research proposed will have a strong academic impact given the novelty & timeliness of the area. Previous involvement of the researchers in REF2014 should ensure that published outputs are of REF quality.
- **Societal impact.** Strong societal impact is assured as the plan has high potential to influence behavioural change as regards public reduction of food waste.
- **Strategic research impact.** The research proposed will have a strong impact in terms of SRUC & Hutton involvement in a strategically relevant area not only for RESAS but also for other funders. The work will match the team's external bids.

RESEARCH DELIVERABLE NUMBER: 3.1.4

Work planning and timetable for Year 1: Showing major milestones (M), deliverables (D), KE/impact events (KE); Reports to RESAS [R] and their timing.

Year 1: 2016/17	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Project meetings, workshops & reports	D1.1					D1.2a					D1.2b D1.3a	KE1a
O1.2 Project outputs											D1.4a	KE2a
O2.1 Secondary data collection								M2.1				D2.1
O2.2 In depth interviews												
O3.1 Secondary data collection								M3.1				D3.1
O3.2 In-depth interviews												
O5. Food waste at household level: O5.1 Literature review				M5.1			D5.1					
O7. Waste reduction at source: O7.1 Case study: primary source waste reduction in potato supply chain					M7.1				M7.2		M7.3	
O8. Waste not want not: valorisation of waste: O8.1 Review of primary & secondary production waste streams & their potential for exploitation							M8.1		D8.1	M8.2	D8.2	
O8.2 Development of case studies												
Annual report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.1.4

Work planning & timetable for Year 2: Showing major milestones (M), deliverables (D), KE/impact events (KE); Reports to RESAS [R]) and their timing.

Year 2: 2017/18	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Project meetings, workshops & reports						D1.2c					D1.2d D1.3b	KE1b
O1.2 Project outputs		D1.5a	KE2b		KE2c						D1.4b	D1.5b
O2.2 In-depth interviews			M2.2			D2.2						
O2.3 Structured survey			M2.3			D2.3						
O2.4 LCA												
O2.5 Network DEA												
O3.2 In-depth interviews			M3.2			D3.2						
O3.3 Structured survey			M3.3			D3.3						
O3.4 MACC analysis												
O3.5 Network DEA												
O4.1 Literature review				M4.1			D4.1					
O4.2 Behavioural experiment												M4.2
O5.2 In-depth interviews & consumer survey			M5.2			D5.2						
O5.3 SCM analysis												

O6.1 Secondary data collection & results												
O7. Waste reduction at source: O7.1 Case study: primary source waste reduction in potato supply chain					M7.4							
O8. Waste not want not: valorisation of waste: O8.2 Development of case studies												
Annual report (Year 2)												R2

Work Package 3.2 Healthy diets and dietary choice

1. Strategic Relevance

Scotland has a richly deserved international reputation for the quality of its food based on the pristine environments in which food is produced and the safety and nutritional quality of that food. However, its population also has one of the poorest diet-related health records in the developed world and a poor diet, and excessive consumption of food and drink contributes to the high rates of the main causes of death and poor health in Scotland. This failure is expensive. The total cost to Scottish society of obesity alone is upwards of £457 million (2008) and set to rise, if unchecked, to around £3 billion by 2030.

Diet quality is strongly linked to socioeconomic status and many of the problems

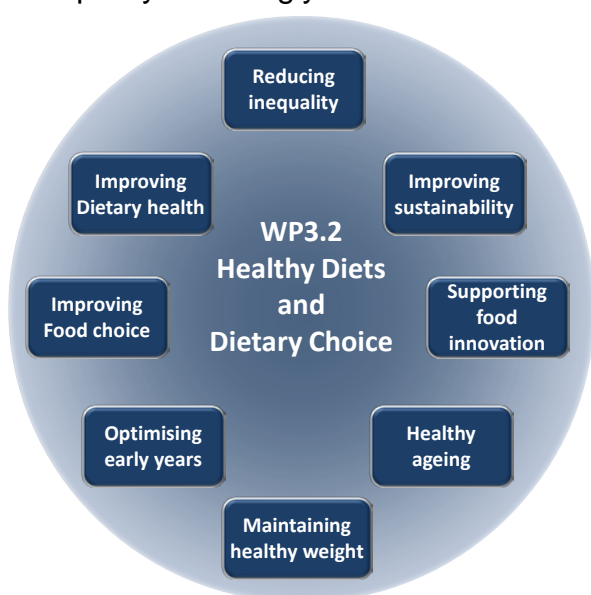


Figure 1. Policy drivers for Work Package 3.2

around poor health related to diet are concentrated in the most deprived sectors of society. Poor dietary habits and attitudes are deep-seated in Scotland and they develop from a very early age. Children's diets are particularly poor and there is evidence of transgenerational transmission of poor health, poor dietary habits and attitudes. Diet is linked to behaviour, lifestyle and the social and cultural environment in complex ways. Understanding these linkages is essential if we are to improve the health of the population. Population based interventions designed to improve dietary health in Scotland have so far met with limited success. We need a deeper and

more sophisticated understanding of the factors operating within communities and individuals if we are to develop more effective health improvement strategies.

Scotland recognises the need for a resilient and sustainable food system. Food, in all its stages, is estimated to account for 31% of greenhouse gas emissions. Not only that but we waste one fifth of all the food we buy. This is expensive and it's bad for our environment; 630,000 tonnes of food and drink is thrown away annually – costing Scots over £1 billion and creating harmful greenhouse gases.

Health is an increasingly important consideration for consumers and this provides an important opportunity for the food industry in Scotland to expand at home and abroad. Dietary health is relevant to all sectors of society but affordability and sustainability are also important and we need to better understand the interplay between these. Alongside attempts to improve public health by influencing behaviours it is important to also have in place a parallel approach of food reformulation based on sound nutritional principles to improve the quality of the choices that are currently being made.

2. Work Package organisation

Work Package 3.2 seeks to address the above policy, industry, and public needs by answering four research questions developed in collaboration with our key stakeholders. Each question corresponds broadly to a research deliverable (RD):

- **RD3.2.1 (Importance of Healthy Diets):** What is the relative importance of diet in maintaining health throughout life and how is this modulated by socio-economic status, lifestyle and the individual response to diet?
- **RD3.2.2 (Dietary Components & their Effects):** How do specific dietary components impact on health, including gut health, weight maintenance, and wellbeing?
- **RD3.2.3 (Sustainability of Healthy Diets):** What is the best way to measure sustainability (personal, environmental, social and economic) and how can advice designed to optimise health, sustainability, and affordability be most effectively communicated to consumers?
- **RD3.2.4 (Food Culture & Dietary Choice):** How do wider cultural factors, customs and habits influence dietary choices in different settings and social environments and how can a better understanding of these be used to improve food choices in children and adults?

3. Coordination and Management

3.1 Management of the Work Package

The management structure of the WP is designed around the delivery of the annual progress reports and other outputs required in the RESAS reporting schedule. It is informed by our experience in two previous Strategic Research Programmes (SRPs). The following PIs have responsibility for coordinating various aspects of the programme based on their expertise and experience:

WP3.2 Coordinator: Paul Haggarty

- RD3.2.1 Coordinator: Paul Haggarty
- RD3.2.2 Coordinator: Petra Louis
- RD3.2.3 Coordinator: Baukje de Roos
- RD3.2.4 Coordinator: Jennie Macdiarmid

The management of the work package is the responsibility of the WP Management Group which consists of the above coordinators, the Food, Health and Wellbeing Theme Coordinator, one additional nominated representative from each of the MRPs contributing to the programme (if the MRP is not already represented), and a representative of BioSS. The WP team (including all PIs) will arrange an annual feedback session for the KE Sectorial Leads (primarily 'Food and Drink', 'Communities' and 'Environment' for this WP) and the Theme 3 Programme Advisor in order to review progress and delivery on the work package. The core WP Management Team will also liaise every 6 months to assess progress and identify any emerging issues that have to be addressed (see Annual Reporting Cycle below). The RD Coordinators have day-to-day responsibility for the progress of their RDs and significant problems will be reported back to the WP Coordinator. Problems that cannot be resolved at WP level will be raised with the Theme Coordinator, Programme Advisors, and ultimately the DEC. The WP Coordinators will contribute to the Theme management meetings. Together with the Programme Advisors, the WP Management Group will use the annual reporting system to identify high impact narratives relevant to policy, industry/innovation and examples

of scientific excellence, including resilience (funding), collaboration and interdisciplinary working (with MRP and/or external partners).

3.2 Co-ordination within the work package

The arrangement of RDs follows that of the tender document but delivery of the overarching aims requires linkage between the RDs at both the conceptual and experimental level (**Figure 2**). The work-package as a whole addresses the ITGF specification but the distribution of the work between RDs was pragmatic (e.g. both RD3.2.1 and RD3.2.2 in the ITGF asked for work on early life, mental health, and lifestage). Where appropriate these have been included in RD3.2.2 but we found it more logical to locate most of this work in RD3.2.1. The separation of the work into four RDs is primarily for the purposes of research management, reporting and publishing. The scientific outcomes for the stakeholders, policy, and industry will come directly from the individual RDs or after synthesis of the RD outputs at WP or Theme level, with input from KE Sectorial Leads and CKEI. The research in WP3.2 is designed around key policy and industry needs. Three of the most important are incorporated across all the RDs as cross cutting themes:

- Inequalities
- Behaviour change
- Knowledge to support the production of healthy foods

RD3.2.1 and RD3.2.4 are linked at a number of levels but most significantly in relation to food choice and behaviour. RD3.2.4 is concerned with the choices people make and the social, cultural, and economic drivers that influence them. RD3.2.1 also considers the way in which diet interacts with the wider social and

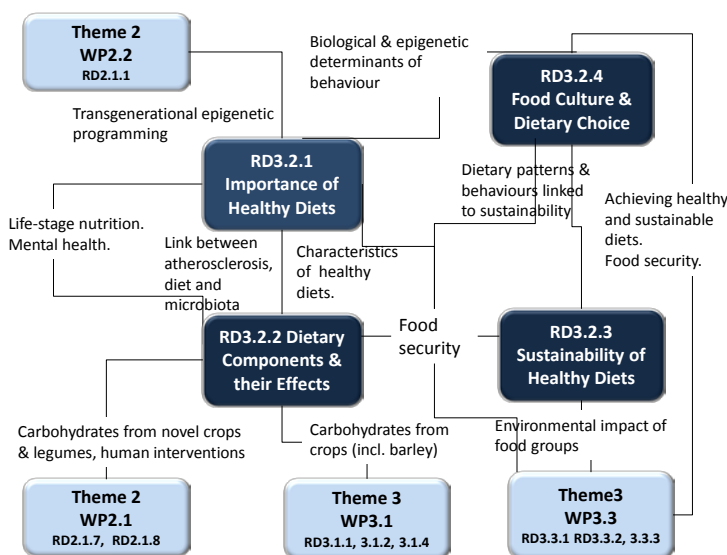


Figure 2. Links within WP3.2 (dark blue), with other parts of the SRP (light blue), and with underpinning capacity (clear).

economic nexus to influence health and behaviour. It uses new paradigms emerging from the social and biological sciences on how the environment, and early life exposures in particular, can 'get under the skin' and influence behaviours across life. This work is relevant to the interpretation of the studies on habituation to food taste in RD3.2.4. Work on early programming of taste preferences is split between this RD3.2.1 and RD3.2.4

with the determinants being considered in the former and the effects in the latter. The work in RD3.2.1 on inter-individual variation links to the work in RD3.2.2 on gut health and the response to diet. Work in RD3.2.2 investigating the link between atherosclerosis and microbial conversion of dietary compounds like choline to trimethylamine also dovetails with RD3.2.1. The work in RD3.2.2 on the influence of diet on the gut and satiety mechanisms links to the work in RD3.2.1 on healthy

weight maintenance across the life-course. The work in RD3.2.2 is also linked to the population scale dietary assessments, and analysis of publicly available databases, carried out in RD3.2.1. The work on specific dietary components in RD3.2.2 will help in the interpretation of the work in RD3.2.1 linking diets to health. The work in RD3.2.3 on sustainability links to findings from RD3.2.2 and RD3.2.1 on what makes a healthy diet. The extensive work on the Kantar database of consumer purchases over time undertaken in RD3.2.3 will also inform the work in RD3.2.1 and RD3.2.2. Work in RD3.2.3 on the uptake of dietary recommendations and the economic and other factors affecting this links directly to the work in RD3.2.4.

3.3 Co-ordination with the wider Strategic Research Programme and Centres of Expertise

The Strategic Research Programme (SRP) provides unique opportunities to tackle large-scale policy and scientific questions through partnership working beyond the scope defined by the individual WPs. WP3.2 has been designed to integrate with work in other WPs and Themes to provide integrated high level outputs appropriate to the needs of our stakeholders. Investigations into the effect of cereals on health in RD3.2.2 link closely with work in RD3.1.1. The fibres studied in RD3.2.2 will include alpha- and beta-linked glycans, resistant starches, pectins, hemicellulosic compounds and various oligosaccharides, from commercial sources as well as from crops under study in other RDs (RD2.1.8, 3.1.1, 3.1.2, 3.1.4) or bred at Hutton (RD3.1.1). Work in RD3.2.2 links closely with several RDs that provide carbohydrate fractions for microbial fermentation studies, including from legumes and novel crops: RD2.1.8, 3.1.1, 3.1.2, 3.1.4. The release of bound phytochemicals from plant fibre (in particular cereal bran and fibres from vegetables and soft fruit) will be investigated in direct collaboration with RD3.1.1. RD3.2.4 has strong links with WP3.3, and interactions with RD3.3.2 (Enhancing food security), RD3.3.3 (Local food), and RD3.3.1 (Food trade and consumption). It is envisaged that the work on sustainability and health in WP3.2 will feed in to the Climate Change Centre of Expertise. All of the RDs in this WP will produce knowledge relevant to Food Security. This work will be collated by the RD and WP leads who will work with the relevant leads in WP3.3 to explore how this can usefully feed into the aims of the WP3.3 Food Security integrating hub. The WP will also link its expertise (e.g. from RD3.2.3) with relevant Think Tank Projects being conducted as part of CKEI activities.

3.4 Working with stakeholders and the wider scientific community

Trans-disciplinary partnership working with scientists and other professionals in a range of organisations is central to the research within this Work Package. The partnerships that form the core of the WP provide access to data, policy and other knowledge and channels of communication that are vital in ensuring that research outputs are salient, credible, timely and above all useful. The research in this WP spans a great many disciplines and will be carried out in collaboration with exercise physiologists, psychologists, behavioural scientists, crop scientists, clinicians, and molecular biologists. It involves research links with a number of HEIs and stakeholders. An important aim in this WP is to shift the stakeholder role from being simply a consumer of our research output to a partner in its development, delivery and implementation. The specific research objectives were designed in consultation with a wide range of stakeholders to ensure that the work is relevant

and the outcomes are likely to have high impact. A series of meetings were held and the following stakeholders consulted in the preparation of this WP:

- Food Standards Scotland.
- Health Improvement Strategy Division, Scottish Government.
- Food, Drink and Rural Communities, Scottish Government.
- Child & Maternal Health, Scottish Government.
- National Maternal and Infant Nutrition Coordinator, Scottish Government.
- Scottish Food and Drink Federation.
- RESAS Agriculture and Rural Development Division, Scottish Government.
- Nourish Scotland

The research questions in this work package were informed by a range of policy relevant documents including: “Becoming a good food nation”: The ScotPho report “Informing investment to reduce health inequalities”: The NHS Health Scotland “Child Healthy Weight Program Review”: The “Obesity Route Map Indicators”: The “Scottish National Diet and Nutrition Survey (NDNS) Report”: The Scottish Parliament Information Centre Financial Scrutiny Unit Briefing on “Preventative Spend”

3.5 Underpinning Capacity

This WP will link to Underpinning Capacity on a number of levels. New initiatives, projects, posts, and studentships will be created within Underpinning Capacity to amplify, complement, and extend promising areas in the SRP. The research programme set out in the SRP is ambitious and scientifically challenging and it requires high quality statistical input across a wide range of projects. This will be provided by Biomathematics & Statistics Scotland (BioSS). The BioSS consultancy for the RESAS Strategic Research Programmes will be funded through Underpinning Capacity Function 7, "Provision of Biomathematical & Statistical Consultancy Services". For this WP the main link will be through the BioSS statisticians named in the relevant RDs.

Based on our experience in the previous programme it is anticipated that we will receive requests from our stakeholders for specific pieces of research not directly covered within the scope of the current programme and associated KE activities, or requiring further development of this work. These requests can range from short briefings to substantive research work and some PI time has been allocated to this activity. These requests will be routed through Underpinning Capacity ‘Support to Policy’ where there are mechanisms in place to deal with significant calls on PI time and other RESAS funded resources.

The linkages with Underpinning Capacity will be overseen by the WP Management Team. The WP Coordinator will be responsible for ensuring the two way flow of information between Underpinning Capacity and the WP.

3.6 The Annual Reporting Cycle

The Programme Advisor with specific remit for Theme 3 will be responsible for overall coordination and oversight of the reporting process on behalf of DEC. Progress will be assessed with respect to the schedule set out in the Tender by the relevant RD Coordinator, coded according to a common scheme (green – on schedule, amber – slightly delayed, red – significant delay). The progress of specific objectives will be monitored internally by the relevant RD and WP

Coordinators. The RD Coordinators will provide the relevant WP Coordinator with summaries of progress on research activities, Milestones reached (e.g. start or completion of a specific activity), key findings, and any specific outputs, outcomes and impacts associated with the research programme. The WP coordinator will collate the findings into a WP level report for compilation into Theme level reporting by the Theme Coordinator for formatting and submission to RESAS annually. A six-monthly update will take place in October of each year. Feedback on amber and red deliverables will be acted upon. DEC will be informed of any red on the risk register (see *Management of Risk*). Each MRP will follow the relevant agreed QA system for its contributions to the reporting (see *Quality Assurance*). The annual reporting system will be used to identify high impact narratives relevant to policy, industry/innovation and examples of scientific excellence, including resilience (funding), collaboration and interdisciplinary working (with MRP and/or external partners). The WP Coordinator is responsible for supplying narrative examples. Much of the work in WP3.2 is trans-disciplinary and the RD Coordinators will be tasked with identifying RD level policy relevant research outputs. PIs responsible for the individual objectives will be encouraged as a matter of good practice to draft 150 word narratives around policy relevant research findings. QA for the original information on narratives is the responsibility of the relevant RD Coordinator. Final editorial responsibility is that of the WP and Theme Coordinators and finally to PAs and the associated secretariat. Stakeholder relevant outputs will be channelled through KE to the relevant policy teams (see Impact and KE below) and follow up activities with stakeholders on implementation and monitoring will be the responsibility of the WP Coordinator.

3.7 Additionality

The research described here is designed to complement work on diet, diet choices, and health carried out elsewhere in the UK and internationally. The need to improve diet is relevant to the whole of the UK but there are specific problems that are particularly acute in Scotland. Examples include the greater problem of deprivation and its persistence across generations, and poorer status for particular foods (e.g. fruit and vegetables) and nutrients (e.g. fibre, fats, folate, vitamin D) in Scotland. This WP focuses on such issues and on problems where a more holistic, cross-disciplinary approach is required. Examples of this include; work linking health benefits to the development of foods elsewhere in the programme; linking biological insights on behaviour with the strategies designed to produce behaviour change; understanding the effect of diet in relation to the particular socioeconomic environment that results in the “Scottish Effect” where the impact of deprivation is amplified. WP3.2 is designed to provide policy ready advice and KE specific to the needs of Scottish society and to help exploit opportunities in the area of Food and Health in Scotland. WP3.2 is designed to complement the wider MRP work programme relevant to diet and health where the relevant funders are UK and international bodies. Within the WP we have highly experienced staff who bring a track record of adding value to the SRP through competitive and collaborative national (e.g. BBSRC, MRC) and international (e.g. EU, NIH) funded research projects. Some PIs within WP3.2 also work with industry and many serve on important national and international advisory panels. These linkages generate considerable knowledge, data, and connectivity that will inform and amplify the research in this WP, including by adding value to CKEI activities Results, information and survey data produced in the course of our externally funded

research contributes to our capacity to deliver this programme of research. Similarly, the capacity that we build by doing this work for RESAS increases our ability to attract external funding. Additionality and added value works both ways.

3.8 Delivery Risks

Within the WP we have an appropriate mix of highly experienced staff with a track record of successful delivery in the current and previous RESAS programmes and on major national and international externally funded research projects. These staff are also experienced at assessing and managing risks to delivery. The first task of the WP3.2 management committee will be to draw up a risk register for the WP and set out the risk management strategies. This activity will be integrated with Theme level organisational structures. Risks will be rated as red/high (likely to occur with a serious impact on delivery), orange/medium (potential to seriously impact on delivery if not effectively managed), or green/low (requires monitoring but minimal management). The following actions will be followed in relation to risk; 1) the status of current risks will be assessed. 2) new emerging risks will be identified and added to the register. 3) mitigation strategies will be proposed, taking into account the research implications for cross programme links and external collaborations including implications for stakeholders. 4) risk assessment will be agreed (e.g. tolerate, monitor, take action, including escalate). 5) The WP management committee will send risk register updates to the Theme Management Committee. The actual risks, and how they will be managed, will depend on the specific circumstances but examples of generic risks and strategies include;

Risk Descriptor	Risk Assessment	Likelihood & Impact	Controls	Risk owner	Update including recommendations for risk mitigation	Management Committee assessment
Staff loss or absence or other reduction in skill capacity	Medium	High/Medium	Anticipation of need for recruitment and planning at WP & Theme level of SRP resource allocation to minimise impact.	WP & Theme Coordinators		
Reduced effectiveness of key RD linkages	Low	Low/Medium	Management intervention at WP/Theme level with possible escalation to DEC (inter-MRP issues).	RD, WP & Theme Coordinators		

4. Impact and KE

The ultimate aims of this WP are to assist our stakeholders achieve their goals in relation to diet and health and identify the policy interventions and strategies likely to be most effective in improving dietary health. The RD is designed to deliver usable outputs sequentially throughout the life of the programme from year 1. In addition, the KE output will extend beyond merely summarising research findings for stakeholders. We undertake to:

1. translate research findings into a form that is useful to our stakeholders

2. ensure that the information is made available to the appropriate organisations, teams, and individuals through membership of advisory committees etc (e.g. UK Scientific Advisory Committee on Nutrition; BBSRC Bioscience for Health Strategy Panel; International Council on Plant Nutrition; UK Advisory Committee on Novel Foods and Processes; a range of Scottish Government advisory groups)
3. assist with knowledge exchange in relation to implementation activities relating to our outputs
4. assist in monitoring the effectiveness of implementation activities

We will carry out a yearly audit with key stakeholders of our impact and effectiveness in meeting these goals. We have discussed with the most relevant stakeholders their preferred approach to KE. Three modes have emerged: 1) Call Down (where stakeholders can request short lay summaries or briefings relevant to their remit). 2) Regular catch up meetings (but only when there is something substantive to communicate); 3) Availability of PIs to contribute to the preparation of policy documents and present scientific consensus in various forums. Substantive requests from our stakeholders for specific research that goes beyond the proposed SRP KE activities will be routed through Underpinning Capacity ('Support for Policy') where there are mechanisms in place to manage significant calls on PI time and other RESAS funded SRP resources. The key to all of these seems to be flexibility, maintaining lines of communication, and responding when necessary. The WP coordinator will be responsible for scheduled 6 month catch-up discussions with key stakeholders throughout the SRP, working closely with the key KE Sectorial leads and the Centre for Knowledge Exchange and Impact (CKEI).

The programme of research to be undertaken in this WP is scientifically ambitious and academic impact is an important deliverable that will also be assessed. Although focused on issues important to Scotland the research is designed to be internationally relevant. Research findings will be published in open access journals where possible and academic excellence and quality will be assessed as part of the REF2020 exercise and using standard publication metrics. The WP will also contribute to economic competitiveness through the development of researchers with novel cross-disciplinary skill sets. Significant opportunities for innovation and economic growth are increasingly to be found at the interface between fields that have traditionally been closed to each other and this interdisciplinary work will foster the development of a new type of researcher able to work in the interface between disciplines. Early career researchers within the WP will receive training in transferable skills, such as effective communication, team working, networking, personal effectiveness, entrepreneurship and career planning, through the relevant MRP Staff Development Programmes (see e.g. <http://www.abdn.ac.uk/rsd/>).

5. Interaction with Central KE resources

The new KE Director and Centre for Knowledge Exchange and Impact (CKEI) will provide leadership, guidance on best practice, QA, evaluation and training in support of all KE based on the RESAS programme, whether delivered directly from the WP/RD or from the CKEI itself. The WP coordinator will liaise closely with the KE Sectorial leads to ensure appropriate contributions from this WP to CKEI-led activities, and to ensure effective delivery of WP-led KE.

6. Key research capacities

This WP builds on a considerable body of work and accumulated expertise and knowledge from the current and previous RESAS programmes. The facilities and resources necessary for this work have been identified and are in place or will be made available as part of the SRP. These include the new Rowett building (worth £40 million and including £12 million of Scottish Government investment) located on the Foresterhill site within the University of Aberdeen and adjacent to the Institute of Medical Sciences within the College of Life Sciences and Medicine. This will transform the research capability of the Rowett and will provide a state-of-the-art Human Nutrition Unit for nutrition studies to complement the University of Aberdeen facilities for behavioural studies. The WP will also utilise the University of Aberdeen Centre for Genome Enabled Biology in Medicine and the Maxwell computing cluster. Also available is the widely used Kantar database of consumer purchases. We hold extensive Kantar cross sectional data for the UK and longitudinal data for Scotland and this resource will support a number of RDs within the WP. Hutton provides considerable expertise in natural product chemistry, including state-of-the art facilities for extraction, analysis and physical characterization of components that can support the development of healthier products. Hutton also has access to unique plant material collections and germplasm which provides routes to obtain plant crops with improved health benefits. The PIs contributing to this programme are internationally recognised leaders in their fields with all the experience and knowledge needed to deliver this programme (see CVs provided elsewhere). The research in this WP is supported by two senior BioSS statisticians with skills matched to the work of the WP and with collaborative links to other relevant specialists elsewhere in BioSS. Many of the PIs in this WP also have extensive experience of KE activities involving the public, industry, government, and policy makers.

7. Quality Assurance (QA)

All the MRPs contributing to this work package have appropriately documented and certified quality management systems (BS EN ISO 9001:2008). The maintenance of this QA standard means that we are fully compliant with the BBSRC/Defra/FSA/NERC 'Joint Code of Practice for quality assurance' and the BBSRC 'Statement on Safeguarding Good Scientific Practice'. The standards and accreditations are routinely checked by external audits. The MRPs (RINH, Hutton, SRUC, and BioSS) associated with WP3.2 are dedicated to achieving and maintaining the highest possible standards of quality in order to meet the requirements of their work and the needs of their internal and external customers. The relevant Quality Management Systems in each MRP will ensure:

- quality performance monitoring through internal and external auditing relating to the pertaining ISO standard
- understanding of specific quality objectives and targets to staff
- planning and developing of standard work processes by means of Standard Operating Procedures where required
- appointment of competent personnel to co-ordinate, implement and review quality management directives (existing MRP QA managers)

We will also ensure adequate allocation of resources to achieve quality objectives and targets; obtain and act upon feedback from key stakeholders and the Scottish Government; and develop and maintain competency of all staff through the

provision of tailored training and the clear communication of quality assurance requirements.

8. Ethical and regulatory issues

The primary ethical issue in WP3.2 relates to research involving human volunteers. All of this work is carried out with the appropriate ethical authorisations from Local and Multi-Centre Research Ethics Committees. These approvals are routinely audited as part of the RINH and University of Aberdeen ethics and research governance procedures. Permissions provided by North of Scotland Research Ethics Committee are also subject to yearly reports and a formal system of reporting full study details, any adverse outcomes, early termination of projects, etc. For new social science survey work in this WP3.2 we will complete the Scottish Government pro forma (signed off by RESAS advisers) for approval by the Scottish Government Survey Control Unit in advance of commencing any fieldwork. This WP also includes a component of animal model work (RD3.2.1 O2; RD3.2.2, O1). All animal research in the UK is controlled by a range of legislation, including the Animals (Scientific Procedures) Act, 1986 Amendment Regulations 2012 (ASPA 2012). Compliance with the Act is monitored by the University of Aberdeen and the Home Office. All projects affecting animals are subject to the University's Ethical Review Process, via its Animal Welfare and Ethical Review Body. Studies are carefully reviewed to ensure that they have well-defined scientific objectives, give due consideration to the welfare of the animals, have sufficient statistical power, minimise the number of animals employed in each test, and avoid unnecessary duplication.

9. Contribution to the 3R's (reduction, refinement and replacement)

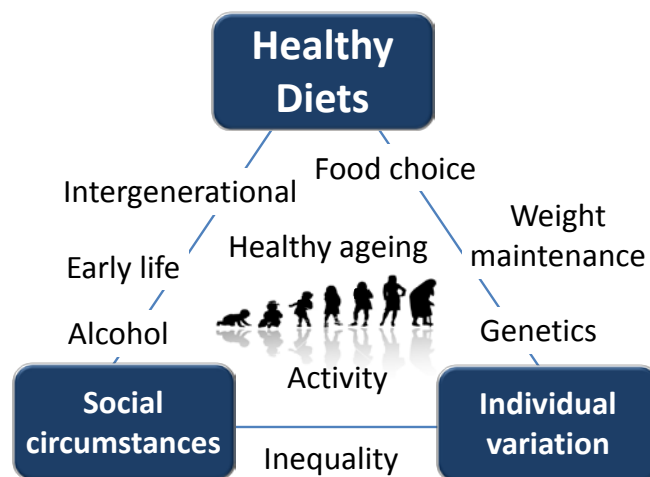
The animal model work in this WP (RD3.2.1 Objective 2) is designed to complement the human studies. Home Office authorisation for this requires a demonstrated commitment to the 3Rs and a description of how the research meets those requirements. RINH has a long track record refining studies of early life nutrition in animals in close collaboration with our experienced animal house staff.

10. Sustainable Development

The MRPs within WP3.2 have environmental policy statements which affirm that they are committed to preventing pollution, and adopting and promoting environmental best practice in support of sustainable and safe practices. The University of Aberdeen's Procurement Team oversees purchasing activity and manages contracts used across the University for items from paper to vehicles. The University is part of an Advanced Procurement for Universities and Colleges (APUC) working group on Sustainable Procurement that has introduced a Supply Chain Policy and Code of Conduct. The other partners in this WP (SRUC, Hutton and BioSS) have equivalent procedures in place and all comply with all relevant environmental legislation and other requirements. The WP will also be pro-active in encouraging best practice through initiatives that include; document sharing and use of discussion boards; use of web-based video-conferencing and encouraging the use of sustainable modes of transport when this is not possible.

Name of RD: 3.2.1 Importance of Healthy Diets

Research aim and key drivers: Poor health in later life is putting an increasing strain on health and social care budgets and there is a need to ensure that physical and mental health is maintained as long as possible into old age. A growing body of evidence indicates that factors acting across life shape health risks for older people and that earlier, more vigorous and longitudinally maintained management of risk factors is required. Strategies designed to promote healthy ageing need to take account of heightened physiological or behavioural plasticity throughout life and particularly at the key biological and social transition points; from birth, adolescence, pregnancy, becoming a parent, menopause through to retirement. Many UK health policies designed to tackle the problem of inequality are aimed at improvement of the diet in poorer socio-economic groups but these have met with limited success because of an inadequate understanding of causality and the way in which deprivation becomes entrenched across the generations. The previous Chief Medical Officer for Scotland highlighted the “Scottish Effect”, whereby the well documented link between poor health and social status is even more pronounced in Scotland than the rest of the UK. Within each social strata there are also sub-populations that respond less well to the food consumed, are less able to maintain a healthy weight, and follow a poorer health trajectory across the life-course. Some of this variation is culturally driven but there is increasing evidence for a biological component which is innate but also



modifiable. Senior citizens have special needs in terms of their dietary requirements due to reduced efficiency of nutrient absorption and homeostatic regulation of body nutrient status yet the food industry does not cater for the changing nutritional requirements and preferences of older people. A better understanding of the health benefits of diet and nutrition would also benefit to the food industry (producers, processors and retailers) in Scotland. This RD considers the individual and the societal context in which they live. It has been designed in consultation with our key stakeholders; Food Standards Scotland; Scottish Government (Child & Maternal Health; Population Health Improvement Directorate; Food, Drink and Rural Communities) Nourish Scotland; Scottish Food & Drink Federation. The work was informed by a range of policy documents including: “Becoming a good food nation”: The ScotPho report “Informing investment to reduce health inequalities”: “Child Healthy Weight Program Review”: “Obesity Route Map Indicators”: The Scottish Parliament Information Centre Financial Scrutiny Unit Briefing on “Preventative Spend”: “Marmot Report on Health Inequalities”: The “Scottish National Diet and Nutrition Survey”.

Summary of the proposal:

This RD is designed to advance our understanding of the following key issues relating to diet and health:

- effects of prenatal parental diet on lifelong physical and mental health of offspring, taking account of socioeconomic circumstances (O1, O2)
- key dietary drivers of physical and mental health and weight maintenance across the life-course (O1, O2, O4)
- impact of dietary variety and quality in women during pregnancy on food preferences at weaning (O3)
- the importance of inter-individual variation in response to diet, weight maintenance and dietary choice (O4)
- routes to better dietary health at different lifestages through development of foods that meet nutritional needs and promote healthy ageing (O5)
- methodologies for monitoring dietary intake, dietary health, and general health and the effectiveness of intervention strategies (O4, O6)

O1: Transgenerational transmission of epigenetic states with long term effects:

Events during the early years, starting before birth, have been linked to health and well-being throughout life –obesity, heart disease, diabetes, cancer, mental health, educational achievement and economic status. In order to develop effective preventative and improvement strategies we need to understand the causal links between key exposures and subsequent health in the individual and the modulating role of wider socioeconomic circumstances. This objective will: 1) elucidate the effect of parental diet and nutrition on offspring epigenetic status linked to later health; 2) determine the importance of both maternal and paternal exposures and the role of grandparents 3) elucidate the modulating role of social circumstances in these relationships; 4) identify the importance of inter-individual variation and genetics; 5); investigate the long term transgenerational consequences and the potential for reversibility. **Key Deliverables:**

D1: An understanding of the transgenerational effects of both parent's diet before birth on long term physical and mental health of the offspring, the modulating role of socioeconomic circumstances, and the extent to which this may be reversible (year 5).

D1.1: Knowledge of the effect of parental diet on offspring epigenetic status and long term consequences (year 5). D1.2: Understanding of the modulating role of social circumstances and the influence of grandparents in these relationships (year 3). D1.3: Knowledge of the importance of inter-individual variation and genetics (year 3). D1.4: Evaluation of the potential for later reversibility of early dietary effects (year 5). D1.5: Development of biological measurements and tools for population scale monitoring of diet and health and the impact of interventions (year 5).

O2: Early epigenetic programming and reversibility in model systems: During brain development nerves form connections (synaptogenesis) which are stabilised by the formation of myelin (myelination). Some of these processes are regulated by epigenetic modifications of the brain cells. Studies of these processes in humans are difficult due to ethical concerns, very limited access to key tissues and confounding by non-nutritional environmental factors such as social deprivation. By feeding animals (rats) a diet that mimics the poor diets consumed by deprived women in Scotland we will produce an animal model of nutritional deprivation which will complement the human studies in O1. Animal studies exclude confounding factors and provide access to key tissues such as the brain. Furthermore the shorter gestation and life span of laboratory animals allows us to study transgenerational effects and their reversibility by nutrition in later life. Outcome measures will include learning, fear/anxiety and social development in the

offspring, brain development and transmissibility/remediation **Key Deliverables:** An understanding of the effects of deprived diets during pregnancy on offspring behaviour, the reversibility of these effects and their transgenerational progression. D2.1: Develop diet and establish F1 generation (year 2). D2.2: Describe behavioural phenotype of F1 (year 2) and F2 generation (year 4). D2.3 Describe how brain development, gene expression and epigenetic parameters are affected by maternal diet (year 5).

O3: Perinatal programming of food preferences: Foods frequently rejected by children include those with greatest importance for later health such as fruit and vegetables (F&V). Scottish Health Survey shows no change in F&V consumption between 2008-2013 with only 13% of 2-13 year olds consuming “five-a-day”. Longitudinal studies suggest that infant eating habits track into adolescence/ adulthood; moreover childhood diets rich in F&V, and fibre lower the risk of CVD/metabolic syndrome in later life. Infants have an inborn preference for sweet and umami flavours and dislike sour and bitter, but there is evidence that sensory experiences beginning early in development can modify these preferences in favour of healthier food choices. Babies are first exposed to flavour through swallowing amniotic fluid and then later through breast or formula milk. There is evidence across species, to show that this can be manipulated particularly during late pregnancy to influence subsequent liking and consumption of individual foods with specific high intensity flavours. However there is a lack of prospective studies evaluating the impact of increasing maternal F&V intake during late pregnancy on a child’s subsequent acceptance of F&V, particularly those with a sour/bitter taste. This objective investigates if interventions to improve maternal dietary variety in late pregnancy 1) impact on infant’s food preference/acceptance at weaning and are modified by choice of milk feeding method (breast/formula/mixed), 2) effect offspring growth/body composition, development of the gut microbiota, immune function and metabolic health. **Key Deliverables:** D3.1: Feasibility and validation of component parts of a maternal intervention designed to improve offspring F&V consumption (year 2) D3.2: Contribution to proof of concept for strategies to improve liking and intake of F&V in children (complimented by RD3.2.4, O2) (year 5).

O4: Dietary, social, and behavioural determinants of health across the lifecourse: The links between poor diet and health in the most deprived sectors of society are poorly understood. There is a need to better understand the role of diet in determining physical and mental health and the interactions between diet and socioeconomic related factors such as alcohol consumption, physical activity, health behaviours. This objective will investigate; 1) the way in which the health response to diet is modulated by social and behavioural factors; 2) the key characteristics of beneficial diets; 3) the role of epigenetics in the link between diet and health; 4) the importance of inter-individual variation and genetics; 5) development of novel biological approaches to assessing dietary and environmental exposures. **Key Deliverables:** D4: Identification of the dietary drivers of physical and mental health and weight maintenance across the life-course and a better understanding of their interaction with socio-economic status and inter-individual variation (year 5). D4.1: development of new biological tools to determine food intake and other complex environmental exposures (year 3). D4.2: knowledge of the role of diet in maintaining a healthy weight, and physical health (year 5). D4.3: knowledge of the role of diet in mental health cognitive ageing (year 5). D4.4: dietary interaction with social circumstances in determining physical and mental health (year 3). D4.5: knowledge of the importance of inter-individual variation and genetics in the response to diet (year 4).

O5: Novel foods for optimal micronutrient status: Requirements for micronutrients change throughout life but apart from foods for weaning infants, the food and drink industry has not marketed customised functional foods to meet these requirements. Children, adolescents need additional micronutrients for growth and development while senior citizens have reduced nutrient absorption efficiency and homeostasis regulation. Food taste and texture favoured in youth and old age may differ depending on gustatory function and dental health, requiring a different approach to functional food design. Nutrient handling may also be partly driven by genetic/epigenetic factors and genetic variation has been associated with nutrient status. Healthy food products, which incorporate crops biofortified with micronutrients, have suitable sensory qualities and which supply adequate intakes of bioavailable micronutrients, could help overcome a genetic/epigenetic predisposition to deficiency. The development of novel functional food products for the young and the elderly would help support growth and development in young people, slow the development of chronic diseases and cognitive decline, and boost Scottish commercial innovation in expanding markets. **Key Deliverables:** D5.1: Determination of SNPs affecting human zinc status (year 2). D5.2: Functional food design for healthy growth and ageing (year 3). D5.3: genome-wide association study outcome for micronutrient status evaluation (year 3). D5.4: efficacy of functional foods in improving micronutrient status in at-risk groups (year 5). D5.5: Improve mineral concentrations and yield of broccoli varieties grown in the field (year 2). D5.6: Produce biofortified broccoli for food formulation (year 5).

O6: Biomarkers of dietary health and biological ageing: Chronic diseases such as cardiovascular disease, diabetes and certain cancers typically take decades to develop. In order to demonstrate health benefits of new foods and diets there is a need to identify early indices of metabolic change leading to disease and early ageing (biomarkers). Gene regulation is a function of genetics, diet, lifestyle and long term health. Recent results indicate that a critical component of cell metabolism, the sirtuin/nicotinamide adenine dinucleotide (NAD) system, shows promise as a biomarker of health status which is sensitive to nutrition. Sirtuin function depends on the bioavailability of nicotinamide adenine dinucleotide (NAD) synthesised from dietary sources of vitamin B3/niacin or the amino acid tryptophan. Current patterns of consuming high energy diets, low fruit and vegetable consumption, coupled with sedentary behaviour, increase demand for NAD in cells and tissues. This objective aims to assess the potential of sirtuin/NAD status to act as a biomarker of health. This will be achieved by studying the effect of diet and lifestyle interventions, including sustainable “healthy meal options”, functional foods and exercise programmes that restore or maintain a healthy sirtuin/NAD status. **Key deliverables:** D6.1: development of new biological tools to assess predictive gene signatures in human blood samples (year 2). D6.2: evaluation of sirtuin/NAD system correlations with diet/lifestyle factors and accelerated aging and modulation by diet and lifestyle factors (year 5). D6.3: knowledge of the importance of inter-individual variation in gene signatures associated with health status and aging (year 5).

Technical approach and detailed work plan

O1: Transgenerational transmission of epigenetic states with long term effects: This work will be carried out using, large human cohorts, and closely studied family groups with information on nutritional and socio-economic status, dietary intake, and relevant exposures. It considers the transgenerational effects of these factors on biology and later health outcomes in the offspring and the role of epigenetics (DNA methylation and other relevant epigenetic mechanisms) in particular. The human studies have all been powered on the key outcomes (weight maintenance, major diseases, cognition and

cognitive decline, etc). It will focus in particular on the imprinted genes and repeat elements which have been implicated in numerous health outcomes and which are important for normal brain function, postnatal neurogenesis, cognition, and behaviour. It uses a range of laboratory methodologies (pyrosequencing, next generation sequencing, mass spectrometry, nutrient profiling), innovative study designs (e.g. Mendelian randomisation using genotype) and a range of statistical approaches (e.g. dimension reduction) involving extensive mathematical modelling (e.g. structural equation modelling).

Workplan: Work in years 1-2 will include investigation of transgenerational effects of parental diet and social circumstances before birth on epigenetic states and selected health outcomes in the offspring. We will; hold a KE event at 6 months to summarise findings from the cSRP for key stakeholders (FSS, SG Maternal and Child Health; SG Health Improvement Strategy Division) (KE1.0 Sep2016); collate key birth cohort information on diet, social status, phenotype, etc (M1.1 Oct2016); develop additional epigenetic assays to augment those we currently use (M1.2 Mar2017); carry out the first phase of laboratory analysis (M1.3 Oct2017) and modelling (M1.4 Mar2018); produce three publications and summarise the results in a briefing paper (KE1.1/2 Mar2017&18); assess the policy and general implication of the outputs from O1, O2, O3, O4 and organise 6 monthly briefings for key stakeholders (FSS, SG Maternal and Child Health; SG Health Improvement Strategy Division) (KEi-iv, Sep/Mar2016/17/18).

O2: Early epigenetic programming and reversibility in model systems: Laboratory rats will be fed a diet which accurately reflects the nutritional intakes of deprived populations in Scotland. The offspring of these animals will be compared with the offspring of dams fed a normal complete diet (control), using standard behavioural tests; e.g. open field, novel object recognition and social association. Animal models have proven to be invaluable in studying the mechanisms of behaviour and these standard tests are well recognised and extensively characterised. We will also measure the effect on body weight, growth and composition (fat/lean). Some offspring will be returned to a complete diet at weaning (recuperated group) to investigate the potential for recovery and recuperation by changing the diet later in life. At maturity, animals will be bred to produce a second generation to investigate transgenerational transmission using the same battery of behavioural and physiological measures. The data from the two generations will provide information on how the diet influences the ability to learn and respond to stress. Post mortem samples will be collected from animals in F1 and F2 generations to examine neural development, myelination, synaptogenesis, gene expression and DNA methylation in brain and other tissues. This will provide information on causal links between diet and behaviour.

Workplan: The initial phase of work will focus on the collation of human diet data and the development of rodent diets based on this information (M2.1). We will conduct a pilot study to test palatability and the impact of the experimental diet on behaviour (M2.2). The experimental diets will then be fed to the first group (F0) of female laboratory rats (n=20). The study is powered on the key behavioural outcomes and based on published studies. These animals will be mated with normal males to produce the first generation (F1) offspring which when weaned will be tested using well established behavioural tests (M2.3). Some offspring will be recuperated by feeding either a complete diet or one enriched in key nutrients known to promote brain growth such as methionine, folic acid and long chain polyunsaturated fatty acids. Surplus animals will be culled and tissue samples taken and stored for post-mortem analysis at a later stage in the project. It is envisaged that when the offspring reach approximately six months of age (in the second

year of the project) these animals will be mated to produce the F2 generation (M2.4). These animals will also be subjected to behavioural testing. Post mortem analysis will explore the development of key brain regions such as the hypothalamus, the distribution of key neurotransmitter receptors and the epigenetic regulation of genes such as the glucocorticoid receptor.

O3: Perinatal programming of food preferences: A scoping exercise involving review of both scientific and grey literature and fact finding involving mothers and health visitors will establish current practice in Scotland with regard to (a) adhering to dietary guidance around fruit and vegetable intake while pregnant, (b) potential barriers to compliance around fruit/vegetables with a sour/bitter flavour while pregnant and (c) age and approach to complementary solid food introduction at weaning. This information will inform intervention design. A pilot study will evaluate the optimal presentation format of each target fruit and vegetable (e.g. raw, cooked, whole, smoothie) and assess their palatability and taste profile. First time mothers with low habitual fruit and vegetable intake will be recruited in mid-pregnancy and their current dietary intake established by questionnaire and 7-day food diary. Women randomised to the intervention will have a range of fruit and vegetables with a predominately sour/bitter flavour provided for 4 weeks during late pregnancy. All women will be asked to complete a food diary during the final week to establish compliance and again at ~3 months post-partum. Maternal blood samples may also be collected to measure biomarkers of fruit and vegetable intake. A lactation history will be recorded to capture the duration and exclusivity of breast versus formula feeding. At onset of weaning mothers will be asked to record what, how and when they introduce solids in a weaning diary and rate their infant's reaction for each new food at first introduction with the expectation that this will vary as a function of the items known taste profile. At ~ 6 and 12 months of age taste acceptance tests will be carried out and related to maternal diet during pregnancy and to infant food intake at 12 months using a 3-day food diary. Infant anthropometry will be recorded to monitor growth. Faeces collected at key phases will facilitate characterisation of gut microbiota in relation to maternal diet, breastfeeding status, infant food experience and known allergies while saliva/buccal samples will be collected to assess biomarkers of cardiovascular and metabolic health.

Workplan: The first two years of the new project on the perinatal programming of food acceptance will focus on designing and validating the component parts of the maternal intervention as this will inform the weaning studies in 3.2.4 (O2). In year 1, a combination of literature review and focus groups involving mothers and health visitors will establish current practice and barriers to change with respect to maternal diet while pregnant, and weaning practice (M3.1). Pilot studies involving both non-pregnant and pregnant women (n=25/group) will evaluate the optimal presentation of target fruit and vegetables, their palatability and taste profile (M3.2). After obtaining ethics permission to collect blood, saliva and buccal samples (M3.3), techniques for measuring biomarkers of cardiovascular and metabolic health will be developed and validated in adults, then infants (M 3.6). Pilot studies will optimise infant taste acceptance test methodology (M3.4) and subject to ethics permission phased recruitment to the main maternal intervention will commence [M3.5].

O4: Dietary, social, and behavioural determinants of health across the lifecourse: The outcomes considered include weight maintenance, biological function, health status and cognitive ageing and the studies are appropriately powered for these. O4 includes analysis of the effects of highly controlled human intervention studies from the cSRP and

observational studies in a number of large cohorts (600-2000 individuals) supplemented by smaller scale studies. This work involves psychological and cognitive evaluation in collaboration with clinicians and researchers from other disciplines. It involves the development of novel approaches to the assessment of complex dietary and other exposures using mass spectrometry and genomic based methodologies. The analytical and statistical approaches are essentially as described for O1, augmented by BioSS research into fitting sparse models to high-dimensional data and integration of different data resources.

Workplan: The first 2 years will include work on publicly available databases and samples and data from previous human intervention studies and large observational cohorts with information on socio-economic status, dietary intake, nutritional status, and relevant exposures across the lifecourse. We will; hold a KE event at 6 months to summarise findings from the cSRP for Maternal and Child Health teams (KE1 Sep2016); collate key adult cohort information on diet and social status, phenotype, etc (M4.1 Oct2016) ; develop new genome based assays to assess dietary and socioeconomic-related exposures (M4.2 Mar2017); identify genetic and epigenetic targets for study (M4.3 Mar2017); and carry out the first phase of laboratory analysis (M4.3 Nov2017); carry out statistical analysis and modelling (M4.4 Mar2018); produce three publications and summarise the results in a briefing paper (K4.1/2 Mar2017&18); assess the policy and general implication of the outputs from O1, O2, O3, O4 and organise 6 monthly briefings for key stakeholders (FSS, SG Maternal and Child Health; SG Health Improvement Strategy Division (KEi-iv, Sep/Mar2016/17/18).

O5: Novel foods for optimal micronutrient status: The major objective is to develop novel foods for at-risk population groups and this will be accomplished in co-operation with Baxters Food Group. Reformulation will be based on the research findings from previous RESAS programs, input from e.g. RD3.1.2, and on the current scientific literature. The Hutton will produce trace element (Zn, Se, I)-biofortified brassicas which will be utilised to produce foods of benefit to people at risk of specific nutrient deficiencies, as indicated by their genotype/epigenotype. GWAS demonstrate that single nucleotide polymorphisms (SNPs) and gene methylation patterns explain a proportion of the variation found when analysing micronutrient status and we shall utilise DNA analysis data from an international GWAS study, including 13,000 people with preserved blood samples, to identify certain key SNPs that associate with the status of selected micronutrients (BioSS). In addition, a limited gene methylation analysis will investigate the association of methylation patterns with lifelong lifestyles and their impact on micronutrient status in youth and older age. People from deprived communities will be targeted, and interventions of at-risk individuals with functional foods will elicit micronutrient status responses.

Workplan: The work will be divided into 2 phases. In the first phase for the first 2 years, there will be 4 parallel strands of work. In the first strand, brassicas biofortified with trace elements such as Zn, Se and iodine will be produced at the Hutton, and genotypes will be screened for their ability to yield and accumulate trace elements in two field trials (M5.7 Jan2017; M5.9 Jan2018). Important negative interactions between Zn-accumulation and P-fertiliser application will also be investigated in two field trails (M5.8 Jan 2017; M5.10 Jan2018). Results of these field trials will be communicated in KE events (KE5.4 Oct2016, KE5.5 Oct2017). In the second strand, the SME (Baxters Foods) will cooperate with RINH in the design and evaluation of healthy functional foods which have both a nutritionally scientific basis for formulation and a sensory quality that is suitable for the elderly (M5.1, Mar2017; M5.6 Oct2017; KE5.1, Oct2016 & KE5.2

Mar2017; KE5.3 Nov2017). In the third strand of work, SNPs and methylation patterns associated with a marked plasma zinc response to acute zinc deprivation will be identified in samples from 45 volunteers in a human zinc depletion study in the current rolling program (M5.2, Oct2016; M5.3, Mar2017). In the fourth strand, blood plasma samples from an international GWAS study will be analysed for particular micronutrients. The micronutrients selected and numbers of subjects (up to 13,000 available) will be determined in consultation with BioSS and will avoid repetition of published work (M5.4, Jul2017; M5.5 Mar2018). In the second phase, high-accumulating brassica genotypes will be selected, grown in field trials then supplied for food formulation. The biofortified brassicas will be incorporated into the functional foods developed with the SME, and the resulting product will be tested in an intervention study (Years 3-5). Volunteers from economically deprived communities will be genotyped for the presence of key SNPs affecting micronutrient status. The volunteers will be grouped according to these SNPs in order to assess their response to the food intervention, in terms of improved micronutrient status, using the functional foods. An appropriate control group will be included.

O6: Biomarkers of dietary health and biological ageing: The work will identify a sirtuin/NAD blood profiles predicting health status and/or long term health of individuals. This will be achieved by studying the status of the sirtuin/NAD system in human volunteers exposed to a variety of dietary and metabolic conditions. Access to human intervention studies and study populations will be achieved through collaboration with nutritionists, exercise physiology scientists, psychologists and clinicians. It will include a range of study designs involving cohorts with information on dietary intake, nutritional status, exercise and life course health markers as well as human intervention studies to test the status of the sirtuin/NAD system under a variety of conditions. Gene expression profiles and circulating biochemical and metabolite analyses (e.g. the molecular profiles of the sirtuin gene family and associated NAD biosynthetic enzymes) will be determined. Diet and/or lifestyle factors (B vitamins, protein sources, amino acid profiles, exercise) will be correlated with molecular profiles of the sirtuin/NAD system. Statistical analysis of gene expression data (e.g. principal component analysis) will be performed with BioSS. Gene expression profiles will be linked to; glucose sensitivity, obesity, diets high in fat and sugar, advanced glycation end products (RD3.1.2, O3); responses to interventions (exercise strategies, sustainable plant proteins, food formulations, amino acid profiles); and other indices of health status (e.g. NAD, NADP, lipid profiles, inflammatory, oxidative markers). It will include analysis of the effects of human intervention studies from the current SRP where dietary protein sources and amino acid profiles were defined and controlled.

Workplan: Work in the first 2 years will include; design and optimisation of assays (M6.1 Nov2016); analysis applied to diabetes/glucose intolerance (M6.2 Feb2017); analysis of effect of protein intervention (M6.3 Nov2017); evaluation of markers of metabolic health (M6.4 Mar2018) correlated with sirtuin/NAD system.

Expertise: This RD builds on effort and expertise from current and previous RESAS programmes. The PIs are recognised leaders in their fields with the diverse skills needed to deliver this programme. They also have extensive experience of knowledge exchange activities involving the public, industry, government and policy makers. They sit on several high level committees providing advice on diet and health. These include; the UK Scientific Advisory Committee on Nutrition; the BBSRC Bioscience for Health Strategy Panel; International Council on Plant Nutrition; Scottish Government short-life working group on maternal nutritional intervention postpartum; Scottish Government short-life

working group on vitamin D.

Key linkages, interdisciplinarity & collaboration: The overarching aims of our stakeholders typically cover more than one RD and this RD is designed to provide outputs in collaboration with other parts of the WP and Theme. These 'internal' links have been set out beside each objective. The work proposed here spans a number of disciplines and will be carried out in collaboration with exercise physiologists, psychologists, behavioural scientists, crop scientists, clinicians, and molecular biologists. It also involves research links with a number of HEIs and stakeholders. This RD adopts a multi-disciplinary approach, bringing together the latest thinking in biology and the social and behavioural sciences to address persistent societal problems in new and innovative ways. **O1, O2, O3** and **O4** all involve consideration of the biology of behaviour change and link directly to RD3.2.4. O1 also involves collaboration with University of Cambridge and UCL on the early socioeconomic determinants of mental wellbeing. **O2 Links:** The animal model work O2 is designed to parallel the work in O1 in an intervention that it would not be possible to carry out in human studies. The work in **O3** precedes and complements studies on flavour exposure at weaning, RD3.2.4.(O2), and links to infant microbiota work in RD3.2.2(O3). The societal, behavioural and lifestyle work in **O4** links with related work in RD3.2.2; RD3.2.4; RD3.2.3; RD3.4.1 RD3.4.2, RD3.2.1 (O1,O5). **O5** will utilise information from RD3.1.2; brassica work has relevance to the genetic improvement of crops (RD2.1.1); resource efficiency (RD2.1.7); O4; Baxters (SME); Nottingham University. **O6** links with work on advanced glycation end products as biomarkers of aging RD3.1.2(O3); accesses expertise in exercise physiology within Glasgow University; and underpins infant biomarker development in **O3**.

Added Scientific Value: The research described here is designed to complement work on diet and health elsewhere. The need to improve diet is relevant to the whole of the UK but there are problems that are particularly acute in Scotland. Examples include the greater problem of deprivation and its persistence across generations, and poorer status for particular foods (fruit and vegetables) and nutrients (fats, folate, vitamin D). This RD focuses on such issues and on problems where a more holistic, cross-disciplinary approach is required. Examples include: work linking health benefits to the development of foods elsewhere in the programme; linking biological insights on behaviour with the strategies designed to produce behaviour change; understanding the effect of diet in relation to the particular socioeconomic environment that results in the "Scottish Effect" amplifying the effect of deprivation. A number of the PIs hold significant non-RESAS grant awards which will work synergistically in areas related to the research described here.

KE, Audiences and Impact

Audience: The provision of advice to support policy and KE is central to the work and is designed to be specific to problems and opportunities in Scotland. The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

The KE plan has been developed in meetings with our stakeholders: Food Standards Scotland; Scottish Government (Child & Maternal Health; Food, Drink and Rural Communities; Health Improvement Strategy Division); NHS Scotland; Nourish Scotland; Scottish Food and Drink Federation.

Impact: The ultimate aims of this RD are to assist our stakeholders achieve their goals in relation to diet and health and identify the policy interventions and strategies likely to be

most effective in improving dietary health. Where possible the RD outputs have been designed to produce complete units of policy relevant information from year one. In order to ensure impact we undertake to: 1) translate research findings into a form that is useful to our stakeholders; 2) ensure that the information is made available to the appropriate organisations, teams, and individuals; 3) assist with knowledge exchange in relation to implementation activities relating to our outputs; 4) assist in monitoring the effectiveness of implementation activities. Research findings will be published in open access formats where possible and academic excellence and quality will be assessed as part of the REF2020 exercise and using standard publication metrics.

Year 1: 2016/17	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1KE: summarising key findings from the previous programme for Maternal and Child Health teams						KE1.0						
O1.1: Collate key birth cohort information on diet, social status, phenotype, lifestyle							M1.1					
O1.2: Develop additional epigenetic assays to augment those currently used												M1.2
O1KE: produce one publication and stakeholder briefing based on O1												KE1.1
O2.1: Collate diet information				M2.1								
O2.2: Prepare and test diet formulation												M2.2
O2KE: Produce publication describing diet												KE2.1
O3.1: Establish current practice/barriers to change re- pregnancy diet and weaning practice						M3.1						
O3.2: Select target fruit and vegetables, evaluate their optimal presentation, palatability and taste profile												M3.2
O4.1: Collate key adult cohort information on diet and social status, phenotype, life history								M4.1				
O4.2: Develop new genome based assays to assess dietary and socioeconomic-related exposures												M4.2
O4.3: review of genetic and epigenetic targets for study												M4.3
O4KE: produce one publication from O4												KE4.1
O5.1: Design of healthy functional foods: diet design for optimum nutrition												M5.1
O5.2: Targeted genotype and epigenotype analysis: sample procurement							M5.2					
O5.3: Targeted genotype and epigenotype analysis: sample analysis												M5.3
O5KE: Discussions with Baxters on functional food design								KE5.1				KE5.2
O5.4: Determine effects of increasing Zn, Se, P and I fertiliser on mineral concentrations and yield of broccoli.										M5.7 M5.8		
O5KE: LEAF Farm Event								KE5.4				
O6.1: Design and optimisation of assays								M6.1				
O6.2: Analysis applied to diabetes/glucose intolerance											M6.2	
O6KE: Conference					KE6.1							

O1/2/3/4 KE4/5 event: Briefings for key stakeholders (FSS, SG Maternal and Child Health; SG Health Improvement Strategy Division) on outputs from O1, O2, O3, O4.						KEi							KEii
Annual Report (Year 1)													R1

RESEARCH DELIVERABLE NUMBER: 3.2.1

Work planning and timetable for Year 2: Please include major milestones: key research milestones (M), deliverables (D), KE/impact events (E), reports (R) and their timing.

Year 2: 2017/18	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.3: carry out the first phase of laboratory analysis							M1.3					
O1.4: carry out statistical analysis and modelling												M1.4
O1KE: produce two publications and a stakeholder briefing												KE1.2
O2.3: Wean F1 and test behaviour								M2.3				
O2.4: Breed F2 generation												M2.4 D2.1 D2.2
O2KE: Produce publication describing behaviour of F1												KE2.2
O3.3: Obtain ethics permission to collect biological samples / develop and validate procedures for measuring biomarkers of health in adults, then infants			M3.3									M3.6
O3.4: Conduct pilot study of infant taste acceptance methods									M3.4			
O3.5: Obtain ethics permission for main maternal intervention and commence phased recruitment												M3.5 D3.1
O4.4: carry out the first phase of laboratory analysis								M4.3				
O4.5: carry out statistical analysis and modelling												M4.4
O4KE: produce two publications from and a stakeholder briefing based on O4												KE4.2
O5.5: International GWAS study analysis: sample procurement				M5.4								
O5.6: International GWAS study analysis: sample analysis												M5.5 D5.1
O5.7: Design of healthy functional foods: diet design for sensory qualities							M5.6					
O5.8: KE events: Discussions with Baxters on functional food design								KE5.3				
O5.9: Determine effects of increasing Zn, Se, P and I fertiliser on mineral concentrations and yield of broccoli.										M5.9 M5.10 D5.5		
O5KE: LEAF Farm Event							KE5.4					
O6.3: analysis of effect of protein interventions on sirtuin/NAD system								M6.3				

O6.4: evaluation of markers of metabolic health correlated with sirtuin/NAD system													M6.4
O1/2/3/4 KE8/9 event: Briefings for key stakeholders (FSS, SG Maternal and Child Health; SG Health Improvement Strategy Division) on outputs from O1, O2, O3, O4							KEiii						KEiv
Annual Report (Year 2)													R2

Name of RD: 3.2.2: Dietary components of healthy diets and their effects

Research aim and key drivers

To achieve the aspirations set out in *Becoming a Good Food Nation*, Scotland's most recent policy document on food, there has to be a rebalancing of the Scottish population's dietary intake. The current crisis in public health (obesity, diabetes, cardiovascular disease, stroke and some cancers) is strongly rooted in an imbalance in dietary components. A healthy balanced diet requires reductions in fat, salt, sugar, and in overall calorie intake, but an increase in fibre and an appropriate level of protein intake. To persuade the population to change their dietary habits, and the food industry to reformulate products to include healthier components requires a strengthening of the evidence base for the benefits of altering dietary consumption. This is directly in line with the Scottish Government's policy drivers: *Recipe for Success / Becoming a Good Food Nation, Supporting Healthy Choices and Prevention of Obesity route map*.

Thus the aim of this RD is to further strengthen our understanding of the role of dietary components (in particular fibre and protein) in a healthy diet. The information gained from this research will lead to better policy advice, particularly in relation to healthy weight management, metabolic control, mental health and intestinal health. It will also lay the foundations to produce healthier primary products and aid the food industry in developing new and healthier products (e.g. products that aid hunger control and satiety). This will be addressed through four interlinked objectives:

O1: Healthy weight management and improved metabolic and mental health

O2: Identification of gut bacteria and compounds of relevance to vascular and gut health

O3: Linking fibre consumption to intestinal microbial communities and health

O4: Mathematical modelling of interactions between diet and gut microbial communities

Food Standards Scotland (FSS), who will be instrumental in transferring the research outcomes into public health, have been consulted in the development of the proposed research. Consultations have also taken place with Scottish Government Food, Drink and Rural Communities, Scottish Government Public Health Division, the Scottish Food and Drink Federation, a UK food retail sector representative, an international food ingredient processor & an international food producer in the area of functional fibres, starches and protein-carbohydrate interactions in novel food development.

Summary of the proposal:

Dietary intake is a major contributing factor for most of the common health problems that affect the general population, including overweight, type 2 diabetes, gut disorders, cardiovascular disease, cancer and mental health. While many of these conditions represent an increasing burden in the ageing population, nutrition during childhood and early development, beginning in the womb, is known to exert an important influence on health in later life. Digestible dietary components (most proteins, fats, carbohydrates and micronutrients) influence metabolism and health following their absorption into the systemic circulation from the upper intestinal tract, but the diet also contains non-digestible components such as fibre that are used by the microbes that live in our intestines ("gut microbiota"). Interactions between the host and the resident gut microbiota are now known to play a role in

multiple health outcomes, including metabolic syndrome and intestinal disorders. Furthermore, research performed under the cSRP revealed that the fibre component of the diet has a major impact upon the species composition and activities of the gut microbiota. The research proposed here will investigate the impact of both digestible and non-digestible dietary components upon human health.

O1. Healthy weight management and improved metabolic and mental health.

Obesity and overweight remain compelling nutrition issues worldwide. Food choices, especially in an environment of ready availability and plentiful supply of cheap ready to eat foods, should be a primary focus of preventative measures. Understanding the mechanisms of hunger and satiety and how particular foodstuffs and nutrients affect appetite and motivation to eat is important for evidence-based interventions to achieve weight control and design of community-wide dietary strategies that are effective across the entire lifespan. Food choices also affect health via activities of the intestinal microbiota, with typical Western diets rich in refined carbohydrates, fats and protein, and low in fibre, likely to be less health-promoting. However, a strong scientific evidence base is required to develop effective strategies to improve diet. Three main approaches will be investigated:

1. Food reformulation i.e. modification of the composition of individual processed food products, is increasingly recognised as a strategy to maximise satiety, and to maintain a healthy body weight. Acute and chronic human dietary intervention trials will be carried out to enable control of a healthy body weight and maintain mental health (**D1.1a**, Y2; **D1.2a**, **D1.6a** Y5), working with the food industry to produce foods that make people feel full for longer, so that they don't need to resort to a calorie restricted diet (traditional dieting). Rodent studies will complement human studies to establish the effect of fibre on appetite regulation (**D1.3a**, Y2).

2. Fibres from cereals might have different health benefits compared with those from fruits and vegetables. Data from a current Programme Strategic Partnership indicate that elevated oat intake may contribute to health by lowering blood pressure. Current recommendations by the Department of Health are that a healthy diet should include 30 g of fibre per day, yet many in the UK fail to meet this target. It will be investigated whether whole grain cereals might constitute a viable healthy eating option for those unable to meet the recommended intake of fruit and vegetables (**D1.4a**, Y4).

3. Over the long term, poor metabolic health (raised blood lipid levels, diabetes) and obesity are risk factors for mental health degeneration (eg Alzheimer's). Responses to high fat diets of markers of neural degeneration that underpin decline in mental health will be determined (**D1.5a**, Y3). The impact of dietary components (fatty acids/fibre) on these (**D1.5b**, Y4) and consequential effects on mental cognition (**D1.5c**, Y5) will be studied and determined.

O2. Identification of gut bacteria and compounds of relevance to vascular and gut health. Microbial activities with relevance for human health are carried out by specific subgroups of intestinal bacteria, which can be targeted by dietary intervention. Certain diets (high in protein and fats) appear to promote production of trimethylamine (TMA) by gut bacteria, which has been linked to atherosclerosis development via the production of trimethylamine oxide (TMAO) from TMA in the liver. TMAO is a novel potent marker for cardiovascular disease risk that can potentially affect blood pressure regulation. However, it is not known which gut

microbes are the predominant contributors to this process or how they may be affected by diet. TMA producers (and possibly utilisers) will be identified and characterised (**D2.1a**, Y1, **D2.2a**, Y2, **D2.2b**, Y3).

Similarly, it has been shown that some diets and gut disorders promote the microbial formation of lactate, which destabilises the balance of the gut microbiota and has been linked to chronic diseases such as inflammatory bowel disease. Fortunately, some bacteria can convert lactate into health-promoting short chain fatty acids (SCFAs) such as butyrate. The aim is to discover which bacteria are most important for carrying out these conversions in the gut, and how they respond to feeding with different dietary substrates (**D2.3a**, Y2, **D2.3b,c**, Y5).

SCFAs produced by the gut microbiota have beneficial effects on the colon but possibly also on blood vessels, as suggested by results from a mouse model. Thus blood pressure-lowering effects of increasing wholegrain consumption previously observed by RINH scientists may originate from the bacterial fermentation product propionate. A human intervention study will look at the effects of propionate supplementation using a colon-targeted delivery system on blood pressure and related regulatory markers (**D2.4a**, Y1, **D2.4b,c**, Y2; **D2.4d,e,f,g**, Ys3-5).

O3. Linking fibre-consumption to intestinal microbial communities and health. Recent reports from the Scientific Advisory Committee for Nutrition and elsewhere highlight the importance of dietary plant fibre and resistant starch (non-digestible carbohydrates or NDC) for gut health, weight control and metabolic health, which are mainly exerted via effects on the gut microbiota. Better understanding is required to justify and refine the case for NDC as health-promoting food components and for regulatory assessment of novel foods that target the large intestine (e.g. prebiotics). Moreover the food industry depends on a proper scientific understanding of the impact of fibre upon the microbiota in order to design health-promoting food products and to substantiate health claims on existing products. The capacity among diverse species of human colonic bacteria to degrade different NDCs and form health-promoting metabolites will be investigated (**D3.1a,b,c**, Y2; **D3.1d,e**, Ys3-5, results from novel crops from other RDs). Defined microbial mixtures will be established to further our understanding of microbial interactions in NDC breakdown and metabolite formation (**D3.2a,b** Y2; **D3.2c,d**, Ys3-5, results from novel crops in other RDs). Western diets low in fibre are hypothesized to drive the development of fundamentally different, and potentially less healthy, intestinal microbial communities compared to fibre-rich diets. Replacing protein from meat with plant-based protein is being investigated within RD2.1.8. This type of reformulation may beneficially modulate the gut microbiota due to the increased ingestion of fibre and other bioactives alongside the plant protein source, which will be investigated by analysis of samples from human volunteer studies carried out in O1.1 (**D3.4a**, study 2, Y3, **D3.4c**, study 3, Y5) and RD2.1.8 (**D3.4b**, Y4).

In addition, the effect of diet on the microbiota and health over the whole life course will be investigated. The infant gut microbiota changes dramatically after the introduction of a more complex diet at weaning and influences the development of the child's immune system. Work carried out in CWP5.2 RD3 has involved collecting samples from babies from birth through to age 5, to establish when an infant microbiota becomes adult-like. These samples will be evaluated to determine the detailed microbial changes occurring in early life (**D3.3a**, Y1, **D3.3b**, Y2). Subsequently the microbial composition of faecal samples from babies and

mothers recruited to the study carried out in RD3.2.1 (Objective 3) will be analysed and results related to maternal and infant dietary intake and frequency data (**D3.3e**, Y5). In children who suffer from inflammatory bowel disease, diets that largely exclude fibre are sometimes used as treatment options. Samples collected from a human volunteer study will be used to ascertain to what extent removing fibre from the diet impacts the microbiota, and how this may in turn impact host inflammatory status (**D3.3c**, Y2). Furthermore, there is evidence that the balance and diversity of the gut microbiota becomes compromised in the elderly, with negative consequences for health, making it particularly worthwhile to examine the benefits of fibre supplementation in this group (**D3.3d**, Y3).

O4. Mathematical modelling of interactions between diet and gut microbial communities. Model building is central to translating the biological knowledge gained from experimental work into useful predictions for digestive health. During the current programme (CWP5.2, RD3), a mathematical model for the investigation of the metabolism of dietary carbohydrates by the human gut microbiota has been developed, which successfully reproduced microbial and metabolite changes seen during a prior study of microbiota response to environmental pH. The model will be expanded to more closely represent the human gut by incorporating multiple compartments and absorption (**D4.1a**, Y1), to enable prediction of response to different dietary carbohydrates (**D4.2a**, Y2). Further work will run simulations to investigate the effect of dietary composition, inter-individual variation and temporal fluctuations on bacterial composition and metabolite production. Data from lab-based continuous culture studies and human dietary studies (both from the cSRP and work performed under this RD) will be utilised. Work under this objective will also be closely aligned to pure and defined mixed bacterial culture work under O3 to address specific questions on NDC degradation potential of specific microbes and cross-feeding interactions between bacteria, which will feed back to improve the model (**D4.3a** Updated model code based on new information from O1-3 including details of cross-feeding interactions (Y4) **D4.4a** Submit manuscript (Y5).

Technical approach

O1. Healthy weight management and improved metabolic and mental health. The combination of *fermentable soluble fibres* (such as pectin or beta glucan) and *insoluble fibre* (such as bran) with a *protein* rich meal are hypothesized to be highly satiating, as this is designed to impact on the physiological satiety cascade from early ingestion (release of gastrointestinal peptides) to short-chain fatty acid (SCFA) production in the lower gut. The dietary protein-carbohydrate balance also drives other microbial processes, including the formation of N-nitroso compounds, which will be monitored in the current study. Meals or snacks/beverages (of high/low protein with different fibre types) will be fed in short term studies to assess within-day appetite control. Both the physiological (gut hormones, glucose, insulin) and psychological (hunger, satiety) responses to feeding will be examined in 20 men & women in a within-subject repeat testing design to optimise a satiety enhancing product (acute human intervention study, **D1.1a**, Y1-2). Collaboration with food industry colleagues will provide ingredients or reformulate existing products and aid the conduction of qualitative approaches for collecting data on consumer acceptance of novel foods/meals. Longer-term energy compensation studies will be designed to include assessment of body weight and body composition, where faecal samples to assess gut microbiota response will also be collected (chronic intervention study, **D1.2a** Y3; pilot and

main intervention study in a vulnerable group (ageing or young) to assess impact of diet on mental health, **D1.6a**, Y4-5). Human work will be complemented by rodent studies (n~4x50) to address whether the satiety effects of fibre are due to gut hormone release (PYY, GLP1) or direct effects of SCFAs, as microbial breakdown products of fibre, on brain appetite centres. Gut hormone and SCFA satiety responses will be determined in mice fed high fat plus fibre enhanced diets. (**D1.3a**, Y2)

Based on in vitro work on wholegrain carbohydrates (O3 D3.1.1), a human study will be carried out in which the effects of two diets containing at least 30 g fibre per day will be compared with a low fibre diet over a 10-week intake period (**D1.4a**, Y4). The high fibre diets will be either cereal-based (focussing on barley) or fruit/vegetable-based. This study will link together with the acute cereal study proposed in RD3.1.1, investigating cereals bred for specific nutritional characteristics. The effects of the two different fibre sources on various health markers will be compared, including gut microbiota (composition and activity), blood pressure, blood cholesterol, blood TMA and TMAO concentrations, inflammatory status and satiety. Work carried out during a current Programme Strategic Partnership led to the development of new recipes, which will provide meal options to increase the amount of barley included in the diet.

Through rodent studies, markers of neural degeneration which lead to cognitive decline and driven by poor diet will be identified, and their responses to different diets investigated. Initially the detrimental effect of chronic high fat diet feeding which affects cognition will be investigated in cells of the entorhinal cortex and hippocampus, most likely sites of early degeneration and these will be compared to chow fed control mice to establish markers (**D1.5a**, Y3). The beneficial nutritional effects of specific dietary components on these markers will be determined (n~4x50) (**D1.5b**, Y4) and cognition studies will assess beneficial responses (**D1.5c**, Y5).

O2. Identification of gut bacteria and compounds of relevance to vascular and gut health. A method for TMA/TMAO determination will be established (**D2.1a**, Y1). Key producers (and potentially degraders) of TMA will be identified from our extensive collection of human gut microbes (**D2.2a**, Y2), and investigated for evidence of how different dietary components can alter their abundance, activity and competitive ability in vitro in pure culture or mixed microbial communities (**D2.2b**, Y3). Activities of the microbiota may also be responsible for wholegrain mediated effects on blood pressure, by increased TMA production and/or increased propionate production, which could modulate the activity of the trimethyl amine oxidase in the liver, leading to a decrease in circulatory TMAO. This will be investigated as part of the dietary intervention with wholegrain under O1 (D1.4.1).

Screening for bacterial lactate utilisers will be carried out in fermentor systems inoculated with faecal slurries and spiked with lactate (**D2.3a**, Y1-2). Altering the environmental parameters (eg substrate supply, pH) will determine their impact on overall lactate consumption. Labelled lactate will also be used for incubations with mixed faecal bacteria and Raman microspectroscopy will be used to detect cells that have incorporated the labelled substrate (in collaboration with University of Oxford). After isolating these cells, the key species that contribute to this process will be identified using techniques such as whole genome amplification and DNA sequencing (**D2.3b.c**, Y2-4). The impact of lactate utilising strains on host immunological markers will also be determined (**D2.3d**, Y5).

A colon-targeted delivery system resisting the digestion process to deliver propionate directly to the colon is currently being developed in collaboration with Quay Pharma. Progress on capsule manufacturing (**D2.4a**, Y1) and stability/efficiency (**D2.4b**, Y2) will be monitored. This will be used to supplement non-treated hypertensive volunteers over 10 weeks to assess the effect on blood pressure and vascular function. Volunteer recruitment will be carried out using general practice register (**D2.4c**, Y2). Non-invasive assessment of arterial function using the SphygmoCor device and 24hr blood pressure measurements will be carried out **three times during the intervention** (**D2.4d**, Y3). Plasma concentrations of SCFA will be determined. **Estimated glomerular filtration rate (eGFR) will be calculated from plasma creatinine concentrations.** Systemic markers of endothelial function and TMAO/TMA concentrations will also be measured (**D2.4e**, Y3). Dietary intake will be assessed prior to the study and during the intervention using 4 day food diaries (**D2.4f**, Y4). A final report will be submitted and a manuscript written and submitted to peer-reviewed journal (**D2.4g**, Y5).

O3. Linking fibre-consumption to intestinal microbial communities and health. This work includes in vitro studies to elucidate the microbial interactions leading to fibre breakdown, as well as analysis of samples from human intervention studies carried out under O1 and RD2.1.8. The group's extensive collection of human gut bacterial isolates will be utilised, as well as mixed faecal bacteria cultured, in order to improve knowledge of the key microbial contributors to fibre degradation (**D3.1c**, Y1-2) and microbial interactions and metabolite production (**D3.2a,b**, Y1-2; **D3.1d,e**, **D3.2c,d**, Y3-5, results from novel crop becoming available during the programme). Novel groups of intestinal microbes will be isolated from human volunteers from both Scotland and more agrarian societies where fibre consumption is much higher (**D3.1b,c**, Y1-2). Bacterial isolates of interest will have their genomes sequenced, using Illumina sequencing. Draft genomes will be studied to identify genes and pathways relevant to activities such as carbohydrate utilisation and TMA production (see O2). The fibres studied will include alpha and beta-linked glycans, resistant starches, pectins, hemicellulosic compounds and various oligosaccharides, from commercial sources as well as from crops under study in other RDs (RD2.1.8, 3.1.2, 3.1.4) as they become available over the span of the SRP. The latter will include carbohydrates from specific crop lines high in β -glucan and arabinoxylan (RD3.1.1, **D3.1a**, Y1-2) to identify specific whole grain foods which may alter microbial fermentation, particularly in the distal colon, to inform a human intervention study carried out under O1 (D1.4.1). Another focus will be on legumes that are being investigated as replacements for dietary meat protein elsewhere (RD2.1.8). Microbial communities in fermentor systems inoculated with faeces and in defined microbial consortia and faecal samples from human dietary interventions (**D3.4a,b,c**, Y3-5), in will be studied with molecular techniques (mainly surveying of 16S rRNA genes using Illumina MiSeq sequencing and quantitative techniques, eg qPCR). Generation of beneficial metabolites, such as SCFAs, will be determined by gas chromatography. The release of bound phytochemicals from plant fibre (in particular cereal bran and fibres from vegetables and soft fruit) will be investigated alongside work in RD3.1.1. Differences in relevant structural attributes (e.g. molecular weight, monosaccharide composition) between active fibres before and after fermentation will be assessed at Hutton.

For work on microbiota-mediated health effects over the life course, samples

collected from 10 babies at monthly intervals for the first two years of life, and subsequently at 6-monthly intervals, will be analysed by qPCR to establish the key timepoints or major microbial changes, and a subset of samples will be analysed using next generation sequencing (**D3.3a,b**, Y1-2). This data will be used to determine the key timepoints at which to collect samples in the intervention study in RD3.2.1, during which microbiota composition will also be analysed (**D3.3e** Y5). To examine the effect of fibre exclusion due to enteral nutrition in children, microbiota profiles will be obtained by 16S rRNA gene sequencing before, during and after the intervention, and correlated with markers of host immunological response, and health outcomes (e.g. remission of their Crohn's disease) (**D3.3c**, Y2). A dietary intervention study will also be conducted to examine the impact of specific fibre supplementation on faecal microbial community composition and diversity in healthy elderly volunteers (n=30, to include both sexes). This will also use high throughput DNA sequence analysis to profile the microbiota, together with analysis of plasma metabolites and selected biomarkers of health (**D3.3d**, Y3).

O4. Mathematical modelling of interactions between diet and gut microbial communities. Firstly, to more closely represent conditions in the human colon, the model will be extended by including metabolite absorption and allowing for multiple compartments (**D4.1a**, Y1). Secondly, the model will be expanded by predicting microbial responses to a range of carbohydrate sources (**D4.2a**, Y2), and validating against in vitro data from the cSRP. Thirdly, with this revised model, simulations will then be run to investigate how dietary composition influences bacterial composition, metabolite production, and fluctuations therein, both within and between volunteers. Where relevant, information from new data (O1-3) will be incorporated into our model as they become available. The model simulations will also generate hypotheses of microbial interactions in fibre breakdown that will be tested and refined using mixed bacterial cultures under O3. Finally, any model improvements will be incorporated into model code already developed and wrapped in a user-friendly software interface (**D4.3a**, Y4) and published (**D4.4a**, Y5).

Detailed work plan (O: Objective, D: deliverable, M: milestone)

O1. Healthy weight management and improved metabolic and mental health.

O.1. Acute human dietary intervention study in lean and overweight men and women (20 subjects, satiety response to test meals). **M1.1a** (Jul16) Governance and Ethics approval. **M1.1b** (Aug16) Implement a food matrix with food industry support **M1.1c** (Jan17) Complete data collection for half volunteers **D1.1a** (Jun17) Report of acute dietary intervention study.

O1.2. Conduct a second chronic dietary intervention study in lean and overweight men and women (20 subjects, 4 weeks) to assess the influence of protein-carbohydrate (fibre) matrix on appetite control and body weight. Assess influence on gut microbiota. **M1.2a** (Apr17) Implement a food matrix with food industry support **M1.2b** (May17) Governance and Ethics approval. **M1.2c** (Nov17) Complete data collection for half volunteers.

O1.3 Determine the role of dietary fibre on satiety responses in mice. **M1.3a** (Sep16) Complete first mouse satiety study. **M1.3b** (Oct16) Obtain Home Office licence for new rodent studies. **M1.3c** (Dec16) Complete second mouse satiety study. **M1.3d** (May17) Distinguish the role of gut hormones compared to acetate on satiety responses in mice fed high-fat, but fibre-enriched diets. **M1.3e** (Sep17) Analyse effects of diets on satiety-related neuropeptide levels using transgenic

mice. **D1.3a** (Mar18) Report on fibre and satiety studies.

O1.4. Dietary intervention study to compare the impact of increased fibre intake from different sources on the gut microbiota activity and composition and markers of cardiovascular risk (60 volunteers). **M1.4a** (Mar18) Ethical approval obtained for fibre intervention study.

O2. Identification of gut bacteria and compounds of relevance to vascular and gut health.

O2.1. Set up an LC-MS method for measuring TMA and TMAO concentrations and analyse samples from bacterial work and human intervention trials. **D2.1a** (Feb17) Method for TMA/TMAO determination available.

O2.2. Screen collection of human gut microbes to identify key microbial producers of TMA, and show how different dietary components such as choline and carnitine can alter their abundance and activity. Assess how changes in dietary substrate provision impact the ability of TMA producers to compete with other gut bacteria. **M2.2a** (Aug17) TMA-producing isolates available. **D2.2a** (Feb18) Genome sequences for TMA producers available.

O2.3. Screen for bacterial lactate utilisers in fermentors inoculated with faecal slurries and spiked with lactate under different environmental conditions, including studies with labelled lactate. **M2.3a** (Aug16) Lactate utilisers identified from fermentor incubations. **M2.3b** (Jan17) Method developed for combining labelled substrates with Raman microspectroscopy **M2.3c** (Jul17) Lactate utilisers identified from labelled substrates by Raman microspectroscopy. **D2.3a** (Jan18) Genomes available from single cell genomics on lactate utilising cells.

O2.4. Carry out randomised placebo-controlled supplementation trial to evaluate the effects of colonic-delivered propionate on blood pressure and related regulatory markers in non-treated hypertensive volunteers (70 healthy men and women, aged 40 to 65, sample size estimated based on 5mmHg difference in systolic blood pressure). **D2.4a** (Sep16) Progress report on capsule manufacturing. **M2.4a** (Mar17) Obtain ethical approval and begin recruiting volunteers. **D2.4b** (May17) Report on stability and efficiency of the system delivery. **D2.4c** (Nov17) Progress report on volunteer's recruitment.

O3. Linking fibre-consumption to intestinal microbial communities and health.

O3.1. Determine the fibre degradation capacity of existing collection of human gut isolates and novel isolates obtained from high fibre-consuming individuals. The results obtained will inform rational choice of strains for investigation of fibres obtained from other RDs, co-culture work (SO3.2) and dietary studies to be carried out later on in the programme. **M3.1a** (Sep16) Key fibre-degrading bacteria identified based on existing strain collection and commercial carbohydrates. **M3.1b** (Jan17) First set of carbohydrates for investigation obtained from Hutton. **D3.1a** (Apr17) Report on bacteria capable of utilising β -glucan and arabinoxylan components of new emerging barley crops. **M3.1c** (Jun17) Panel of novel gut isolates available in pure culture. **D3.1b** (Nov17) Genome sequences available for novel fibre-degrading isolates. **D3.1c** (Feb18) Report on dominant bacterial species characterised for their degradation capacity of a panel of commercially available carbohydrates and first set of carbohydrates originating from Scottish crops.

O3.2. Establish microbial inter-dependencies in fibre breakdown with defined mixed bacterial cultures and faecal slurries, including examination of the impact of

species identified from pure culture work that have enhanced fibre-degradation abilities on microbiota composition and metabolic activity to faecal incubations from individuals with a low capacity for fibre degradation. **M3.2a** (Mar17) Methods for microbial community analysis of defined mixed consortia established. **D3.2a** (Sep17) Report on key microbial cross-feeding interactions based on simple microbial communities (3-6 members). **D3.2b** (Mar18) Report on key microbial cross-feeding interactions based on more complex microbial communities (10-20 members).

O3.3 Establish microbiota-related health effects over the life course. **D3.3a** (Dec16) Report on changes occurring in the infant microbiota around weaning. **D.3.3b** (Jun17) Report on inter-individual variation in babies and key times at which the microbiota reaches an 'adult-like' status. **M3.3a** (Aug17) Fibre exclusion study: correlation of microbiota compositional profiles with host inflammatory and health biomarkers. **D.3.3c** (Jun17) Manuscript describing the impact of excluding dietary fibre sources on the human microbiota and on host inflammatory status.

O4. Mathematical modelling of interactions between diet and gut microbial communities.

O4.1. Extend model to allow for multiple compartments that reflect different sections of the gut (and hence differences in environmental conditions such as pH) and to incorporate metabolite absorption. **D4.1a** (Dec16) Model code that incorporates multiple compartments and absorption.

O4.2. Extend model to predict response to different types of carbohydrate using data from current programme, initially focusing on inulin and pectin to derive growth parameters for the model. Validate revised model against mixed microbial population data from existing continuous fermentor studies. **D4.2a** (Jan18) Model code that incorporates bacterial growth on different types of carbohydrate.

Key linkages, interdisciplinarity & collaboration

Human intervention trials in RD2.1.8 will provide human faecal samples to establish effects exerted via the gut microbiota (O1/3).

The investigations into the roles of cereals on health (O1/3) link closely with work in RD3.1.1, where new cereal lines with specific nutritional benefits are being bred and barley accessions screened for enhanced nutrition and phytochemical content.

Work within O3 links closely with several RDs that provide carbohydrate fractions for microbial fermentation studies, including from legumes and novel crops: RDs 2.1.8, 3.1.1, 3.1.2, 3.1.4.

Work on life stage and mental health (O1/3) links closely with RD3.2.1.

Through a RESAS-funded HEI collaboration (**HEI bid 7**) with the University of Glasgow on a project entitled 'Food reformulation and exercise for healthy ageing' there will be an additional cohort to examine the impact of diet in combination with exercise, particularly on longitudinal changes in body composition.

Work in O1 on the beneficial effects of fibre-enriched diets in healthy weight management will be supported by studies proposed for an underpinning capacity project with a link to Cambridge University to assess epigenetic modification in enteroendocrine cells as a contributory factor in gut hormone secretion and long-term weight management. This work will also be supported by collaborative links with Lunenfeld-Tanenbaum Research Institute, Mount Sinai Hospital, Toronto, Canada and Garvan Institute of Medical Research, Sydney, Australia for transgenic GLP1-R and PYY null mice respectively.

Linkages will be managed via Theme and WP management meetings as well as

by individual communication between PIs carrying lead responsibility for the respective linkage. The work in RD3.2.2 also builds on existing collaborations, such as the Wellcome Trust Sanger Institute (DNA sequencing support) and the University of Oxford (Raman microspectroscopy) (for details see Added Scientific Value).

Added Scientific Value

Human microbiota research has grown exponentially in the last decade and intestinal microbes have been shown to have a range of critically important impacts on host health. Work contained within this proposal will add significantly to these international efforts by providing essential information on the link between specific dietary components, gut microbial activity and host health. Added value in these ventures comes from existing collaborations with the Wellcome Trust Sanger Institute (DNA sequencing support), other UK/international partners including the University of Oxford (Raman microspectroscopy), and clinicians (source material for experiments). The proposed work is also closely aligned to research supported by other funders, including Research Councils UK (e.g. BBSRC grant on mechanism of polysaccharide degradation by gut bacteria), EU (e.g. Satin, <http://www.satin-satiety.eu>; Fibebiotics, <http://www.fibebiotics.eu>) and commercially supported projects (e.g. BBSRC-Case PhD studentship on prebiotics with Cargill and a new multicentre project on human gut bacteria funded by Chr. Hansen). The work is also highly relevant to the new collaborative International Joint Programme Initiative 'A Healthy Diet for a Healthy Life (JPI HDHL), as well as with the aims of the EU Framework Horizon 2020 *Better Health for All*.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas (e.g. Food Matters Live) and educational events (e.g. Aberdeen May Festival). At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders, e.g. electronic and print publications/newsletters aimed at various interest groups and by one-to-one discussions with specific stakeholders on an ad-hoc basis. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

Audience Food Standards Scotland, Scotland Food & Drink, NHS Health Scotland, Community Food and Health (Scotland), professionals from the food industry, retail and health sector. We are building on existing collaborative links (in Scotland, UK and international) and will also expand our stakeholder interactions during the events detailed above and by ad-hoc engagement where appropriate. Specific KE activities planned for Y1&2: Events: Attendance at Food Matters Live in London (Nov16; KE1), Presentation during Edinburgh International Science festival on the theme "fibres, gut bacteria and health" (Mar17; KE2). Reports (R): Report on health benefits of wholegrains (Jan18; KE3).

Impact The research outcomes from this RD will have impact in the following areas: achieving further growth of Scotland's Food & Drink Industry, preventing overweight and obesity in Scotland and supporting healthy diet choices. Our work will aid the food industry in developing new ingredients based on dietary carbohydrates (prebiotic products) and/or novel bacterial strains (probiotic products) with health promoting properties, thus contributing to the growth of the Scottish Food and Drink industry. Food reformulation work will impact on the design of novel healthy diets, which will aid in the prevention of overweight and

obesity in the Scottish population and improve health by reducing cardiovascular disease. This will be achieved by interactions with the food manufacturing sector as well as professional bodies as detailed above to provide advice towards improved dietary policy.

RESEARCH DELIVERABLE NUMBER: 3.2.2

Work planning and timetable for Year 1: Please include major milestones: key research milestones (M), deliverables (D), KE/impact events (E), reports (R) and their timing.

Year 1: 2016/17	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
KE								KE1				KE2
O1.1 Acute human dietary intervention study				M 1.1a	M 1.1b					M 1.1c		
O1.2 Chronic human dietary intervention study												
O1.3 Role of fibre on satiety responses in mice						M 1.3a	M 1.3b		M 1.3c			
O2.1 TMA and TMAO method development											D 2.1a	
O2.2 Characterisation of TMA-producers												
O2.3 Characterisation of lactate utilisers					M 2.3a					M 2.3b		
O2.4 Propionate human intervention trial						D 2.4a						M 2.4a
O3.1: Bacterial fibre-degradation capacity						M 3.1a				M 3.1b		
O3.2: Microbial inter-actions of fibre breakdown												M 3.2a
O3.3 Microbiota-related health effects over the life course									D 3.3a			
O4.1: Incorporate absorption and multiple compartments into model									D 4.1a			
Annual report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.2.2

Work planning and timetable for Year 2: Please include major milestones: key research milestones (M), deliverables (D), KE/impact events (E), reports (R) and their timing.

Year 2: 2017/18	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
KE										KE3		
O1.1 Acute human dietary intervention study			D 1.1a									
O1.2 Chronic human dietary intervention study	M 1.2a	M 1.2b						M 1.2c				
O1.3 Role of fibre on satiety responses in mice		M 1.3d				M 1.3e						D 1.3a
O1.4 Obtain ethical approval for barley study												M 1.4a
O2.2 Characterisation of TMA-producers					M 2.2a						D 2.2a	
O2.3 Characterisation of lactate utilisers				M 2.3c						D 2.3a		
O2.4 Propionate human intervention trial		D 2.4b						D 2.4c				
O3.1: Bacterial fibre-degradation capacity	D 3.1a		M 3.1c					D 3.1b			D 3.1c	
O3.2: Microbial inter-actions of fibre breakdown						D 3.2a						D 3.2b
O3.3 Microbiota-related health effects over the life course			D 3.3b		M 3.3a						D 3.3c	
O4.2 Extend model to predict response to different carbohydrates										D 4.2a		
Annual report (Year 2)												R2

Name of RD: 3.2.3. Sustainability of Healthy Diets**Research aim and key drivers**

The importance of considering the sustainability of healthy diets is now widely recognised, but the area is still relatively poorly understood. The complexity of the multi-dimensional nature of sustainable diets (e.g. personal, environmental, social and economic factors) means that a greater understanding of how these factors can be combined to optimise the diet of the Scottish population is needed. The overarching aim is to improve health and limit the environmental damage, while taking into account the economic impacts and cultural preferences. It is critical that these factors are considered together to avoid unintended consequences in the different sectors and to communicate a single clear message about dietary advice to consumers. Current dietary intakes of the Scottish population do not meet the Revised Dietary Goals for Scotland and are having a significant negative environmental impact (e.g. climate change; the food system in the UK is responsible for approximately 20-30% greenhouse gas emissions (GHGE)). Climate change mitigation and tackling the poor dietary intakes of the population are both priority areas highlighted in the policy document *Becoming a Good Food Nation*, and reduction in GHGE is a key target for the Climate Change Act (Scotland) 2009. A greater understanding of what constitutes sustainable healthy diets in different groups of the population (e.g. income levels, and location), and how these can be measured, is needed. There is no single healthy, sustainable diet, since there are many different ways of achieving the dual dietary goals for health and environmental sustainable, and dietary intakes and the types of food chosen differ across different populations. This adds to the complexity of assessing and translating dietary advice to consumers. The research in this RD will provide a more comprehensive understanding of healthy sustainable diets in different sectors of the population and how these can be measured. This research will provide evidence that can inform the development of future dietary goals or guidelines, which will need to include environmental sustainability, in order to achieve the aim of a greener and healthier Scotland. It will also provide a web-based tool to monitor the dietary intakes of the Scottish population, not only in terms of health but also GHGE. This work is highly relevant to Food Standards Scotland and the Population Health Improvement Directorate in the Scottish Government. It will provide a practical monitoring tool that can be used among community groups in the evaluation of dietary interventions.

The research in this RD has been discussed with Food Standards Scotland (Heather Peace, Anne Milne, Susan Pryde) and the Population Health Improvement Directorate in the Scottish Government (Peter Fassen de Heer, Daniel Kleinberg). The development of the new assessment tool has been discussed for use with community groups with Bill Gray at Community Food and Health (Scotland).

Summary of the proposal:

The RD comprises four interlinked and complementary objectives (O):

O1: To assess dietary patterns for sustainable, healthy diets across households (by income, composition and location), using the outcomes to inform future dietary

guidelines and advice to consumers.

O2: To assess the impact of food based recommendations on diet quality and GHGE.

O3: To assess the impact of adopting healthier and more sustainable diets on the food and drink supply chain in Scotland.

O4: To develop practical ways to measure and communicate healthy sustainable diets to consumers.

The Objectives build on the current SRP (CWP7.1) and will integrate work proposed in RD3.3.1. They comprise a range of methodologies, including secondary data analysis, modelling existing data (Kantar data for Scotland), and further development of a web-based dietary assessment tool to be used for collection of primary data. The overarching aim of the RD is to provide a greater understanding of sustainable healthy diets, and assessing how these can be communicated to consumers.

O1: To assess dietary patterns associated with sustainable, healthy diets.

Measures of diet quality have been incorporated into the RINH Kantar (KWP) database as part of the CWP7.1. Extensive work has been done as part of the current SRP to create a modified version of the KWP dataset that can be used for detailed dietary analysis. In addition, nutritional information collected by KWP has been collated and linked to the purchase data. Together these data allow an in-depth analysis of estimated diet quality against food based guidelines (Scottish Dietary Goals, and the Eatwell plate) and nutrient based guidelines. Environmental impacts data (e.g. GHGE and land use) will be collated and added into the KWP dataset as part of RD3.3.1 (Food Trade & Consumption). The dataset, comprising purchase data, nutrient composition data and environmental data, will then be used in this RD to examine the dietary patterns associated with achieving sustainable and healthy diets.

The KWP database records food and drink purchases, not consumption, and therefore consideration of diet quality (i.e. a measure of healthiness of the overall diet) and food or nutrient intakes at an individual level (i.e. dietary guidelines) will need to account for the differences between purchase and consumption data (e.g. food preparation weight changes and food waste). Methodologies for these adjustments at food group level, which have been developed in CWP7.2, will be used.

In this RD statistical analysis (e.g. Principal Component Analysis, and Cluster Analysis) and modelling of the dataset generated in RD3.3.1 will be used to identify food and drink purchasing patterns consistent with healthy (i.e. Scottish Dietary Goals) and sustainable (e.g. lower GHGE) diets. Prices paid by the consumer will also be considered to assess the effects on affordability of moving towards more sustainable and healthy diets. Groups of households with similar diets, in terms of sustainability and meeting dietary targets, will be identified using techniques such as Cluster Analysis. The outcomes of these analyses will provide a greater understanding of the range of eating patterns that contribute to sustainable diets and how these could be used to help develop new dietary guidance for the Scottish population. The output will also be used to inform O2 within this RD and will be linked to RD3.2.4 (Food Culture). Dietary patterns, the linking of foods that tend to be bought together and how these relationships are altered by, for example, household

size and composition, are highly relevant to the Agent Based Modelling work of RD3.2.4 that will investigate the factors influencing food choice. Completing the database (RD3.3.1) and the statistical analysis described above will be achieved in the first two years. Modelling the effects of achieving more sustainable and healthy diets on affordability of the diet, and how this affects different consumer groups, such as different income groups, those living in urban and rural locations, and across SIMD, will be conducted in years three to five. In addition, existing data from the National Diet and Nutrition Survey will be analysed to quantify how far diets depart from current and proposed goals. Dietary goals will be considered jointly rather than singly, and build on work that investigates the amount of dietary change needed to achieve health and sustainability targets. Understanding cultural and non-cultural factors being investigated in RD3.2.4 will be considered when assessing how to shift dietary patterns towards healthy and sustainable diets.

Information on the characteristics of healthier and more sustainable diets will be incorporated into an existing online dietary assessment tool to allow a measure of the environmental impact of diets (see O4). This will be used to assess both aspects of consumers' diets, and provide individualised feedback to consumers on their diet.

Key deliverables:

D1.1: Publication of the results from the statistical analysis of purchasing patterns of food and drink that are consistent with healthy diets (Year 1).

D1.2: Publication of the results of purchasing patterns of food and drink that are consistent with healthy & sustainable diets (Year 2).

D1.3: Modelling the effects of sustainable and healthy diets on affordability of the diet, and the effects on different consumer groups (e.g. different income groups, urban/rural locations, SIMD). In conjunction with O4, develop a tool to assess sustainability of consumers' diets (Year 5).

O2: To assess the impact of food based recommendations on diet quality and GHGE

This objective will evaluate how the diversity of diets of the Scottish population would respond to food based dietary recommendations and their impact on nutrition quality and GHGE. Consumers are increasingly urged to modify their consumption habits to comply with dietary recommendations such as 'eat at least five portions of fruits and vegetables a day' or 'reduce meat consumption'. However, the effect of complying with those recommendations on the composition of the entire diet is uncertain because of potential substitutions made by consumers (e.g. increases in the consumption of a food category are probably at the expense of other food categories, if remained within the boundaries of the current expenditure). The work in this objective, which is linked to work currently developed under the ERANET-SUSDIET project ("Implementing sustainable diets in Europe"), consists of formulating a model that extends the microeconomic theory of the consumer choice under rationing to the case of multiple linear constraints and using it to evaluate the effect that food based recommendations may have on nutritional quality of the diet and the environment (the affordability constraint of the diet is already satisfied within the model). The model will use information on consumer preferences such as price and expenditure elasticities of demand, consumption levels (some elasticities and consumption have been computed for different Scottish population groups using the KWP data under the CWP), and technical coefficients for each food category (e.g.,

nutritional composition, GHG emissions).

Key deliverables:

D2.1: Review paper of the available recommendations (Year 1).

D2.2: Publication of the assessment the impact of food based recommendations on diet quality and GHGE (Year 5).

O3: To assess the impact of healthy sustainable diets on the food and drink supply chain in Scotland

Adopting a healthier sustainable diet will change the demand for food and drinks in Scotland with implications for the food supply chain. Based on the results of O1 & O2, this project will measure the impact of adopting healthier and more sustainable diets on the economic sustainability of the Scottish food and drink supply chain (and the rest of the Scottish economy). The work will adapt the methodologies used in Arnoult et al (2010) and Wolf (2011) to measure and model the likely impact of adopting the aforementioned diets. This will be done by mapping the change in food demand (e.g. reduction in the consumption of beef) into the change of commodity demand (e.g. reduction of slaughtered livestock). In addition, industry input-output tables, which provide a relationship between demand and production for the different sectors of the Scottish food and drink supply chain, and the environmental input-output table for Scotland will be used. This objective will link with the work being carried out in RD 2.3.9 (Integrated Management Systems).

Key deliverables:

D3.1: Report with the methodology to evaluate the impact of dietary changes on the Scottish supply chains (Year 2).

D3.2: Publication of the impact of sustainable diets on the food and drink supply chain (Year 5).

O4: To develop ways to measure, validate and communicate healthy sustainable diets

There is no single healthy and sustainable diet, which adds to the complexity of translating dietary advice to the consumer. The work of this objective will extend an existing web-based dietary assessment tool to assess dietary patterns at an individual or household level, in terms of how closely diets come to achieving dietary targets, such as the Scottish Dietary Goals, and environmental sustainability.

The modified web-based dietary assessment tool, which will include the environmental impact of the diet (GHG emissions), will be tested using rapid usability testing and cognitive interviewing, and validation of the dietary data. In years 3-5, through existing links with community led project teams (e.g. Community Food and Health Scotland (CFHS)), community projects will be identified in which the tool can be used for evaluation (e.g. dietary patterns and environmental impact) and to communicate best practice. The use of the web-based tool in a community will help to gain insight into how to communicate information about healthy and sustainable diets to the public.

Key deliverables:

D4.1: Development of a web-based tool to measure and communicate nutrition and

environmental impact (Year 2).

D4.2: Publication of the methodology of the development and testing of the new tool (Year 2).

D4.3: Complete development and testing of new tool. Use community project as a case study and publication of results (Year 5).

Technical Approach

The experimental approaches will include statistical analysis of secondary data, mathematical modelling, development of a new dietary assessment tool, and evaluation of community projects. Given the complex nature of healthy sustainable diets, a multidisciplinary approach will be taken, combining health, nutritional, environmental, social and economic factor associated with dietary intakes.

O1: Dietary patterns associated with sustainable, healthy diets.

The following research will be conducted over a 5 year period.

i. Estimating diet quality and sustainability: Statistical approaches, such as Principal Components Analysis, will be used to identify the foods and drinks that tend to be purchased together for diets that meet (or at least approach) the dietary goals and sustainability aims. The analyses will be conducted on purchase data from different times of the year to control for the effects of seasonality and availability. Diets will be characterised according to how closely they achieve the Scottish Dietary Goals and on their environmental impact. Cluster Analysis, or similar statistical approaches, will be employed to describe common household characteristics according to achievement of the dietary and environmental goals. These analyses will provide an insight into how to measure healthy sustainable diets and help inform the development of future sustainable dietary goals.

ii. Effects on affordability: In the next step, mathematical models will be developed, using economic modelling techniques, to allow the effects of dietary change towards meeting the revised Scottish Dietary Goals, and environmental aims on food and drink expenditure to be evaluated. The model will be used across different types of household (e.g. SIMD, household composition and urban/rural location) to consider the effects of recommended dietary changes on diet affordability faced by different households.

iii. Evaluation of the recommendations and further simulations: The model will be used to evaluate the selected recommendation on the diets of the different population groups and on the environment. It will also be possible to simulate different degrees of compliance with the recommendation and to calculate trade-off between environmental and health impact when modifying the diet.

O2: To assess the impact of food based recommendations on diet quality and GHGE

i. Selection of recommendations to evaluate: The approach will start with summarising the range of recommendations to increase nutritional quality or sustainability of diets. This will provide the starting point to evaluate how disaggregated food categories should be included in the assessment model. This will be done in conjunction with O1.

ii. Planning and formulation of the model: This stage of the project will consist of consideration and review of a number of aspects required for the construction of the model, such as the degree of aggregation of the model and the population groups to consider. Based on this, the mathematical model will be constructed. The model will extend the microeconomic theory of the consumer choice under rationing to the case of multiple linear constraints. This work will be based methods used by Irz *et al.* (2014) and further developed in the context of SUSDIET.

iii. Computation of parameters for the model: The next step will be calculation of parameters of the model. These are price and expenditure elasticities of demand, consumption levels (both elasticities and consumption have been computed for different Scottish population groups), and technical coefficients for each food category (e.g. nutritional composition, GHGE). Whilst some estimation of elasticities have been done using the KWP data under the CWP 5.1, the use of different food and population groups will require further estimations.

iii. Evaluation of the recommendations and further simulations: The model will be used to evaluate the selected recommendation on the diets of the different population groups and on the environment. It will also be possible to simulate different degrees of compliance with the recommendation and to calculate trade-off between environmental and health impact when modifying the diet.

O3: To assess the impact of healthy sustainable diets on the food and drink supply chain in Scotland

i. Compilation and preparation of statistical information: The initial tasks will be to prepare the input-output tables (industry and environmental) for the analysis, and to map food categories into commodities in preparation for use the modelling.

ii. Planning and formulation of the model: The purpose of this activity is to blend two methodologies available in the economic literature, that is as used by Arnoult *et al.* (2010) and by Wolf *et al.* (2011). Both aim to measure the impact of changes in diets (reflected in changes in the demand for food and drink products and subsequently on commodities) on sustainability aspects of food supply chains; however, they focus on different aspects, the former model focus on land use whilst the latter by using input-output tables (a general equilibrium model) extends the analysis to the entire economy. The methodologies will need to be adapted to the available data for Scotland.

iii. Evaluation of the impact of adoption of sustainable diets on supply chains: This will consist of using the formulated model (i.e. the blended model) to evaluate the impact on sustainability (e.g. economic, environmental and social) of the adoption of sustainable diets.

O4: To develop ways to measure, validate and communicate healthy sustainable diets

i. Evaluate existing web-based dietary assessment tools.

Two candidate web-based dietary assessment tools (REALITY™ and INTAKE24™) will be evaluated for technical feasibility, cost of implementing the development and any contractual considerations (e.g. intellectual property rights and copyright).

ii. Identify environmental data and match food groups to those used in the web-based tool:

The initial task will be to identify and match environmental data (e.g. GHGE) to the

existing food and nutrient datasets used in the web-based tool. This will link to the work in O1 and RD3.3.1 to ensure consistency of approach and methodologies.

iii. Develop algorithm to output data: In the new web-based dietary assessment tool, new algorithms will be developed to output the data for nutrient quality and environmental impact.

iv. Evaluation of community based projects: A collaboration will be established with CFHS or other community groups to identify suitable and relevant community projects that could use the new web-based tool to evaluate the health and environmental consequences of dietary change, through community based interventions. This approach will also allow a method for providing feedback to consumers to be tested, in order to communicate the different aspects of healthy sustainable diets. It can provide insights into the best ways to communicate sustainable diets to the public (e.g. understanding of what is a sustainable diet, why it is important, and recommendations).

In the first two years the web-based tool will be developed. In subsequent years it will be tested and the use of it in evaluation of community projects developed.

Detailed work plan (years 1-2)

O1: To assess dietary patterns associated with sustainable, healthy diets.

M1.1 Description of purchasing patterns of food and drink that are consistent with healthy diets (Sept 2016).

M1.2 Description of groups of households that meet Scottish Dietary Goals (Mar 2017).

D1.1 Publication and dissemination of the results relating to M1.1 (Mar 2017).

M1.3 Description of purchasing patterns of food and drink that are consistent with healthy & sustainable diets (Sept 2017).

M1.4 Description of groups of households that meet Scottish Dietary Goals & sustainability targets (Mar 2018).

D1.2 Publication and dissemination of the results relating to M1.3 (Mar 2018).

O2: To assess the impact of food based recommendations on diet quality and GHGE

M2.1 and D2.1 - Review paper of the available recommendations (Nov 2016).

M2.2 – Formulated model (Jul 2017).

M2.3 – Empirical implementation of model (Mar 2018).

Years 3-5

Evaluation of the recommendations and further simulations of the impact of substitutions, and publication and dissemination of the findings.

O3: To assess the impact of healthy sustainable diets on the food and drink supply chain in Scotland

M3.1 – Finish preparation of statistical information (Dec 2016).

M3.2 – Formulation of model adapted to Scotland (Mar 2018).

D3.1 – Report with the methodology to evaluate the impact of dietary changes on the

Scottish supply chains (Mar 2018).

Years 3-5

D3.2 - Evaluation of the impact of adoption of sustainable diets on supply chains.

O4: To develop practical ways to measure, validate and communicate healthy sustainable diets

M4.1 Evaluate REALITY and INTAKE24 for suitability as a tool to measure and communicate healthy sustainably diets (June 2016).

M4.2 Develop and test REALITY or INTAKE24 to measure and communicate healthy sustainably diets (Mar 2017).

M4.3 Incorporate environmental data into REALITY or INTAKE24 (Sept. 2017).

M4.4 Design and setup case study to evaluate the health and environmental consequences of dietary change (Mar 2018).

D4.1 Web-based tool to measure and communicate nutritional and environmental impact of dietary change (Mar 2018).

D4.2 Publication of the methodology of the development of the web-based tool (Mar 2018).

Expertise

The objectives in this RD will build on work in the current SRP. The RD extends and develops the link between RINH and BioSS through new analysis using the KWP data to incorporate indicators of environmental sustainability. Within the current SRP an extensive knowledge of this complex dataset has been gained, which will be combined with expertise from other areas within the MRPs to link to the environmental impact of food and drinks. If considered the most suitable, the dietary assessment tool REALITYTM, developed in CWP7.1, will be extended to measure the environmental impact of diets, which will build on work completed at the MRPs. The partners delivering these objectives bringing together an interdisciplinary collaboration across MRPs (RINH, BioSS) and expertise in nutrition, health, environment, statistics and mathematical modelling.

Key linkages, interdisciplinarity & collaboration

The objectives in this RD will link to the following RDs:

- RD3.3.1 Food trade and consumption. The work linking the environmental data (GHGE) to the KWP dataset is central to both RD3.3.1 and RD3.2.3. The work will be coordinated and managed by the lead researcher (SW) for O1 in RD3.2.3.
- RD3.2.4 Food culture. Close collaborative links will be maintained with RD 3.2.4 (in particular O1.1) using the results from the studies in each of these RDs to inform the development of the projects throughout the programme. For example the results from this RD will be used as evidence to support the development of the model and understand dietary patterns of the Scottish population in the Agent Based Modelling project. The understanding and interactions of cultural and non-cultural aspects of food choices developed in 3.2.4 will be feedback to help inform the analysis and modelling in this RD. This will be managed by SW.

The RD brings together the disciplines of nutrient, health, environment, and mathematical modelling, with collaborations between RINH and BioSS. The collaborations across MRPs and the interdisciplinary nature of the work will be extended by linkages with the RDs described above.

Added Scientific Value

The integrated approach proposed in the objectives in this RD adds scientific value in a field where single disciplinary research has traditionally been carried out. Research in the area of food security and health is rapidly evolving and the proposed research will add significant internationally scientific value by increasing our understanding of sustainable food systems and health. The work will build on research currently being carried out at RINH, which is internationally recognised as leading in the research on sustainable diets. The approach to measure dietary patterns associated with healthy sustainable diets is novel because it considers the implications of dietary change on both consumption and production together. This adds considerable scientific value and advances the science as these are typically considered separately.

KE Outputs, Audience and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders.

In addition to reports, conference presentations and publications in peer-reviewed journals, the research in this RD will have wide ranging implications for health, nutrition and environmental research. It will lead to significant advances in the tools that can be used in diet studies/monitoring, as well as provide evidence that can be used to help inform development of healthy sustainable dietary guidelines or goals. The web-based dietary tool will be available for use by other researchers and community workers in the UK. The work will be disseminated beyond academia to stakeholders in the Population Health Improvement Directorate, Food Standards Scotland (FSS), community groups (via Bill Gray, Community Food and Health (Scotland)) and other relevant organisations, through a variety of events (e.g. Tech Fest, Science Festivals). Working with Bill Gray enables direct work with the communities that the tool is intended to help. The tool will not only measure the impact of some food initiatives but also communicate important messages relating to healthy sustainable diets. It has also been agreed RD PIs will have regular meetings with FSS about the research and outcomes (specifically the Nutrition section with Heather Peace).

Audiences: FSS, Community Food and Health (Scotland), NHS Health Scotland, Department of Health and those working towards a Low Carbon Scotland (Scottish Government), Scotland Food and Drink and community groups (via Bill Gray).

Impact: The proposed work is highly relevant to targets set by the Scottish Government for health (e.g. Revised Scottish Dietary Goals) and reductions in GHGE (e.g. Climate Change Act 2009) and addresses issues highlighted in Becoming a Good Food Nation. The impact of the research would come from providing evidence to inform the development of new Scottish dietary guidelines for healthy sustainable diets. Early discussions have taken place with FSS about developing Dietary Guidelines for Scotland, which will continue as the research progresses, the bases of which will need a better understanding of the sustainability of current dietary habits across the population. In the cWP7.2 we have an excellent track record in disseminating research effectively and widely (e.g. Livewell Project).

This has been disseminated and widely cited by national and international government, industry, NGOs and the general public through a variety of public engagement events. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

RESEARCH DELIVERABLE NUMBER: 3.2.3

Work planning and timetable for Year 1: Major milestones (M), deliverables (D), KE/impact events (KE) and their timing.

Year 1: 2016/17	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Knowledge exchange event						KE1						
O1.1: Identify healthy diet purchasing patterns Description of purchasing patterns of food and drink that are consistent with healthy diets.						M1.1						D1.1
O1.2: Identify healthy diet purchasing patterns Description of groups of households that meet Scottish Dietary Goals												M1.2
O2: Assessment of impact of food based recommendations on diet quality and GHGE								M2.1 D2.1				
O3: Assessment of impact of healthy sustainable diets on the food and drink supply chain in Scotland									M3.1			
O4.1: Communication of healthy sustainable diets Evaluate REALITY and INTAKE24 for suitability as a tool to measure and communicate healthy sustainably diets			M4.1									
O4.2: Communication of healthy sustainable diets Develop and test REALITY or INTAKE24 to measure and												M4.2

communicate healthy sustainably diets													
Annual Report (Year 1)													R1

RESEARCH DELIVERABLE NUMBER: 3.2.3

Work planning and timetable for Year 2: Major milestones (M), deliverables (D), KE/impact events (KE) and their timing.

Year 2: 2017/18	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Knowledge exchange event		KE2										
Knowledge exchange event		KE3										
Knowledge exchange event							KE4					
O1.3: Identify health diet purchasing patterns Description of purchasing patterns of food and drink that are consistent with healthy & sustainable diets.						M1.3						D1.2
O1.4: Identify health diet purchasing patterns Description of groups of households that meet Scottish Dietary Goals & sustainability targets.												M1.4
O2: Assessment of impact of food based recommendations on diet quality and GHGE				M2.2								M2.3
O3: Assessment of impact of healthy sustainable diets on the food and drink supply chain in Scotland												M3.2 D3.1
O4.3: Communication of healthy sustainable diets Incorporate environmental data into REALITY or INTAKE24						M4.3						
O4.4: Communication of healthy sustainable diets Design and setup case study												M4.4
O4.5: Communication of												D4.1

healthy sustainable diets Web-based tool to measure and communicate nutritional and environmental impact of dietary change.													D4.2
Annual Report (Year 2)													R2

Name of Research Deliverable: **3.2.4 Food culture and dietary choice**

Research aim and key drivers

Scotland, in common with many other countries faces a crisis in public health as a result of non-communicable disease of dietary origin (i.e. obesity, type 2 diabetes, CVD, stroke). To achieve a healthy balanced diet requires reductions in fat, salt and sugar, and in overall calorie intake. The Revised Dietary Goals for Scotland (2013), and its predecessor documents, highlight the challenge of achieving population-scale dietary targets where these require major changes in intake of individual dietary components, macronutrients or food groups. Although there have been small improvements in the last decade, none of the earlier 'Targets' have been met. Food reformulation should have a role to play in promoting dietary change – creating a healthier food environment – but food culture and food-related behaviour, including dietary choice, are clearly of critical importance. The goal is to support consumers to achieve beneficial behaviour change towards a healthier (and more sustainable) diet, which will need changes in the food culture within Scotland and a shift in social norms. Research in RD3.2.4 targets a number of complementary, interdisciplinary strategies to this end. There are clear linkages within the RD, which '*build upon and extend current MRP research in this area*', and opportunities for further connectivity across Theme 3, with RDs 3.2.1, 3.2.3, 3.3.1, 3.3.2 and 3.3.3 in particular.

Approaches to supporting consumer' behaviour change in a dietary context are directly relevant to the following SG policy drivers:

- Recipe for Success / Becoming a Good Food Nation
- Supporting Healthy Choices
- Prevention of Obesity route map

Policy and stakeholder groups consulted during the preparation of this proposal:

- Food Standards Scotland (FSS)
- SG Food, Drink & Rural Communities Department
- SG Public Health Directorate – Health Improvement Strategy Division
- SG Child and Maternal Health
- Scottish Food and Drink Federation

Summary of the proposal:

To support changes in food culture, social norms and dietary choices towards 'a sustainable and healthy, balanced diet', this integrated interdisciplinary research programme will apply socioeconomic and behavioural approaches to (i) characterise cultural and non-cultural factors affecting dietary choice and behaviours in different population groups and life-stages, and (ii) assess the potential benefit of innovative dietary interventions to change dietary habits. The output will collectively inform policy makers and further the development of dietary interventions. The studies will investigate, for example, the impact of dietary information and education on food choices, the effect of parental behaviour on children's diets, food preference and habit formation in early life, whether habitual food purchasing patterns reinforce or moderate behaviour change, and the dehabitualisation of unhealthy dietary choices through changing food preference with repeated exposure. It is known that dietary choices occur within a complex social system, influenced by cultural and non-cultural factors, and affect people in different ways. These interacting factors and pressures influencing food choices will be brought together using a systems approach by constructing a social simulation tool (an Agent Based Model).

Critical knowledge is lacking regarding determinants of food choice, optimal strategies to promote behaviour change, and how to motivate individuals to change, which defines the Objectives in RD 3.2.4. The proposed objectives integrates research skills across MRPs and disciplines through strong internal linkages.

O1: Socioeconomic analysis and systems modelling to better understand influences on food choice, consumer attitudes and beliefs, and effects of policy changes.

O2: Dietary intervention strategies to support healthier habits and food choices through changes in taste preference and understanding food purchasing habits.

O1: Socioeconomic analysis and systems modelling.

This objective comprises three interlinked projects:

O1.1. Systems approach to model cultural and non-cultural influences: Dietary choices and behaviours are influenced by complex interacting individual and societal pressures, habits and cultures. We will improve understanding about how factors such as food preferences, peer pressure, social norms, affordability and availability interact and determine the food choices of individuals and groups in a complex real-world social system. Scenarios will be used to explore how to encourage people to move towards healthy, sustainable diets, and how these outcomes are influenced by geographical, cultural and non-cultural factors, which will help to inform policies. Building on quantitative studies and qualitative insights into food cultures and sustainable diets in the current programme (cWP7.1), and ongoing EU FP7 work (GLAMURS project), an Agent-Based Modelling (ABM) systems approach will be used. Output from RD3.2.3 (and links to 3.3.1) on sustainable diets will be used to inform the ABM, with close links being maintained throughout the programme. A PhD studentship will be used to explore factors influencing food practices in the home (e.g. competence, responsibilities, budgets, cooking, growing your own food, food security), which will link to RD3.3.3 and RD3.3.2, and the findings used in the ABM. The project builds on existing interdisciplinary collaborations (RINH, Hutton, BioSS), providing a test environment for policy implications implied by other work in the RD.

O1.2. Impact of dietary information in different populations: Attempts have been made to improve consumers' dietary education by providing nutritional information on pre-packaged foods but information about healthier eating does not necessarily lead to healthier choices. We will examine how consumers think about food and nutritional information and relate it to their everyday lives, which complements and build on current research (cWP7.1) relating to consumers' responses to nutritional information and to their socio-cultural perceptions of food choice. Q methodology is a form of mixed-methods factor analysis applied to data resulting from Q-sorting, which is a ranking of variables, typically a set of statements about a particular topic that have been derived from interviews, focus groups, or other sources. This will generate a number of profiles, that is, detailed descriptions of different points of view which will enable the identification of target groups for messages to promote healthier choices.

O1.3. Influences over children's food choices: Adults have some influence over their own food choice, but a child's choices are limited by the environment created by their parents, peers, and food providers e.g. schools. Previous analysis in cWP7.1 suggests that household factors have a substantial effect. Influences on children's food choices will be investigated using Scottish datasets (Scottish Health Survey, Scottish FSA Survey of Diet among Children) and panel data sets (Growing Up in Scotland/Millennium Cohort). Initial focus will be on parental and household influences, including any available data on food preparation and barriers to healthy

eating, before assessment of the feasibility of measuring other food provider impacts, including existing nutritional interventions (e.g. nutritional standards in schools) or geographic differences between Scotland and other UK countries, to design natural experiments. This analysis will seek to integrate findings from Q methodology but will place more emphasis on the role of economic determinants (e.g. price/income/affordability) as well as parental education and health behaviours.

Key deliverables: **O1.1:** ABM modelling: **D1.1a:** Collate evidence and data to build a prototype model (Yr1/2). **D1.1b:** Appoint PhD student (Yr1). **D1.1c:** Develop a conceptual framework and prototype simulation model (Yr2). **D1.1d:** Refine the framework for simulation models (Yr3). **D1.1e:** Report on initial baseline scenarios implemented in the simulation models (Yr4). **D1.1f:** Report on policy implications arising from the simulation models (Yr5). **O1.2:** Q methodology: **D1.2a:** Correlation and factor analysis to identify distinct groups, or different shared perspectives (Yr3). **O1.3:** Secondary data analysis of children's diet: **D1.3a:** Presentation/report on parental and other influences on children's diet from cross-sectional analysis (Yr2) and over the life course (Yr4). **D1.3c:** Comparative analysis with England/the rest of UK to consider structural differences or natural experiments affecting children's diets (Yr5).

O2: Food choices and habits.

This objective will evaluate strategies to increase preferences for healthy foods (e.g. fruit and vegetables) and prevent poor dietary habits being established in infancy. It will consider both defining and reversing poor dietary habits that have become entrenched in adult life, as well as increasing preference for healthy foods through increased taste-based preference for these foods.

O2.1. Flavour exposure at weaning: Habitual diet is usually firmly established in adult life, yet we know that taste preferences are malleable. The development of food preferences begins at conception and the majority of our preferences are learned via repeated exposure. Even foods that are initially disliked can become acceptable through the process of tasting them over time. Foods that tend to be rejected by children include those with the greatest importance for later health e.g. fruit and vegetables. Infants have an inborn preference for sweet/umami flavours and dislike sour/bitter, but sensory experiences early in development can modify these preferences, through repeated exposure. This could theoretically be manipulated by increasing exposure to a variety of flavours during both prenatal and early postnatal periods. Two approaches will be investigated to increase liking and intake of fruit and vegetables in children (see RD3.2.1;O3 intervention). Both age and variety of foods at weaning transition impact a child's later food choices but few studies have compared repeated exposure to initially "unliked" vegetables on consumption at weaning, which may attenuate neophobia later in childhood, and none have tested combining multiple flavours. Together the pregnancy and weaning aspects examine the earliest stages at which parental behaviour and hence dietary choices made on behalf of others has the potential to impact a child's long-term dietary behaviour.

O2.2. Flavour exposure and dehabitualisation in adult life: Repeated exposure is rarely used to modify food preference in adults, and a better understanding of how this approach might be utilised is required. The aim of the studies is to dehabitualise unhealthy preferences and replace them with healthier alternatives by altering sensory evaluation of the targeted foods and drinks during adulthood. Studies will target reductions in sugar and the balance between healthy and unhealthy diets, with

consumers supported through changes in taste preference. Strategies will be tailored to different population groups, for example at different life stages.

O2.3. Food purchasing habits: How individuals respond to behaviour change interventions can depend on the nature and strength of their habits. In the absence of other data giving repeated observations of food consumption over time, food purchasing data (Kantar) will be used to analyse the strength of habitual behaviour for specific food categories using either traditional demand models or discrete choice models. Habit formation will be captured using past purchasing behaviour as a factor influencing current purchases, while accounting for socio-economic characteristics, including purchasing power.

Key deliverables: **D2.1:** Contribution to proof of concept for strategies to improve liking and intake of fruit and vegetables in children (preceded/complemented by RD3.2.1,O3; Yr5). **D2.2a:** Report on the initial effectiveness of manipulation on preferences (Yr1); **D2.2b:** Report on the findings from initial studies (Yr2); **D2.2c:** Dissemination of studies (publication/conference) (Yr3); **D2.2d:** Summary report on the findings investigating the long term effects of repeated exposure on spontaneous choices and long term preferences (Yr4); **D2.2e:** Dissemination of the follow-up study (publication/ conference) (Yr4); **D2.2f:** Report on the findings from a 'real-life' intervention investigating how repeated exposure findings can be applied (Yr5); **D2.2g:** Submission of academic paper/abstract describing the results from the intervention (Yr5); **D2.2h:** Report highlighting key findings and implications - optimal strategies for applying repeated exposure dehabituating in adults (Yr5). **D2.3:** Analysis of habitual behaviour on food choices and responses to price change (Yr5).

Technical approach

O1: Socioeconomic analysis and systems modelling.

O1.1 The aim is to assess the likely impact of interventions to encourage the uptake of healthy, sustainable diets across different socioeconomic, cultural and age groups. Using ABM we will explore (i) how interacting cultural, societal, environmental and individual factors determine food choices of individuals and groups in a complex social system (i.e. real-world) and (ii) how different scenarios can help to achieve healthy, sustainable diets by influencing dietary choices in different groups. ABM allows the heterogeneity of the population to be incorporated. In year 1 there will be links to ongoing ABM work through collaborations on the EU FP7 'GLAMURS' project (www.glamurs.eu). To ensure empirical grounding, data used in the model will come from both previous studies in CWP7.1 and 7.2. Existing datasets, supplemented with collection of new data using quantitative and qualitative methodologies, and published literature will contribute to understanding cultural factors, eating habits and food choice used in the ABM. A PhD studentship to explore food practices in the home, will help to inform aspects of the ABM. Stakeholder workshops with policy, HEIs and non-academic partners, will be run to develop and review the plausibility of the model. Once built the ABM will be used to explore the impact of different scenarios (e.g. policy, changes in the supply chain) on dietary choices across sectors of the population, and identify any unintended consequences, and to generate hypotheses.

O1.2 Q methodology comprises a set of inter-connected techniques that will be used

to explore “subjectivity” relating to food choice by reducing a dataset of opinions/beliefs to a simple structure. This is based on factor analysis and correlations, consisting of a manageable number of rich descriptions of the different points of view generated. It will be used to understand and describe the attitudes and beliefs held by consumers (n=40-60) on the subject of food choice and how nutritional information impacts on those choices.

O1.3 Secondary data analysis of children’s diet will be carried out using methods including cross-sectional mixed effects models and multilevel panel data models for longitudinal data. These methods allow for joint modelling of correlated processes underlying the structure of observed data. For example, not only will mixed effects models adjust for selection bias in estimating effect of parental characteristics on children’s dietary behaviour, but they will also give an estimation of how important parental vs children’s characteristics are in the outcome of interest. Natural experiments relating to interventions in other settings (e.g. schools) will be designed using econometric methods appropriate to the available data.

O2: Food choices and habits

O2.1 A scoping exercise involving mothers and health visitors will be carried out to establish current practice in Scotland with regard to age and approach to complementary solid food introduction at weaning, to help design an intervention. A cohort of maternal-infant dyads will be recruited (n=45) to assess the impact of exposure to single and multiple combined flavours at weaning on dietary intake of target foods. A baseline measure of the infants’ consumption of test flavours will be obtained providing a measure of initial liking (weight consumed, parental report and facial response). Infants will then be randomised to receive 12 days of either flavour ‘x’, flavour ‘y’ or the combination of the two flavours, at home. On days 16, 17 and 18, the infants will return to retest their ad-lib consumption of tastes x, y and xy. Test flavours will focus on vegetables that are generally disliked by children (e.g. green beans, broccoli, cauliflower). A follow-up may also be used to examine the liking of these flavours after a set period (e.g. 6-months later). The findings will be used to inform a wider intervention and will complement the pregnancy study in RD3.2.1 (O3). In addition to evaluating food preferences in targeted infants, we will determine if both approaches positively impact on the dietary choices of mothers themselves and hence the food culture within the wider family.

O2.2 This objective comprises three studies defining the potential for repeated exposure to increase the liking of tastes (preference), including the optimal strategy to adopt depending on the food, the individual, and their initial preferences. Three aspects of dietary preference change will be considered: (i) facilitating the reduction, replacement or removal of sugar, (ii) increasing liking/preference for healthy food alternatives (e.g. white vs wholemeal bread), and (iii) increasing intake of healthy foods towards recommended levels (e.g. fruit and vegetable intake). Participants (n=15 per group) will be recruited simultaneously to the studies in order to allow allocation of participants based on their current habits. Baseline responses to a range of tastes will be measured using self-report liking/wanting and preference order, behavioural choice and purchase behavior and appropriate biomarkers. Following a prescribed change in consumption of 1-3 months duration, the measures will be repeated post-intervention. Studies 1 and 2 will attempt to dehabitualise current, unhealthy food and drink preferences (e.g. high calorie, high sugar, fizzy

drinks). Study 3 aims to increase baseline consumption of healthy foods. The research will address: Can preferences be dehabituised, how is this achieved, and over what time scales? Do current eating habits have to be replaced (e.g. with a lower energy/sugar fizzy drink) or can they just be stopped (e.g. the cessation of consumption reduces the preference for the substance over time)? Once a period of taste exposure has occurred, does this lead to spontaneous consumption of target foods (fruit and vegetables) within people's everyday diet? Self-report, behavioural and, if possible, brain imaging measures will be used in these studies. Subsequent studies will address how newly adopted habits, formed through repeated exposure, are encouraged post intervention. For example, is it sufficient, once the liking for a new substance has become a preference, for the habit to be continued? Or would additional health-related messages be beneficial to increase motivation? Also, how can people be motivated to repeatedly consume a food or drink that is initially disliked until it becomes preferable? For those who are motivated to change, we hypothesise that information alone may be sufficient to prompt people to attempt this strategy towards a goal of increased health. However, for those with a lower motivation to change, it may be possible to utilise institutional (e.g. schools, work-based or community projects, including growing and cooking) schemes and/or reward-based schemes, at least for an initial attempt at changing an unhealthy dietary habit. This work will include collaboration with the Health Psychology Group (Univ Aberdeen) and link to work in RD3.3.3 on local growing schemes.

O2.3 Kantar Worldpanel data will be used to investigate the effect of habitual purchasing on household demand for healthy or unhealthy items using demand systems modelling or discrete choice modelling. In the first approach, household demand for specific products or groups of products will be described by a set of equations relating the quantity purchased to price and individual characteristics of the household. The system of equations allows for substitution between products or groups of products to be identified. Discrete choice modelling is an alternative approach in which more prominence is given to identifying specific characteristics of a product which affect household demand and how these are traded off against other factors, such as price. Using the repeated observations in the Kantar data, the effect of past purchases can be incorporated into both modelling approaches to measure the influence of habitual behaviour. Either approach can use household characteristics to identify different patterns of habitual behaviour in different population groups and the interaction with key socio-economic factors such as education and income. The analysis will focus on the extent to which past purchasing affects future purchasing behaviour and whether the response to interventions, such as price changes, differs between habitual and occasional purchasers.

Detailed work plan: Milestones (M#), Deliverables (D#) and KE events (KE#).

Year 1 (2016 - 2017)

O1: Socioeconomic analysis and systems modelling

O1.1 Develop a prototype ABM (**D1.1a; April 2017**). Appoint PhD student (**D1.1b**). Stakeholder workshops to inform and review the model as it develops (**KE1**).

O1.2 Identify the Concourse, which consists of all possible statements and relevant aspects of all the discourses regarding how consumers think about food and nutritional information (**M1.2a**).

O1.3 Data preparation for secondary analysis of children's diet (**M1.3a**).

O2: Food choices and habits

O2.2 Gain ethical approval for studies and complete SOPs (**M2.2a**). Begin recruitment and data collection for studies 1-3 (**M2.2b**). Report detailing the initial effectiveness of manipulation on preferences (**D2.2a**).

Year 2 (2017 - 2018)

O1: Socioeconomic analysis and systems modelling

1.1 Develop a conceptual framework and prototype simulation model from which hypotheses will be generated (**D1.1c**). Secondary analysis to highlight areas where data do not exist and therefore where subsidiary studies are required to refine the model (**M1.1a**). Plausibility of the model tested with stakeholders (**KE2**).

1.2 Q methodology will use the Concourse to identify a representative sample of consumers' views, opinions and beliefs about food and nutritional information (Q-set) and create Q-decks (sample of representative statements from the Concourse printed in separate cards) (**M1.2b**), and the pilot will be conducted (**M1.2c**).

1.3 Analysis of secondary data relating to influences on children's diets (**M1.3b**). Draft report of findings (**D1.3a**).

O2: Food choices and habits

O2.2 Complete recruitment and data collection - studies 1-3 (**M2.2c**), complete data input and analysis - studies 1-3 (**M2.2d**). Prepare report - studies 1-3 (**D2.2b**).

Expertise

In this RD, researchers from three MRPs will contribute to a multidisciplinary research programme drawing upon complementary expertise which includes modelling, psychology, physiology, endocrinology, nutrition, public health, sociology, human-computer interactions and economics. This strong project team has extensive experience of different research methodologies and is uniquely placed to deliver the integrated programme of research. Many of the researchers have worked together previously on successful research projects (e.g. RESAS, externally funded projects, PhD supervision), or have extensive experience of working in large collaborative projects (e.g. EU FP7). The proposal builds on several components of CWPs, and aims to develop viable strategies to support consumer' behaviour change.

Key linkages, interdisciplinarity & collaboration

ABM modeling integrates existing MRP expertise and interdisciplinary approaches from RINH, Hutton and BioSS. The RD has strong links with WPs 3.2 and 3.3, and interactions in WP3.1.

3.1.1. *Improving Primary Produce* and 3.1.2. *Improving Food and Drink Production* – interaction of changes in production and consumers' preferences.

3.2.1 *Importance of healthy diets* – validating the component parts of the new project on perinatal programming of food acceptance (maternal intervention and impact on infant taste acceptance, metabolic health) will inform the design of the weaning intervention assessing repeated exposure and multiple flavours.

3.2.3 *Sustainability of healthy diets* - outputs from analysis of healthy, sustainable diets and household composition will be used to inform the development of the ABM.

3.3.1 *Food trade and consumption* - interaction of modeling activities with other work using Kantar data analysis in WP3.2 and WP3.3.

3.3.2 *Enhancing food security* and 3.3.3 *Local food* – interaction of the modeling activities and PhD on food practices with the community-based work in WP3.3.

In addition to existing links with departments at the University of Aberdeen, we will

link with other HEI in Scotland during the programme, through a number of stakeholder events run as part of the projects in this RD.

Added Scientific Value

O1: The added value of the ABM is that it will attempt to bring together many of the dietary influences that are usually studied in isolation or in unrealistic settings. It is a novel approach that takes account of cultural factors associated with making food choices, which are often neglected. Q methodology is a true mixed-method that allows the exploring of subjectivity, beliefs and values while retaining the transparency, rigour and mathematical underpinnings of quantitative techniques. Understanding the influence of parents and others on children's diets will enable the design of better interventions to promote healthy choices.

O2: Current literature on the prenatal manipulation of food preferences largely focuses on mothers consuming single high intensity flavours with short term measures of recognition at birth, or liking and consumption at weaning. The added value of the dietary intervention strategies to be evaluated here is that they focus on manipulating an infant's liking for a range of fruit and vegetables at weaning and beyond with associated implications for behavioural change in the mother herself and thereby the food culture within the wider family. During adulthood most interventions are aimed at encouraging healthier eating through one of three methods: food reformulation, education and motivation towards better choices or targeting automatic processes. This is despite research showing that sensory attributes are the dominant (or limiting) factor in food choice and that these aspects are less negotiable than other influential variables. The aim of the work proposed here is to prompt the adoption of a healthier diet by developing taste preferences over less healthy alternatives. Analysis of patterns of habitual purchasing behaviour and differences in response for frequent and occasional purchasers will enable better estimation of how different groups will be affected by behaviour change interventions such as tax or subsidy.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders.

Audience: Research output from this RD will be most immediately relevant to SG policy teams and FSS. The best way to handle KE from this and other related RDs has been discussed at several stakeholder meetings, notably with SG (Food, Drink & Rural Communities, Public Health Directorate, Child and Maternal Health) and FSS. It has been agreed that there will be regular catch-up or themed meetings approx. every 6 months as well as ad hoc interactions on specific research issues between individual PIs or groups and stakeholder representatives, as appropriate. These engagements could include cross-Gov Directorate meetings at WP or Theme level exploiting joined-up research outputs and expertise, along the lines of the science-policy workshop 'Promoting behaviour change in food and drink production & consumption' organised for SG in 2014, or food and drink industry-facing seminars along the lines of the successful FHIS events in the current programme. In addition, the ABM team will be running stakeholder workshops (**KE1,2**), which aim to involve colleagues from these organisations. KE to wider audiences will include presentations at events (**E**) such as the Edinburgh International Science Festival and

'Food matters Live', and contributions to ezines and social media (**PUB**).

Impact: The knowledge, intervention strategies, and models that will be the output of the RD will benefit the immediate policy-related stakeholders looking for the evidence informed policy, but also the wider public for whom interventions at different levels will be critical to the success of attempts to effect beneficial behaviour change. There is potential for economic, social, environmental, and dietary interventions for different sections of society pursuing longer term health goals. Delivery on potential impact will, initially, involve interactions with policy stakeholders, but could also involve the private sector and contribute to sustainable economic growth, including in the food and drink industry. The planned ongoing dialogue with stakeholders will maximise the impact of this RD. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

RESEARCH DELIVERABLE NUMBER: 3.2.4 Food culture and dietary choice

Work planning and timetable for Year 1: Showing major milestones (M), deliverables (D), KE/impact events (KE) and their timing. KE events include talks and presentations (E), ezine/social media (PUB).

Year 1: 2016/17	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Knowledge exchange								E				PUB
O1.1 ABM modelling							KE1					D1.1b
O1.2 Q methodology												
1.2.1 Identify concourse						M1.2a						
1.2.2 Construction of Q-set and Q-deck												
O1.3 Secondary data analysis of children's diet												
1.3.1 Prepare cross section data for analysis												M1.3a
O2.1 Flavour exposure at weaning												
O2.2 Flavour exposure and dehabitualisation in adult life				M2.2a	M2.2b							D2.2a
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.2.4 Food culture and dietary choice

Work planning and timetable for Year 2: Showing major milestones (M), deliverables (D), KE/impact events (KE) and their timing. KE events include talks and presentations (E), ezine/social media (PUB).

Year 2: 2017/18	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Knowledge exchange								E				PUB
O1.1 ABM modelling	D1.1a			M1.1a						KE2		D1.1c
O1.2 Q methodology												
1.2.2 Construction of Q-set and Q-deck	M1.2b											
1.2.3 Pilot									M1.2c			
1.2.4 Data collection and Q-sorting												
O1.3 Secondary data analysis of children's diet												
1.3.2 Data analysis									M1.3b			
1.3.3 Draft report of findings												D1.3a
O2.1 Flavour exposure at weaning												
O2.2 Flavour exposure and dehabitualisation in adult life						M2.2c				M2.2d		D2.2b
Annual Report (Year 2)												R2

Work Package 3.3 Food security

1. Overview

This WP focuses on different scales of food security in Scotland. At the macro level, as shown in Figure 1, it studies three interrelated demands for food: (1) foreign demand for Scottish products (which, if served by domestic producers, reduces the domestic availability of food); (2) domestic demand for imported products (which, if served by foreign producers, increases the domestic availability of food); and (3) domestic demand for domestic food products.

These demands play different roles in the sustainability of the Scottish food system: demands (1) and (3) determine the potential demand that domestic producers face and understanding them is key for sustainable economic growth; demands (2) and (3) together represent the total domestic demand for food, they determine the aggregated domestic diet and have implications for nutrition and health. It should also be noted that the products satisfying the different demands are not necessarily perfect substitutes and, therefore, there are potentially trade-offs in terms of all the sustainability components and health. This macro-scale study will be undertaken in RD3.3.1.

Whilst the macro perspective will provide information about drivers and trends of the different demands, analysis at sub-national scales is also required for this WP to build a meaningful understanding of food security in Scotland and of the contribution that 'local' foods (food and drink products whose geographical provenance is known to consumers) can make both to it and to Scotland's food sovereignty.

At the micro scale, RD3.3.2 will research the extent and lived experience of food insecurity at the household level. This work will develop and test a local-level index of vulnerability to food access insecurity that can be applied throughout Scotland. It will also devise policy tools and approaches for enhancing the security of food access for vulnerable households.

Spanning the micro and macro scales, RD3.3.3 will investigate the role and potential of local food production in Scotland. The Scottish Government aims to encourage the consumption of more local produce and to support the food and drink sector to increase the export potential of foods with 'local' Scottish provenance. This RD will build a better understanding of short food supply networks in Scotland and propose measures to strengthen them. From this basis, it aims to enhance the contribution of short food supply networks to producer and community empowerment, rural development and to food security; thereby linking to both RD3.3.1 and RD3.3.2.

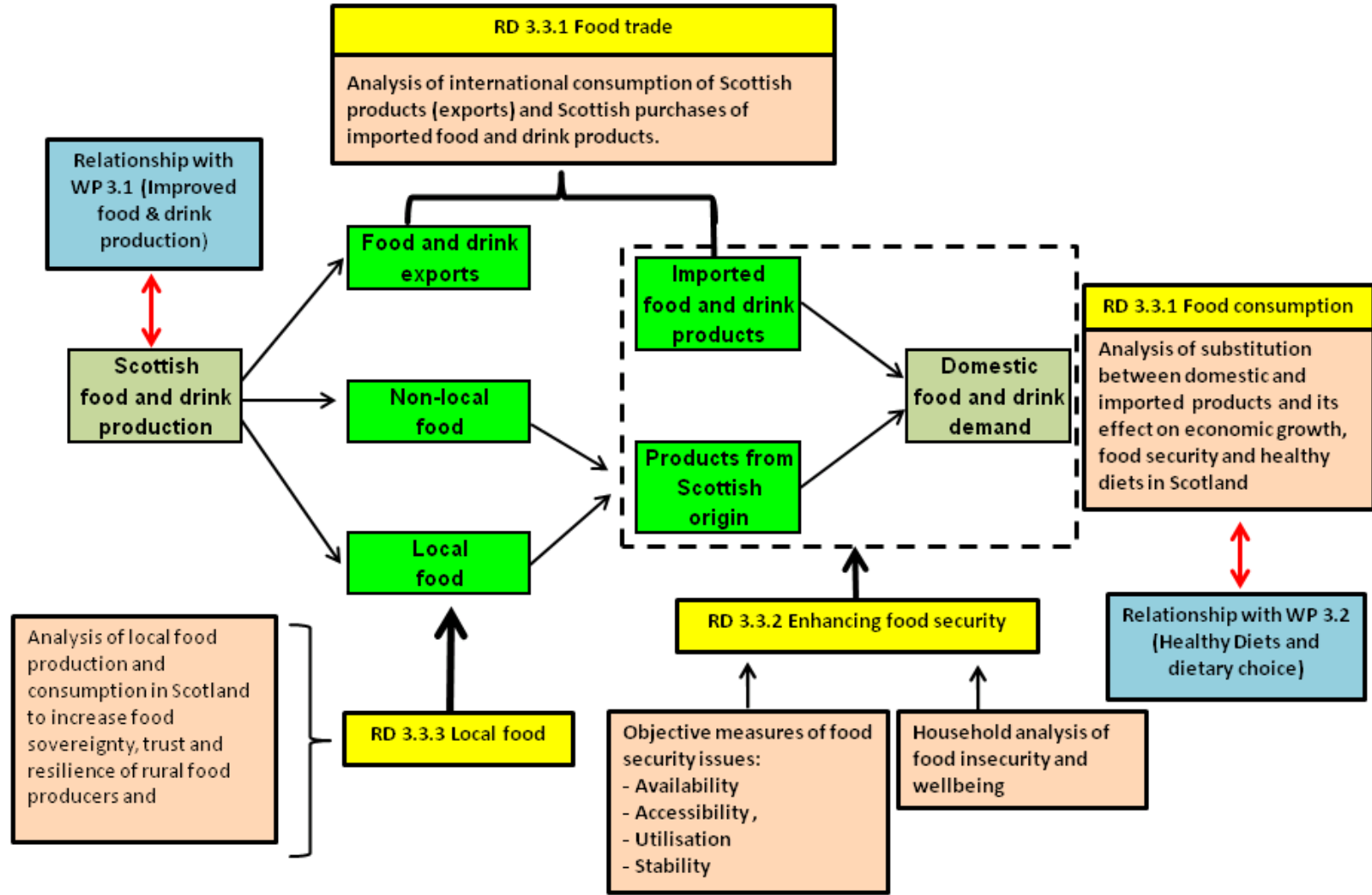


Figure 1: Relationships within the work package

This WP responds to Scottish Government policy drivers as set out in Recipe for Success, Becoming a Good Food Nation, and the Equally Well Taskforce. It addresses issues of relevance across the policy ‘landscape’, such as sustainable economic growth, rural development, food security, health and health inequalities, and food poverty. It also links to cross-Government Research Programmes on improving the sustainability of the food system, and to the needs of stakeholders such as Scotland Food & Drink, Scottish Food & Drink Federation, National Farmers Union of Scotland, retailers, traders, Nourish Scotland, Poverty Alliance, NHS Health Scotland, Food Standards Scotland and local authorities.

2. Coordination and management

2.1 Interaction within and between the MRPs and any partners included in the Work Package

This WP brings together colleagues from three MRPs in a new and innovative collaboration (see Figure 2). The cross MRP WP Team will be chaired by a Coordinator (Dr. Cesar Revoredo-Giha, SRUC) and will contain the RD Coordinators, two per RD, who will represent Hutton and RINH, and other MRP (including BioSS) representatives as appropriate.

Each RD will have its own management structure which will be integrated with the arrangements made for WP level management. PIs working on objectives within an RD will report to their RD Coordinator and the latter will monitor project progress against the agreed timeline. The RD meetings will be sequenced before WP meetings to allow feedback from RD to WP level.

The WP team will meet on a six-monthly basis, using online collaboration facilities where feasible and appropriate.

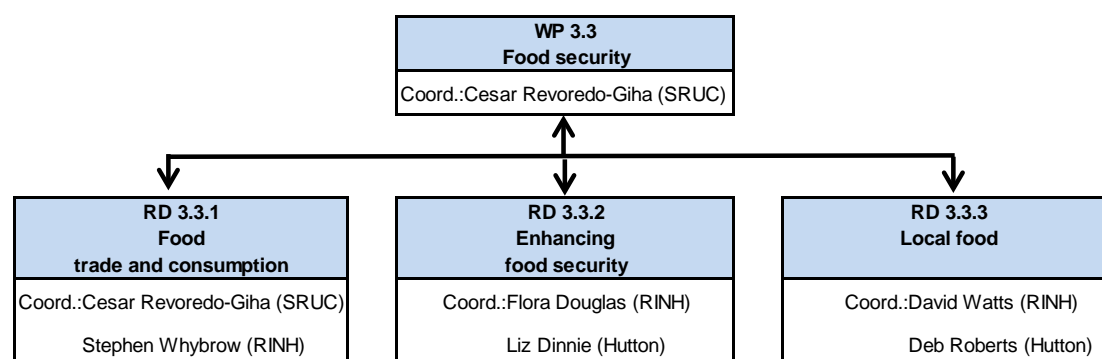


Figure 2: Management structure of the work package

RESAS advisors and other key stakeholders (Food, Health and Wellbeing Theme Coordinator, KE Sectorial Leads and appropriate Programme Advisor) associated with the WP will be invited to meet on these occasions in order to review progress and provide steering advice. The aim of WP meetings will be partly focused on management issues (annual monitoring of progress against

objectives for all RDs, facilitating resolution of problems, reporting of progress) and the development of WP level KE outputs. Minutes of WP meetings will be communicated to all staff in the WP.

There will be strong collaborative links between the work undertaken in this WP and other key WPs within the Theme and SRP, in particular RD2.3.8 (Alternative management practices), RD2.4.2 (Resilience of rural economies to key external drivers), RD3.1.1 (Improving Scottish primary production), RD3.1.2 (Improving food & drink production), RD3.2.3 (Sustainability of healthy diets), RD3.2.4 (Food culture and dietary choice) and WP3.4 (Communities and wellbeing). Interaction with those RDs and WPs will be based on a pragmatic approach. In most of the cases it will be through common researchers and where meetings are needed these will be set up by the WP Coordinator or by the RD Coordinators. The linkages are presented in the table below

2.2 Interaction with scientists in the CAMERAS and wider science communities

Cross collaborations with other scientists will enhance the quality of the research and will allow us to advise policymakers and stakeholders in the most relevant way.

The interaction with CAMERAS scientists, policy teams (at national and local level) and other key stakeholders will be important because the topic of the WP is closely connected to the CAMERAS' topic of improving the health and welfare of the Scottish population. The interaction with them, which is part of the KE strategy, will be based on providing information (e.g., through progress reports) and consultation (e.g. as part of an advisory group), and through participation (as members of an advisory group, helping to shape the output to ensure its relevance, and perhaps as research partner).

Linkages between WP 3.3 and the other WPs in the Programme

Theme 3: Food Health and Wellbeing				Theme 2: Productive and Sustainable Land Management and Rural	
WP3.3: Food security	WP3.1: Improved Food and drink production	WP3.2: Healthy diets & dietary choice	WP3.4: Communities and wellbeing	WP2.3: Agricultural systems and land management	WP2.4: Rural industries
RD3.3.1: Food trade and consumption	RD3.1.1: Improving Scottish primary production RD3.1.2: Improving food & drink production	RD3.2.3: Sustainability of healthy diets RD3.2.4: Food culture and dietary choice		RD2.3.8: Alternative approaches to sustainable land management	RD2.4.2: Resilience of rural economies to key external drivers
RD3.3.2: Enhancing food security		RD3.2.4: Food culture and dietary choice			
RD3.3.3: Local food			RD 3.4.1: Demographic change in remote areas RD3.4.2: Place based policy RD3.4.3: Rural landscape and wellbeing RD3.4.4: Community resilience		

2.3 Interaction with underpinning capacity

PhD students and new seed corn projects within institutional Underpinning Capacity funding may provide the opportunity to expand and amplify this work and to develop greater capacity. Appropriate linkages between the Institutional underpinning funding are likely to be made through the Theme 3 Coordinator, the Programme Advisors and the Institute Directors.

Funding for BioSS inputs of a collaborative or advisory nature will be provided as described at the Theme level through Underpinning Capacity Function 7, "Provision of Biomathematical & Statistical Consultancy Services". Management level inputs will be provided through identification of a BioSS Work Package Contact, who will be invited to work package level meetings and be involved in the preparation of annual reports and Knowledge Exchange activities. The nomination of a BioSS Work Package Contact will ensure that no scientist contributing to the work package is left without a point of contact in BioSS. In addition, the BioSS Work Package Contact will be well placed to maintain a watching brief over BioSS-MRP interactions in the work package and to identify gaps in coverage or other mismatches between resource and demand which will be discussed with the BioSS Theme Contact along with other appropriate managerial staff in BioSS and the MRPs.

2.4 Management of the annual reporting cycle

The management structure described in Figure 2 will take responsibility for the management of the annual reporting cycle. Coordination will initially be in the hands of the RD Coordinators, who will ensure that all the reporting outputs are assembled and reported on to the WP Coordinator as required by the Theme Coordinator, Theme Management Group, Programme Advisors and ultimately RESAS. PIs working on objectives within an RD will report to their RD Coordinators.

2.5 Additionality generated by management structures proposed at Work Package level

The WP has an appropriate mix of highly experienced researchers who have experience in applied interdisciplinary research projects. They bring not only complementary skills when delivering the SRP work but also a track record of adding value to the programme through different linkages (with other academics within the UK and abroad), links to the industry (through SAC Consulting, SAOS, NFUS, QMS, Scotland Food and Drink, and the Scottish Food and Drink Federation) and from building additional capacity and techniques through competitive and collaborative UK and EU funded research projects. These linkages generate considerable knowledge, data and connections that will increase the value for money of the work funded by RESAS.

2.6 Key risks to delivery at a Work Package level and means to manage them

The following table provides the key risks that may potentially affect the WP operation, their likelihood, their consequences and mitigation measures.

Risk descriptor	Risk assessment	Likelihood and impact	Control	Risk Owner
Reductions in funding greater than those currently anticipated	Medium	Medium-high	WP will be modified in consultation with RESAS.	DEC, Theme Coordinator & KE Coordinator
Staff loss	High	Low-High	Whilst the teams will help in the short term, the aim will be to find a replacement promptly.	WP & Theme Coordinators
Weak linkages with other RDs and WPs	Low	Medium	Cross WP working and the selection of common case studies across RDs in WP3.3 and WP3.4	WP & Theme Coordinators
Recruitment of survey participants	Medium	Medium	Survey recruiter companies will be used.	RD Coordinators
Divergence in stakeholder and research priorities	Low	Medium-High	The regular WP management meetings will be used to ensure communication and early identification of potential issues.	WP & Theme Coordinators
Divergence in priorities between partner MRPs	Low	Medium-High	Regular WP management meetings will be used to ensure communication and early identification of potential issues.	WP & Theme Coordinators

3. Impact and KE

The research in the WP will generate a range of outputs that will be of value to stakeholders particularly in Scotland (e.g., The Scottish Government, Scotland Food & Drink, Scottish Food & Drink Federation, National Farmers Union of Scotland) but also in the UK and internationally. The outputs will help to:

- understand the relationship between Scottish exports and domestic demand for those exported products and to what extent the goals of the SG of expanding the exporting base is compatible with food security. This will also be of use to Scotland Food & Drink and Scottish Enterprise;
- appreciate the relationship between Scottish consumption of domestic food and drink products versus imported products; and whether purchases of a particular provenance are due to prices or any other reasons (e.g., terroir characteristics) and its implications for sustainability and food security;
- comprehend international factors that may influence food security in Scotland, which will be useful to the SG food security policy;
- establish the nature of household food insecurity in Scotland, what societal sectors and communities are affected by it and are responding to it, how it affects health and wellbeing, and what can be done about it. These outputs will be important for policy at different levels - macro (SG) and local authorities;
- understand the operation of short food supply chains, their potential for improving food security and sustainability. In addition, the provision of baseline data for Scotland will support the efforts to measure the importance of short supply

chains.

- construction of policy proposals for mechanisms to support food sovereignty, short food supply chains and the empowerment of resilient communities.

The WP team will participate in twice-yearly scheduled discussions with key stakeholders, which may be organised at WP or Theme level. Policy-relevant information will be discussed with policy colleagues at RD meetings, presented on the CKEI website and through the Rural Policy Centre, and by existing interactions with Defra and the European Commission.

As regards publications, the team will aim to disseminate to different segments, namely through high impact publications in relevant journals, and also relevant academic blogs (e.g., The Conversation and Global Food Security).

The WP team will also contribute to KE activities organised in conjunction with KE Sectorial Leads and the Centre for Knowledge Exchange and Impact as appropriate and including contributions to the CKEI Think Tank's selection and planning of Horizon Scanning and/or position paper projects.

4. Quality Assurance (QA)

The SRP Themes will employ a Quality Management System across all participants to ensure that International ISO 9001:2008 standards are met. This will cover issues such as analyses, data management and archiving. In relation to modelling activities it will be the responsibility of the individual partners to archive data, maintain appropriate records of data, experiments, software, and communications with stakeholders and of project meetings. Quality management issues will be reviewed periodically by the WP management team.

5. Ethical and regulatory issues

The Surveys detailed in the RDs where they require response from the public or stakeholders will seek appropriate approval and ethical review from RESAS (if appropriate including SG Survey Control Unit) and relevant Research Ethics Committees at respective MRPs.

6. Contribution to the 3R's (reduction, refinement and replacement)

The research in this WP does not involve animals.

7. Sustainable Development

The Scottish MRPs associated with WP3.3 have Environmental Policy Statements which affirm that they are committed to preventing pollution, adopting and promoting environmental best practice in connection with operations, and in support of sustainable and safe practices. This is managed via an ISO 14001 environmental management system.

In order to address wider sustainability issues collaboration software including Web 2.0 technology will be used to facilitate messaging, group calendars, document sharing with versioning, and discussion boards organised around teams of people. Web-based video-conferencing will be used, integrated with concurrent sharing of the desktop display across multiple sites and organisations. The use of public or cost effective transport will be encouraged throughout the lifetime of the WP. We will monitor the impact of travel and where possible reduce the need to travel through use of tele-conference and video-conference facilities.

Name of RD: RD 3.3.1 Food trade and consumption**Research aim and key drivers**

The aim of this RD is an examination of trends in the domestic and international consumption of Scottish food and drink products (i.e., Scottish exports) and the penetration of imported counterparts in Scotland, in order to assess any conflict between them as regards promoting the consumption of locally-produced food and drink, encouraging food supply-chain resilience, increasing the economic performance of the food and drink sector, food security and consumption of a healthy diet in Scotland. The key drivers for the RD are:

1. Scottish Government (SG) and production related stakeholders' interest for increasing the market for Scottish products (including both the rest of the UK and abroad) to improve food supply-chain resilience and increase the economic performance of the food and drink sector. These are key components of the SG policy documents: 'Recipe for Success' and 'Good Food Nation'. They are also present in the Scotland Food and Drink (SF&D) export plan for Scotland: "Tomorrow: the World" and sectoral documents such as the Scottish Dairy Review: "Ambition 2025" Report and Beef 2020 Report.
2. SG interest, as shown in the 'Good Food Nation' document, on improving nutrition and food security through healthy, sustainable diets and the consumption of locally-produced food and drink.
3. International trends such as greater interest abroad for Scottish products as shown in Scotland Food and Drink export plan for Scotland presented in the "Tomorrow: the World" document.

Research in this RD responds to, and will have impact on, these drivers by:

- Providing analyses of: (a) the relationship between Scottish exports and domestic demand for those exported products; (b) the relationship between Scottish consumption of domestic food and drink products versus imported products; and (c) the implications of (a) and (b) on overall environmental, social and economic sustainability, economic growth, food supply network resilience and food security.
- Providing an analysis of international factors that may influence food security in Scotland.

Stakeholders consulted in developing this proposal

The current proposal is based on evidence from work that has been done in Scotland and elsewhere. Discussions have been held with several stakeholders at different stages of the proposal, including RESAS, FSS, NFUS, Scotland Food and Drink Ltd, Scottish Enterprise and Nourish Scotland and the Scottish Government Food, Drink and Rural Communities Division.

Summary of the proposal:

The work responds to the ITGF requirements for RD3.3.1 and it will study the relationship between domestic purchases and international trade (i.e., exports and imports) from two perspectives:

The first perspective (micro) will consist of two parts: (a) The relationship between Scottish exports and domestic demand for those exported products.

This part will study a selected group of Scottish food and drink supply chains (the selection will be based on several criteria such as their importance to exports, healthy consumption) to analyse the balance between exports and domestic consumption in Scotland and its effect on food security and healthy diets in Scotland. (b) Relationship between Scottish consumption of domestic food and drink products *versus* imported products. As regards the degree of substitution between Scottish food products and food products from other origins, this RD will investigate and model the effect of country or region of origin on food and drink purchased in Scotland to examine whether purchases of a particular provenance are due to prices or any other reasons and the implications on overall environmental, social and economic sustainability, economic growth, food supply network resilience and food security. (b) The second perspective (macro) will focus on international factors that may influence food security in Scotland, and will develop a model that links global food production, land use, diets and consumption and their feedbacks for the first time. Using the model, various scenarios will be investigated, which may include climate change impacts on domestic crop and livestock production, rising incomes, land acquisition, soil, water and fertilizer shortages, aid, war and migration and demographic change. The effect of these on the robustness and mix of different strategies will be evaluated.

The key deliverables of RD3.3.1 (years 1-2) will be:

D1.1: RINH Kantar Worldpanel (KWP) database expanded with GHG and other environmental variables and complete country of origin data (Year 1).

D2.1: Analysis of trade-off between domestic consumption and exports (Year 2).

D3.1: Analysis of substitutability between domestic and foreign products for specific food categories for Scotland (Year 2).

D4.1: Analysis of consumers' attitudes and preferences regarding provenance and purchasing behaviour using economic experiments (Year 2).

D4.2: Analysis of consumers' attitudes and preferences regarding provenance and actual purchasing behaviour using data from KWP's "LinkQ". (Year 2).

D7.1: Agent-based model implementation of the conceptual model to measure international factors that may influence food security in Scotland.

The key deliverables of RD3.3.1 (years 3-5) will be:

- Analysis of the impact that changes in the demand for Scottish food products may have on environmental, social and economic sustainability in the Scottish food and drink supply chain (Years 3-5).
- Report of simulation using multimarket models of the trade-offs between domestic consumption and trade under different scenarios for different food categories (Years 3-5).
- Report of results of simulations of different scenarios using an agent-based modelling approach at the national level, together with global spatially disaggregated data of food production, a global food demand model, and global information on national diets and trade (Years 3-5).

Technical approach

The RD will follow seven work Objectives (below each Objective are the activities corresponding to years 1 and 2):

Objective 1 - The KWP database for Scotland will be expanded to complete missing country of origin data and incorporate environmental data. The KWP database includes country of origin for a third of products, including many that are particularly relevant to the Scottish food and drink industry – meat, vegetables, soft fruit, cheese, and drinks. Key food groups are missing, however, such as fish and seafood, and these missing data will be added. Environmental data, where available, will be linked to the KWP database. These include GHG estimates, land use and water use for key food groups. Key to addressing the RD is including research around consumption data, but the KWP database is of food and drink purchases, not consumption. Any consideration of diet quality and food or nutrient intakes at an individual level (as dietary guidelines, such as the Scottish Dietary Goals, are expressed) needs to account for food preparation weight changes (unavoidable food waste) and avoidable food waste. Data to allow these adjustments on a food group level, and to allow an assessment of diet quality in relation to the Scottish Dietary Goals, are being collated as part of the current (c)WP 7.1.1 and will be incorporated into this RD. This will be linked with RD 3.2.3 and RD 3.2.4.

Deliverable D1.1 – KWP database expanded with GHG and other environmental variables and complete country of origin data (March 2017).

Objective 2 - Export trends (i.e., the interest of importers of Scottish products) along the supply chain and the hypothesis that this export negatively affects domestic consumption by reducing the availability of healthy food products, will be studied. This will be done based on two data sources: (a) KWP database to understand 'rest of UK' interest in Scottish produce and (b) Scotland's Global Connection Survey, UK HM Revenue & Customs, UN-COMTRADE for international (outside UK) interest in Scottish products. In addition, the work will be supplemented by secondary information and participation of relevant stakeholders.

Activity: - Compilation of information on trade. We shall consider exports to the rest of the UK (major market for Scotland) and abroad. In addition, data for domestic consumption of similar products will also be compiled.

M2.1 – Compilation of database needed for the analysis (September 2016).

Activity: - Analysis of export trends along the supply chain and their relationship with domestic consumption. This will use descriptive statistics and regression analysis to test the hypothesis that increases in exports negatively affects domestic consumption.

D2.1 – Paper testing the hypothesis of a trade off between domestic consumption and exports (May 2017).

Objective 3 - Demand analysis (i.e., food and drink choice) using KWP data for considering selected food and drink categories, where Scottish products contribute. This will allow analysis of the effects of a number of variables such as price and provenance, and control of the results by urban/rural, household composition, and SIMD. The Exact Affine Stone Index (EASI) demand system developed by Lewbel and Pendakur (2009) will be used for the analysis, given that it accounts for preference heterogeneity. Similar work has been done for Scottish beef by Revoredo-Giha et al. (2010) using the Deaton and Muellbauer's Almost Ideal Demand System (AIDS). The demand systems will be used to simulate the effect that changes in prices (and other variables) have on the demand for food products from different provenance. The modelling work will be extended to explore how these changes in demand and changes in origin are likely to impact on diet quality and environmental sustainability, the promotion of healthy, sustainable diets, and in moving the population towards achieving the Scottish Dietary Goals.

Activity: – Preparation of SRUC Kantar Worldpanel data for the demand analysis for selected products.

M3.1 – Dataset ready for the econometric work (January 2017).

Activity: – Demand analysis of provenance. Analysis of domestic purchases (imported versus domestic products) using an EASI demand system. Computation of substitution elasticities for products from different origins within a category.

D3.1 – Paper estimating the substitution between domestic and foreign products for specific food categories for Scotland. (December 2017)

Objective 4 - Consumers' attitudes and preferences regarding provenance and purchasing behaviour will be studied from two perspectives: (a) Value elicitation methods (e.g., choice experiments, contingent valuation) will be used to complement the work done with the Kantar data and they will allow for analysis of perceived barriers to purchasing more local produce, as well as perceived trade-offs between attributes such as country of origin, sustainability, and health; (b) The link between consumers' attitudes and preferences regarding provenance and purchasing behaviour will be assessed through KWP's "LinkQ" service, by issuing 'attitudes and beliefs' questionnaires to current KWP participants and comparing these to retrospective purchase behaviour.

Objective 4.1 (O4.1) - Consumers' attitudes and preferences regarding provenance and purchasing behaviour.

M4.1 – Preparation of protocol for experiments (March 2017)

D4.1 – Paper reporting results from the experiments. (December 2017)

Objective 4.2 (O4.2) - Consumers' attitudes and preferences regarding provenance using KWP's "LinkQ" service.

M4.2 – Preparation of data for the analysis (March 2017)

D4.2 – Paper reporting results of the analysis of the data from KWP’s “LinkQ”. (March 2018)

Objective 5 - The results from O2, O3 and O4 will be used as the starting point to estimate the impact that changes in the demand for Scottish food products and imports along the supply chain may have on environmental, social and economic sustainability in Scotland. This will be done using Scottish input-output tables (including the environmental input-output tables). Activities occur after year 2.

Objective 6 - Modelling trade-off by food category using partial equilibrium (PE) models. The information from O2 to O5 will be summarised using multi-market models for selected categories to measure the trade offs between domestic products and trade (imports and exports). Activities occur after year 2.

Objective 7 – To model international factors that may influence food security in Scotland, this Objective will employ an agent-based modelling approach at the national level, and use global spatially-disaggregated data of food production (from environment to crops and livestock, University of Minnesota), a global food demand model (FEED-ME, University of Dundee), and global information on national diets and trade. Agents will calculate their food demand based on nutritionally balanced diets, and will be given the goal of meeting those commodity demands, either by local production or through trade, which they will follow different strategies to achieve. Economic variables such as prices and interest rates will be used as input parameters that can be varied to investigate sensitivity. Later versions of the model may incorporate them explicitly as functions of supply and demand. Within the whole project, various scenarios will be investigated, which may include (depending on stakeholder feedback) a subset of climate change impacts and other factors on domestic crop and livestock production, rising incomes, land acquisition, soil, water and fertilizer shortages, aid, war and migration and demographic change. The effect of these on the robustness and mix of different strategies will be evaluated. The proposed work will focus on the Scottish perspective and how it relates to the rest of the world.

M7.1 - Conceptual model of food supply and demand at the global and national level incorporating economic and socio-political constraints on food production and trade (March 2017).

D7.1 - Agent-based model implementation of the conceptual model in Milestone 7.1 (March 2018).

Years 3-5: Further milestones and deliverables will be agreed at end of Year 2, but are likely to focus on the use of the model to examine different scenarios of food production and consumption and the factors that influence them.

Expertise

Scotland's Rural College (SRUC) has considerable expertise in food supply chains and consumption, innovation and behavioural economics, and resource efficiency applied in the current and previous RESAS SRPs and ongoing or previous EU, Defra, DFID, FAO and ESRC projects. SRUC's socio-economic work in this RD builds on these strands of research in the CWP's (e.g. cWP 4.1, cWP 4.2, and cWP 5.1) and further develops socio-economic methods used by the team, such as demand analysis, choice experiments, and partial equilibrium models. In addition, SRUC has developed strong links with various representatives of the Scottish food and drink industry, which will assist with the involvement of the industry in a co-construction process in this RD.

The Rowett Institute of Nutrition and Health (RINH) has relevant expertise in human nutrition, specifically in dietary analysis and the secondary analysis of dietary and related data. Analysis of KWP data is central to cWP 7.1 (relationship between diet, food availability and affordability). It also contributes to cWP 8.3 and has contributed to the climate exchange (CXC) network of excellence. This has involved merging other data sources to the KWP data, and developing extensive knowledge around adjusting purchase data to consumption values. The proposed work will develop and extend the RINH's expertise in analysing the nutritional aspects of consumer purchase data, and link to RINH's expertise in the sustainability of diets.

The James Hutton Institute (Hutton) has considerable expertise in agent-based modelling applied to a number of climate change and natural resources issues. The work proposed in this RD will build on methodologies developed in previous projects in the cSRP and will complement other agent-based modelling work in the ITGF Programme, notably WP2.4 (Rural Industries) and RD3.2.4 (Food culture and dietary choice), but it will also develop a new area of research in applying agent-based modelling at the national level. In particular, the proposed work will contribute directly to the DEVIL project (Delivering Food Security on Limited Land), an international project funded by the Belmont Forum.

Key linkages, interdisciplinarity & collaboration

Objectives 1 to 6

These Objectives have linkages to RD3.1.1 as regards the supply for domestic produce, RD3.1.2 for the supply for domestic processed products, RD3.2.3 on sustainable diets, RD3.2.4 on food culture and dietary choice, RD2.3.8 on alternative approaches to sustainable land management, RD2.4.2 on Resilience of rural economies to key external drivers and EPIC III Module 5.

They have a close link with work carried out on Scottish demand as part of the cSRP under CWP5.1 on sustainable supply chains and food security.

The work in these Objectives has relation to the ERANET-(Implementing Sustainable Diets in Europe) SUSDIET project, where Scottish demand analysis is also being carried out.

Objective 7

The Hutton researchers involved, Robin Matthews and Gary Polhill, have worked on joint projects for a number of years together with their colleagues from the Universities of Aberdeen and Dundee (Pete Smith, Terry Dawson and Jennie Macdiarmid (RINH)) under the Scottish Food Security Alliance (SFSA), an alliance between Hutton and the Universities of Aberdeen and Dundee. They currently have four PhD studentships working on different aspects (sustainable intensification, environmental impacts, food demand, diets) of the DEVIL project won recently by the SFSA. The work proposed in Objective 7 of this RD will contribute directly to this project with the focus on Scotland, providing an excellent way to internationalise Scottish-funded research. Within the ITGF Programme, the work will link with WP2.4 on Rural Industries and with RD3.2.4 on Food culture and dietary choice

Added Scientific Value

- Part of the work in Objectives 1 to 6 (i.e., demand analysis using the EASI model and developments in experimental economics) will complement the work carried out in the ERANET project “SUSDIET: Implementing sustainable diets in Europe”, which is coordinated by INRA-ALISS (France) and encompasses 15 highly-experienced teams from 9 European countries. SRUC work is funded by Defra and coordinated by Dr. Revoreda-Giha.
- The work proposed in Objective 7 of this RD will contribute directly to the DEVIL project with the focus on Scotland, providing an excellent way to internationalise Scottish-funded research. DEVIL is a high-profile international project funded by the Belmont forum and coordinated by the University of Aberdeen (Pete Smith, Deb Roberts (Hutton)). The purpose of the project is to examine the challenge of delivering food security now and in the future on limited land area, which will entail examining feedback interactions between land use change and food security dynamics. It will use high resolution, spatially disaggregated global models and databases of soils, land-use, crops and livestock, developed by consortium partners to provide information on food supply, and the global FEEDME model, informed by FAO statistics and nutritional demand, to derive country level dietary demands for food products. The work proposed in this RD will develop and use a country-level agent-based model, that includes economic and sociopolitical constraints on food production and trade between countries, to satisfy the demand for food either locally, or through trade (constrained by international trade statistics), given the soil, crop and livestock resources available. It will therefore add considerable value to the overall DEVIL project by linking food supply and demand for the first time, and to the RESAS programme by providing a global context for the work focused on Scotland.

Specific contributions of the WP will be:

- Creation of a consumer database expanded by provenance and environmental variables.
- Use of the EASI demand model for provenance analysis and incomplete demand system.
- Developments in experimental economics through use of new discrete choice models for experiment analysis.
- Use of agent-based models for modelling international trade, food allocation

between imported and domestic products, food security and impact on environment and natural resources.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders.

The **Knowledge exchange** plan will include:

- Knowledge exchange with stakeholders will be important for the development of the RD. At the RD level the KE will be on Scottish export developments (with Scotland Food and Drink, Scottish Enterprise and RESAS) and Scottish consumption trends and consumers' interest on Scottish food and drink products (with FSS, Scotland Food and Drink, Scottish Enterprise and RESAS). We envisage that these will be with specific experts in the aforementioned institutions.
- In addition, the RD will join-up at Theme or WP level to engage with other KE initiatives such as knowledge transfer to public: e.g., presentation of research at public events such as Royal Highland Show, Edinburgh Science Festival.
- Knowledge transfer to academics: publications in peer-review journals; presentations at national and international conferences; contribution to academic blogs such as 'The Conversation', 'Global Food Security'.
- For the agent-based modelling work, in addition to the above, knowledge exchange will be through CCAFS (the CGIAR Climate Change Adaptation and Food Security initiative), the World Bank and Future Earth, supported by knowledge exchange experts from the ETH Zurich World Food System Center, who will organize a series of workshops and summer schools. The project partners have regional networks in South Asia, sub-Saharan Africa, and South America, as well as international networks through which further KE will occur.

Audience

The content of this RD is very policy-oriented and this is reflected in its audience, which will comprise stakeholders such as policy makers, food and drink supply chains stakeholders, academia and public. The proposal's communication and dissemination plan includes outputs and methods of communication relevant to each of these categories of stakeholders.

The outcomes of the project will be particularly relevant for:

- Policy makers (SG, FSS and NHS Health Scotland), who will benefit from the trade analyses and the implications of the results in terms of food security, health and sustainability.
- Food and drink supply chains stakeholders (Scotland Food & Drink, Scottish Food & Drink Federation, National Farmers Union of Scotland, retailers, traders, Nourish Scotland) will benefit from the different demand analyses as regards provenance, since these are key outputs for marketing.

- Academic circles will be interested in the applications of new theoretical developments as well as the empirical results.
- For the agent-based modelling work, in addition to the above, the audiences include: 1) international agencies with an expressed interest in project outcomes, 2) other high level stakeholders (e.g. policy makers in international organizations like FAO, WHO or the World Food Program, government departments in partner countries, industry and agri-food businesses), 3) regional farmers, land managers, practitioners and extension workers, but also food processing industry and retailers, 4) students and those in training, and 5) the international scientific community through the larger DEVIL project.

Impact

The work in this RD should:

- Inform the Scottish government and Scottish food supply chain stakeholders as regards current policy of export promotions, demand for domestic food products and foreign interest for domestic products;
- The impact will be in terms of policy coherence (i.e., assurance that current policies will not affect domestic food security and sustainability goals) and in terms of providing evidence and analyses;
- Inform Scottish food supply chain stakeholders on the importance of provenance to consumers' purchasing behaviour. This should help inform decisions about the balance between domestic supply and exports.
- The work will inform FSS and NHS Health Scotland on the key healthy eating messages in terms on balancing Scottish Dietary Goals, environmental and economic sustainability.
- In addition to the above, the agent-based modelling work will contribute through the DEVIL project to improved assessments of ways to feed 9 to 10 billion people by 2050, one of the greatest challenges humanity has ever faced, doing this on the limited land available, while minimising the encroachment onto other valuable ecosystems.
- To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

RESEARCH DELIVERABLE NUMBER:

Work planning and timetable for RD3.3.1 Year 1:

(M)=Milestone, (D)=Deliverable, (KE)=Knowledge exchange activity

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
KE								KE1				
O1 - Add environmental and country of origin data into KWP												D1.1
O2 - Foreign versus domestic markets analysis						M2.1						
O3 - Imported versus domestic products analysis										M3.1		
O4.1 - Consumers' analysis using value elicitation methods												M4.1
O4.2 - Consumers' analysis using KWP's "LinkQ"												M4.2
O5 - Impact on sustainability in Scottish F&D supply chain 1/												
O6 - Trade-offs by food category using PE models 1/												
O7 - To model international factors influencing security												M7.1

in Scotland													
Annual Report (Year 2)													R1

Note: 1/ Activities start after year 2.

**RESEARCH DELIVERABLE NUMBER:
Work planning and timetable for RD3.3.1 Year 2:**

(M)=Milestone, (D)=Deliverable, (KE)=Knowledge exchange activity

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
KE						KE2						
KE				KE3								
KE											KE4	
O2 - Foreign versus domestic markets analysis		D2.1										
O3 - Imported versus domestic products analysis									D3.1			
O4.1 - Consumers' analysis using value elicitation methods									D4.1			
O4.2 - Consumers' analysis using KWP's "LinkQ"												D4.2
O5 - Impact on sustainability in Scottish F&D supply chain 1/												
O6 - Trade-offs by food category using PE models 1/												
O7 - To model international factors influencing security in Scotland												D7.1
Annual Report (Year 2)												R2

Note: 1/ Activities start after year 2.

Name of RD: 3.3.2 Enhancing food security

Research Aim This Research Deliverable aims to establish the nature of household food insecurity in Scotland, what societal sectors and communities are affected by and respond to it, how it affects health and wellbeing, and what can be done about it. The Food and Agriculture Organisation of the United Nations (FAO) definition of food security is the underpinning concept of this RD (i.e. *“when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active life”*).

Key Drivers

1. Scottish Government (SG)’s current concern regarding the emergence of, and trends in, emergency food aid (bank) use and related government policymaker concern with the nature and extent of household level food insecurity in Scotland found in existing documents such as Recipe for Success – Scotland’s National Food and Drink Strategy, the SG’s ‘Severe Poverty in Scotland’ Report (March 2015) and the ‘The nature and extent of food poverty/household insecurity in Scotland’ (Douglas et al forthcoming, for NHS Health Scotland due May 2015).
2. UK Government’s concern regarding food poverty and hunger.
3. Public Health Faculty (UK) and third sector/NGO concern regarding contemporary trends in emergency food aid use and adverse population health consequences, i.e. more under- or malnutrition appearing in the general population.
4. Interest in the role locally grown food, including Grow Your Own schemes, might play in enhancing food security - at macro and micro levels – and addressing other issues such as health, climate change and community cohesion (Recipe for Success – Scotland’s National Food and Drink Strategy, 2009; Community Growing in Scotland - Towards a framework for action; Grow Your Own Working Group Report, 2011; The True Value of Community Farms and Gardens).
5. Work in current SRP: specifically cWP 7.1, Factors affecting Food Choice and cWP 8.2, ROs 8.2.4 and RO8.2.6.

Impact

Despite the fact that, at the macro level, the UK is deemed to be food secure, **it is not known how many people are food insecure at the household level in the UK or Scotland**, nor which subgroups or communities may be more vulnerable to household food insecurity than others, to what degree it is being experienced by such communities, or what can be done to alleviate such food insecurity in a sustained and sustainable manner. Moreover, international evidence indicates that food bank use statistics (used by some policy makers as an indirect measure of Household Food Insecurity (HFI)) is a very poor indicator of the nature and extent of HFI in the wider community.

Therefore, this research will generate, interrogate and use evidence, including from selected demonstration areas, in pursuit of the following 5 objectives:

1. who is affected by household food insecurity (HFI) in Scotland and the degree to which particular population sub-groups are affected by it;
2. the ways in which HFI is experienced and managed by individual households and communities identified as most badly affected;
3. existing and potential community level responses and resources aimed at

- making individuals, and households within their midst, food secure;
4. the role that locally and self-produced food plays, or might play, in mitigating HFI amongst communities where it is found to exist;
 5. maps of the range and availability of culturally acceptable foods.

These data will be co-produced with key policy maker stakeholders, with the aim of supporting the development of scale-appropriate policy principles, tools and advice associated with ensuring food security for all at the community and household level in Scotland. It is envisaged that this research would provide the SG, policy makers, the public health community of practitioners and researchers, and the public itself with a clearer picture of the proportion of particular population sub-groups that are affected by severe food insecurity, and with data that can facilitate the development of public policy and community-led interventions and programmes that would help to enhance the food security status of those most badly affected in urban, rural and remote areas of the country.

The following people have been consulted in the formulation of this RD: Pete Ritchie (Nourish Scotland); Bill Gray (NHS Health Scotland); NHS Health Scotland: Food Poverty Group; Prof Liz Dowler (Univ of Warwick); Prof Graham Riches (Emeritus Prof: Univ of British Columbia); Dr Rachel Loopstra (Univ of Oxford); Julian Holbrook (Climate Interchange - Just One World), Peter Faassen de Heer from the SG's Population Health Improvement Directorate, Public Health Division, and members of the Scottish policy teams in the Food and Drink Division.

Summary of the proposal

This RD represents a novel area of research for the SRP that has been developed in response to the contemporary policy and public health drivers outlined above. The RD proposes an integrated suite of studies that rely on both established and novel research methodologies, both quantitative and qualitative, to address the five objectives listed under 'impact' above. It will take stock of current research on food poverty/ household food insecurity in Scotland funded by NHS Health Scotland (supported with matched funding from the cSRP associated with its focus on food choices and health inequalities, and support from the Chief Office for Science funded Health Economics Research Unit), which is due to report in May 2015.

This RD proposes to develop two new complementary quantitative measures of community and household level food security in Scotland.

- One is intended to provide policy makers with the means of assessing the extent to which HFI is evident in the Scottish context, including those groups likely to be most at risk of HFI, and to enable monitoring of the outcomes of policy interventions intended to mitigate it.
- The other measure is intended to provide a small-scale spatial indicator of food accessibility across Scotland.

This RD is also underpinned by an ethnographically-informed qualitative approach to identify and analyse the complex layering of factors linking food insecurity and wellbeing. Thus, this RD will deliver increased understanding of food choices made by socially and economically disadvantaged groups. It will ask why these choices are made, and which of the local and national level factors that contribute to food choices by these groups are amenable to local and national government policy interventions. Therefore, the influence and impact of socio-economic status and geographic location on HFI in the population will also be assessed, and will build on

quantitative secondary data work in the cSRP, WP 8.1, as well as qualitative self-reporting (as used in the community resilience model in cSRP WP 8.2.).

This RD will pursue the following objectives:

O1 Develop a culturally relevant measure of household level food (in)security applicable to the Scottish context in collaboration with policy maker stakeholders in, for example, the Div of Population Health Improvement (SG, NHS Health Scotland).

O2 Explore the feasibility and means by which such a measure could be used to determine which individuals and households in Scotland are food insecure according to the FAO definition

O3 Quantitatively and qualitatively establish the extent to which particular groups within Scottish society perceive themselves to be at risk of or are currently food insecure and nutritionally vulnerable. This objective will be explored in urban, rural and remote settings as agreed with the stakeholder steering group.

O4 Identify promising community-based assets/resources/food growing programmes that have the potential to reduce HFI in the short and longer term.

O5 In relation to O1, 3 and 4 above – and building on mapping work to be done in RD3.3.3 – this will include undertaking a review of the availability of culturally-appropriate foods for a healthy and sustainable diet in the Scottish context. It will also include the creation of a local-scale composite indicator of security of access to culturally-appropriate foods necessary for a healthy and sustainable diet.

O1 Feasibility work to identify, develop and determine the dimensions and utility of a Scottish Experience of Household Food Insecurity (EHFI) index. It is envisaged that issues of food quantity, quality, (un)certainly of access, social acceptability, safety and meal pattern frequency would be explored with respect to individual and household members' perceptions and experience of HFI. Candidate measures include the FAO Food Insecurity Experience Scale, and the US Household Food Security Survey Module, but other existing relevant measures will be explored.

Key deliverables O1.1 EHFI steering group convened and terms of reference and research processes agreed with the responsible PI (Yr1) **[M1.1]**. **O1.2** Scoping study to define literature review (Yr1) **[M1.2]**. **O1.3** Literature review **[D1.3]**. **O1.4** Policy briefing paper presenting outlining the components of the EHFI index for field testing and validation arising from the literature review and discussion of the findings for the EHFI steering group. End of Yr1 **[D1.4]**.

O2 Field testing and validation of the relevant domains identified and specified in **D1.4**. The main outcome of this work would be a robust and validated EHFI measure that would enable the demographic characterisation of the scale and nature of household level food (in)security in Scotland at population and community levels.

Key deliverables O2.1 Prototype EHFI field testing report (Yr2) **[D2.1]** **O2.2** Validation study report (Yr2) **[D2.2]**. Policy briefing paper containing a summary of the results of the EHFI field testing, validation study and recommendations regarding means of data collection at the local and national levels (Yr2) **[D2.3]**.

Outputs from **O1** and **O2** will feed into **O3** in respect of assessing their usefulness as a means of testing hypotheses associated with access and availability of locally

grown food and household food security/HFI. In addition to its monitoring potential for the extent and severity of HFI experienced by different 'at risk' groups, it will also be useful to assess possible impacts HFI on physical and emotional health and well-being, and health care use caused by HFI. This will be explored through additional sources of funding. The anticipated impact of this work will be the generation of a policy tool that can be used to inform, develop and evaluate future policy HFI mitigations and interventions intended to enhance household level food security.

O3 and **O4** produce policy guidance outlining lessons learned and recommendations regarding promising interventions / approaches that have been found to enhance food security at the household and community levels, through 'real-world' observation in four specially selected case study areas across Scotland. Consequently, this guidance will also provide insights into: **a.** community and household level interactions with locally available retail, community, charitable and other locally-based food resources and public perspectives about the role they play at the household level in ensuring (or otherwise) food security; **b.** public perspectives about the role and value of locally grown food in their day-to-day food purchasing and meal planning practices; **c.** public perspectives about values, motivations and commitment associated with the idea of growing food for personal consumption; and **d.** linking with **O1** and **O2** above, the extent to which locally grown food can contribute to food security at the community and household level.

Key Deliverables O3.1 Memorandum of agreement between policy maker and community stakeholders, and research investigators identifying the 4 research sites selected for planned investigation (Yr 2) **[D3.1]**. **O3.2** Policy briefing papers outlining emergent learning, conclusions and recommendations: (Yr 2) **[D3.2a]**; (Yr3) **[D3.2b]**; (Yr4) **[D3.2c]**; (Yr5) **[D3.2d]**. **O3.3** Interim oral reports outlining progress and emergent to EHFI steering committee (Yr2) **[M3.3a]**; (Yr3) **[M3.3b]**; (Yr4) **[M3.3c]**; (Yr5) **[M3.3d]**.

Key Deliverables O4 Inventory of food growing activities, governance, and funding regimes by (Yr1) **[D4a]** and (Yr2) **[D4b]**.

O5 (linked to **O1**, **O3** and **O4** above) would develop a robust and validated measure of access to culturally appropriate healthy food to inform policy development. Drawing on previous food access mapping work, this research will develop a small-scale spatial indicator of food accessibility across Scotland, the so-called 'Culturally Appropriate Food Accessibility' (CAFA) – based on data such as food store locations, their home-delivery radii, local public transport routes etc. – in order to complement and inform the EHFI index developed in **O1** and **O2**.

Key deliverables and timeline O5.3 Policy briefing paper outlining the agreed components of the CAFA Index for field testing (**yr1**) **[D5.3]**. **O5.4** One policy briefing paper outlining the results of the CAFA testing the validity and means by which such data may be gathered at the local /national levels **Yr2** **[D5.4]**.

Three KE workshops for local and national stakeholders interested in food security, and, socially and economically disadvantaged groups, will take place to share the emergent learning (**indicative schedule by the end of (Yrs1, 2, 3, 4, 5)**).

This RD will be undertaken by a team of PIs and researchers drawn from RINH and Hutton, representing academic expertise in the areas of social and public health

sciences, human geography and nutritional science.

Technical approach: Work Plan

O1 and O2 To ensure that the EHFI is developed in collaboration with the wider policy and practitioner community we propose that an EHFI steering committee is convened at the start of the project, with representation drawn from: the Public Health Directorate: Scottish Government; NHS Health Scotland (Community Food and Health Scotland); Scottish Public Health Observatory; the Food Standards Agency, Scotland, Nourish Scotland, Poverty Alliance, RESAS and international and UK food poverty academic experts **[M1.1]**. The process of identifying and engaging relevant group members would commence at the start of the 2016-2021 contract, with ongoing regular engagement with the steering group for the lifetime of the RD. (See KE section below for more detail of this engagement). A literature review identifying the prototype EHFI index for testing would be completed by end of **Yr 1 [M1.1], [M1.2], [D1.3] and [D1.4]**. Following agreement about the components of the prototype EHFI index with the steering group, a pilot/feasibility study of the measure would take place in a specially identified sub group and location (considered at this stage most likely to be trialled in one of the case study areas referred to below), with a proposed reporting periods mid and end of **Yr2 [D2.1], [D.2.2] and [D2.3]** respectively. Further testing in contrasting population groups and locations, and validity and reliability studies would be completed in **Years 3-5** to confirm or refute its suitability for national use. One policy briefing paper outlining the extent to which sub groups and/or communities are deemed food insecure based on this measure would be prepared using EHFI data derived and extrapolated from the sub-studies outlined above **end of Yr4 [D3.2c]**. At least one journal manuscript would be prepared for submission outlining HFI index development process and outcomes by end Yr4.

O3 and O4 This work will comprise of case-study research in four areas which will examine the multiple environments which shape food related decision-making that relates to health and wellbeing by examining food acquisition and consumption patterns, behaviours and attitudes in disadvantaged communities. Studies will trace the connections to local people's understandings of their health and well-being. Case study areas will be selected, in discussion and with agreement from the EHFI steering committee, across multiple measures so findings can be extrapolated to other areas across Scotland with similar characteristics (e.g. urban/rural categorisation, population density and SIMD score). It is anticipated that sustained community engagement will enable us to capture the complexity of the food choices and food-related decision-making taking place in the respective study areas, and will help identify promising interventions and impacts on HFI, health and well-being. It is envisaged that this will link to work taking place in RD3.2.4, Food culture and dietary choice, and RD3.4.4, Local assets, local decisions and community resilience by exploring the multiple and interlinking factors influencing food choices, including culture, knowledge, availability of land and other capacities affecting local opportunities for growing food locally. Field work will be qualitative, consisting of in-depth interviews and ethnographic-style participation with a range of local actors including those working across different areas to alleviate HFI (including food bank stakeholders if and when they emerge in the case study areas), and also those thought to be (potentially) at risk of HFI. This will involve observations and recording of those over time using established qualitative methods such as interviews and

focus groups, as well as participatory, action-research orientated methods (such as Photovoice, 'think out loud', walk or go along methodology), over an extended periods of time (ideally 2 years or more). Interviews and field work will explore existing local food environments and accessibility; strategies, practices and attitudes of those experiencing HFI and those working to prevent and/or alleviate HFI through a variety of means including those providing local public services engaged in supporting and caring for vulnerable groups, delivering and using employability programmes, welfare support programmes, food education, local growing and cooking events. Nutrient insecurity is an important dimension of food insecurity. However, to undertake the additional detailed work within this RD to directly assess the nutritional quality and quantity of food consumed by community based participants is difficult to do directly. However, this RD will link with **RD3.2.3 (Sustainability of Healthy Diets)** to inform work undertaken in 3.3.2 in relation to this question. Our RD3.3.2 proposal to develop and pilot a household level food insecurity measure for use and application in community-based settings will provide an indirect means of assessing and monitoring the nutritional adequacy of diets consumed within households and in different population subgroups in Scotland.

Interim reports outlining **1.** the early and developing stages of the ethnographic case study research, **2.** the degree of community engagement achieved in the selected study areas, and **3.** emergent findings would be prepared by **end Yr2 [D3.2a] and mid and end (Yr3) [M3.2a] and [D3.2b]**, (Yr4) **[M3.2b] and [D3.2c]** (Yr5) **[M3.3c] and [D3.2d]**. At least one journal article reporting on this exploratory study will be prepared ready for submission for publication by **end Yr3**. Journal papers presenting the findings of this work associated with, for example, understanding of socio-cultural, economic and environmental factors that contribute to food choices of low income groups and community perspectives of food growing, will be prepared at various stages during **2019-2021** as findings emerge. A final policy briefing paper outlining lessons learned, conclusions and recommendations regarding promising interventions or intervention approaches identified as likely to enhance food security at the community and household level will be prepared by **end Yr 5 [D3.2d]**

Working with **RD3.3.3, Local Food**, we will conduct desk-based enquiry and consultation with stakeholders (such as Nourish, Scottish Allotments and Gardens Society, Federation of City Farms & Community Gardens, Greenspace Scotland) to identify and map the nature and activities of local food growing projects across Scottish regions that have the potential to impact HFI and sustainable food systems in the short and longer term. Based on mapping and identification of different kinds of local food growing, an inventory of these projects will be developed. The inventory is thought likely to include kinds of activity, organisation, governance and funding regimes, and assess this against their potential to alleviate HFI (using the EHFI index described above) and contribute to the development of sustainable food systems (e.g. at a city scale **[D4a]**). Based on this inventory we will provide an indication of the potential of local food growing to contribute to sustainable food systems and food security at a large (e.g. city) scale as well as at a household level.

O5 Food use – Based on the indicator developed as part of the work on food access (see above), a number of case study communities (selected on the basis of variables such as urbanity/rurality and food security/insecurity) will be selected for in-depth study. Working with RD3.2.4, local community groups and residents

(stratified according to gender, age, social class, ethnicity etc.) will be engaged in the co-creation of policy tools and recommendations for increasing the use and final consumption of culturally-appropriate foods for a healthy and sustainable diet. This will draw on the outcome of previous studies and from ideas and strategies being developed in research and debates over food sovereignty, alternative food networks (e.g. local food initiatives) and choice editing.

Food access – Working with **RDs 3.2.4 & 3.3.3**, the objective is to create a local-scale composite indicator of security of access to culturally-appropriate foods for a healthy and sustainable diet. On the supply side, this will compile and use: shop location data (cross-referenced with data on sale of relevant foods); data on home delivery radii from food shops; ‘alternative’ retailers location data (e.g. farmers’ markets, farm-based retail, community supported agriculture); non-commercial food sources location, such as local authority data on allotments; community food production; community gardens producing food and charitable outlets (e.g. food banks). On the demand side, readily-available data (e.g. index of multiple deprivation) will be used; however, the tendency of economic deprivation to be ‘masked’, notably in rural areas, will necessitate the identification and use of additional proxy variables.

A literature review identifying the prototype CAFA index for testing will be completed by end of Yr1 **[M5.1]**, **[M5.2]** and **[D5.3]**. A pilot/feasibility study of the measure in specially identified locations will be completed by end of Yr2 **[D5.4]**. Further testing in contrasting locations and validity and reliability studies will be completed in Yrs 3-4 to confirm or refute its suitability for national use. Policy briefing papers will be prepared and reported annually, and one journal manuscript, will be prepared for submission outlining CAFA index development process, outcomes and applicability.

Detailed Work Plan (first 2 years – see Gantt chart below)

The first two years will set the foundation for the empirical work planned for **Years 3-5**. In the first year, an EHFI steering group (described above) would be convened **[M1.1]**, terms of reference and research processes would be agreed with the responsible PI. The research would then proceed with the scoping and conduct of two literature reviews: (1) one to identify existing suitable measures of HFI for consideration and discussion with the steering group **[D1.4]** and (2) the other to identify the composite indicators of access to culturally appropriate foods **[D5.3]**. Towards the end of year one work, into year two, the process of selection of case study areas and engagement with key community stakeholders will take place for the empirical work intended in Yrs 3-5 **[D3.1]**. This will include a mapping of local food growing projects and activities (region/scale to be decided depending on resources) **[D4a]** and **[D4.b]**. Mapping will identify different kinds of food growing projects with a view to selection for more in-depth study according to such criteria as governance, potential to scale-up, replicability, contribution to local food systems (meso-level food security) and impact on micro-level (household) food security, building on work undertaken by Greenspace Scotland in ‘Community Growing in Scotland’ and the Grow Your Own Working Group. It is intended that case study areas will be selected on the basis of their demographic characteristics and their potential generalisability, but we will seek to select, compare and contrast communities found to have obvious food growing activity within them, with those that do not.

In year two we will conduct two feasibility studies to test and pilot the indicators identified in year one [D2.1] [D2.2]. Based on the mapping work we will develop an inventory of different types of local food growing projects [D4b] and assess their contribution to HFI, and food secure systems at larger scales. Reports and publications will be produced from all strands of work described above.

Key linkages, interdisciplinarity & collaboration

This RD will link directly with **RD3.2.4 Food culture and dietary choice**, **RD3.2.3 Sustainable Healthy Diets**, **RD3.3.1 Food trade and consumption**, **RD3.3.3 Local Food** and **RD3.4.4 Local assets, local decisions and community resilience**. The data generated about individual and community level experiences of food insecurity and wellbeing during the lifetime of this RD will enable us to compare and contrast the various experiential HFI data generated against the meso level data generated in **RD3.3.3, Local food**, and in the longer term with macro level food security data generated in **RD3.3.1, Food trade and consumption**. It has been also been conceptualised to link with and provide relevant data to **RD3.2.4, Food culture and dietary choice** and **RD3.4.4, Local assets, local decisions and community resilience**. Specific investigation of household food practices in this RD in respect of O3 and O4 will be enhanced by linking with the PhD studentship on this topic that will be offered and managed within RD3.2.4.

During Ys 3-5, our planned ethnographic work will involve exploring the lived experiences of people in low and very incomes, and their interactions with the various food systems they use (domestic, retail and charitable) and engage with to procure food for themselves and their families to eat, and plan to determine the extent to which those interactions enhance or otherwise their experiences of food security. Our analysis of these findings will be based on the ethical principles set out in the Food Ethics Council Ethical Framework. Furthermore, it is envisaged that the formulation and agreement about a national EHFI index would allow new lines of academic and policy research enquiry to open up and develop, for example, in relation to questions of supporting sustained behaviour change, dietary-related chronic conditions (i.e. obesity and diabetes) and deprivation, that might be further understood using a EHFI 'lens' (see for example US studies linking HFI and obesity).

Added Scientific Value

Discussion has already taken place with international experts in HFI based in England and Canada, who are keen collaborate on the development of a Scottish EFHI index. Researchers based in Oxford Univ and Sheffield Univ are currently exploring what could be developed for use in the English context, and therefore there is an opportunity to work on this objective in a collaborative manner with researchers in other jurisdictions of the UK.

Community food growing builds on work by Greenspace Scotland and the Federation of City Farms and Community Gardens, as well as research on factors encouraging or inhibiting community resilience and empowerment (e.g. Joseph Rowntree Foundation, ESRC/AHRC Connected Communities Programme).

Other links have been established with organisations providing community food programmes (including food bank services) across Scotland, including the north east of Scotland, Skye and Lochalsh, Lanarkshire, Glasgow and Edinburgh.

Knowledge Exchange

To gain maximum impact, this RD is premised on the active engagement of the key policy maker stakeholders in the co-production of the respective EHFI and CAFA indices, and mutual selection and agreement over the particular case study areas that would be asked to engage and participate in the generation of learning intended to enhance food security in Scotland for all, i.e. **the Public Health Directorate, Scottish Public Health Observatory, NHS Health Scotland, Nourish and Poverty Alliance** in particular. Early indications from the preliminary conversations and engagement that has taken place with relevant individuals suggest this proposal would find favour with them. However, more detailed discussions on this issue are planned in the forthcoming months on the back of the publication of the NHS Health Scotland commissioned Food Poverty Study. For example, a meeting has been scheduled in May 2015, to discuss the findings of the Scottish Food Poverty Study and the proposed RD3.3.2 objectives and work plan in collaboration with key stakeholders from the Public Health Division SG and NHS Health Scotland. Should this proposed means of co-production for this research and outputs be taken up by the proposed EHFI steering group, to ensure reciprocal sharing of emerging intelligence and policy questions arising, it is envisaged the this steering group would continue to throughout the lifetime of the RD. While the details of this process of engagement have not been agreed as yet, it thought that this would take the form of information sharing and mutual KE exchange between PIs and steering group members on a bi-monthly or 6 monthly basis, depending on what was agreed by the committee. Thus the KE points highlighted below are indicative points only.

The KE outputs envisaged from this work from midpoint i.e. **October 2018** onwards include generating a clearer and more precise picture of the numbers and groups of people in Scottish society on annual or bi annual basis that are food insecure (such that people are experiencing periods of hunger and/or extreme uncertainty in the quantities and quality of the food they can consume). It is envisaged this would enable national and local policy makers identify who is most at risk of severe food insecurity in their localities, by generating local pictures of the same.

Due to the collaborative and participatory design of this RD, it is also envisaged that additional KE activity will be formulated in conjunction with stakeholders, including community groups and policy advisors over the lifetime of the SRP in line with the nature of the research proposed and building on findings and policy priorities. It is anticipated that this will include KE during periods of ethnographic fieldwork as well as determining more precise components of the RD to be included on the final programme through more formal activities such as workshops, publications and policy recommendations. We also anticipate working actively with Greenspace Scotland, Nourish and other stakeholders to co-create activities and opportunities to exchange ideas across various sectors including governmental, local authority, community, third sector and public throughout the lifetime of the RD. The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

Audience: The content of this RD is policy oriented and its anticipated audience includes stakeholders such as policy makers, health and social care professionals groups, non-government organisations and charities, including the growing community sector, the public and academic colleagues. The proposal's

communication and dissemination plan includes outputs and methods of communication relevant to each of these categories of stakeholders. The outcomes of the project should be particularly relevant for:

- Policy makers (SG, FSS and NHS Health Scotland), who will benefit from knowledge of the scale and nature of household food insecurity and implications of the results in terms of food security, health and well-being.
- Food growing stakeholders (local retailers and traders, Nourish Scotland, Greenspace Scotland, Federation of City Farms and Gardens) who will benefit from the insights gained in terms of understanding their current and future role in ensuring household food security.
- The public in general given public concern at the growth of emergency food aid centres in Scotland in recent years and renewed interest in growing-your-own.
- NGO organisations such as Poverty Alliance, Oxfam and Child Action on Poverty
- Academic community will be interested in the applications of new theoretical developments as well as the empirical results, and emerging research questions and lines of enquiry that will emerge from this.

Impact: It is anticipated that amongst other impacts this research will generate:

The proposed EHFI Index will provide policy makers, SG and researchers with: (a) national and local data to identify and monitor groups found to be highly nutritionally vulnerable amongst already vulnerable groups; (b) data to develop and target public policy interventions intended to tackle HFI. For example, it may identify numbers and community locations of low income women and young children (found to be the most food insecure groups in other international jurisdictions), or older people (who are currently a group of concern amongst policy makers in Scotland) who might be living in food poverty in Scotland to the potential detriment of their physical and mental well-being, due to under or malnourishment; (c) data, that could be used by policy makers and community actors, to support them to develop or implement interventions that would enhance the food security status of those found to be highly food insecure.

The ethnographic findings should provide insights and intelligence about factors that predispose, enable or reinforce food security and / or food insecurity in local, low income communities. These data should enhance public policy development and would also be available for interested and relevant agencies (such as Community Food and Health, as a programme of NHS Health Scotland) to support community-led food security work.

The Food Growing Inventory and CAFA data should also provide additional local level contextual data to enhance understanding and be available to inform public policy and community-led interventions intended to enhance local food security.

RESEARCH DELIVERABLE NUMBER: RD3.3.2

Work planning and timetable for Year 1: Showing major milestones (M), deliverables (D), KE/impact events (KE) and their timing. KE events include talks and presentations.

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1 Formation of the EHFI steering group and ongoing engagement	KE		M1.1			KE				KE		
O1.2 Scoping study to identifying appropriate search terms and databases for existing measures of HFI					M1.2							
O1.3 Literature review of existing measures of HFI										D1.3		
O1.4 Write up policy briefing paper specifying prototype EHFI index for field testing												D1.4
O3 Case study selection discussions with RESAS stakeholders												M3
O3a Ethical approval application preparation of the feasibility EHFI and CAFA studies planned for Year Two.												M3a
O4 Desk based and stakeholder enquiry into local food growing activities												D4a
O5.1 Literature search determining indicator of access to culturally appropriate foods				M5.1								
O5.2 Literature review determining indicators of access to culturally appropriate foods								M5.2				

O5.3 Write up summary of literature review determining indicators of access to culturally appropriate foods												D5.3
Annual report (year 1)												R1

RESEARCH DELIVERABLE NUMBER: RD3.3.2

Work planning and timetable for Year 2: Showing major milestones (M), deliverables (D), KE/impact events (KE) and their timing. KE events include talks and presentations.

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Ongoing engagement with EHFI steering group	KE				KE				KE			KE
O2.1 Field testing of prototype (EHFI)						D2.1						
O2.2 Validation study report												D2.2
O2.3 Policy briefing paper												D2.3
O3.1 Work to develop the memorandum of agreement between policy maker and community stakeholders and PIs identifying the 4 research sites selected for planned investigation					D3.1							
O3.2 Policy briefing papers outlining emergent learning, conclusions and recommendations												D3.2a
O3.3 Interim oral reports outlining progress and emergent												M3.3a

to EHFI steering committee													
O3&4 Preparatory work for ethnographic and mapping work identified in agreed case study areas for Years three to five													
O4 Inventory of food growing activities, governance, and funding regimes													D4b
O5.4 Feasibility and pilot testing of measure 2 (CAFA)													D5.4
Annual report (year 2)													R2

Name of RD: 3.3.3 Local food

Research aim and key drivers

Becoming a Good Food Nation outlines the Scottish Government's vision to transform the relationship Scottish people have with food. While Scotland is internationally renowned for producing foods of the highest quality, many of these products are destined for export. One approach to address Scotland's paradoxically poor diet and health relationship with food is to increase access to, and the supply of, more locally produced food. It is anticipated that this will not only contribute to the increased consumption of fresh, healthy and environmentally sound food, but also that it will improve our understanding of the relationship between good food, lifelong health, and the sustainability of Scotland's food and drink sector and of its rural communities.

The aim of this RD is to assist the Government and the country to realize the vision of Scotland as a Good Food Nation. It will do so by building a better understanding of short food supply networks (SFSN) in Scotland and proposing, in conjunction with relevant stakeholders, measures to strengthen them. 'Short', in this context, refers to reducing the distance between 'farm and fork' in terms both of miles – e.g. local food – and awareness, for instance through 'locality' foods whose geographical provenance is made known to consumers. In doing so, it also aims to provide an evidence base that will help stakeholders to better understand, and therefore to enhance, the contribution of SFSNs to food sovereignty and to the resilience of rural food producers and communities.

The key drivers for this RD are:

- The Government's (*Good Food Nation*) vision that the 'food industry will be a thriving well-known feature of local and national economies, with each part of Scotland rightly proud of its culinary heritage, past and present'.
- The Government's (*Good Food Nation*) desire to maximise the resilience and security of Scotland's food supply by helping to strengthen SFSNs.
- The Government's commitment to increase the production and consumption of local food, e.g. through its funding of 'Think Local' and the Food Provenance 'Happier Mealtimes' campaign; and the interest in local food and local economies that emerged in the public discussion of the national food policy (Leat *et al.* (2008) *The Future for Food in Scotland. Analysis of Responses to the National Discussion*, pp.iii & 15).
- The pressure on rural small and medium-sized food producers (esp. small farmers and agriculturally-active crofters) and processors (e.g. regional speciality food producers) to work together and diversify in order to remain sustainable (as evidenced, e.g. in Scottish Government (2014) *Economic Condition of Crofting 2011 – 2014*, p.41).
- The need to maximise the effectiveness and additionality of public policy mechanisms, such as the Scotland Rural Development Programme (SRDP) 2014-20: e.g. Crofting Agricultural Grant Scheme; Small Farms Grant Scheme; Food Processing, Marketing and Co-operation; LEADER.
- The Strategic Research Programme (SRP)'s growing focus on supporting SFSNs and the production, consumption and export of foods with local

provenance; in particular, the need to enhance links between consumers and food producers, processors, caterers and retailers at the local scale.

- The SRP's growing focus on community empowerment through food (RD3.4.4) and, in particular, the need to enhance links between consumers and food producers and processors.
- The lack of robust evidence on local foods (Watts *et al.* (2011) *Regional Studies* 45, pp.1187-1205) with which to inform Government policy.

Research in this RD responds to, and will have impact on, these drivers by:

- Generating new data and knowledge about SFSNs in Scotland. This will provide much-needed robust evidence for policy makers on the role of SFSNs in helping to promote rural development, empower resilient communities, and enhance food sovereignty and sustainability.
- Co-creating, with stakeholders, proposals for policy mechanisms to support food sovereignty, SFSNs and the empowerment of resilient communities that are built on, and can enhance, trust, equality, and sustainability.

Support for research into local foods was expressed by Nourish Scotland at a high-level KE event in Edinburgh and contact is ongoing.

Summary of the proposal:

This research starts from a very limited evidence base. The EU Foodlinks project provided some evidence on the contribution of SFSNs to sustainable rural development in Europe, and Watts and Revoredo Giha have undertaken research into SFSNs in Scotland (e.g. Watts *et al.* 2011). However, given the exploratory nature of previous work, the evidence base is in urgent need of development if the aims of this RD are to be realised. That work also needs to be brought into dialogue with research that has been done on the role and significance of inter-business networking in rural Scotland (e.g. Atterton (2007) *Sociologia Ruralis* 47, pp.228–245; Pangbourne and Roberts (2015) *European Planning Studies* 23, pp494-508. <http://www.tandfonline.com/toc/ceps20/23/3>) and elsewhere (e.g. Esparcia (2014) *Journal of Rural Studies* 34, 1-14; Newbery *et al.* (2013) *Environment & Planning A* 45, pp.967-985).

The overall objectives of RD3.3.3 over five years will be:

- To generate baseline data on different forms of SFSN in Scotland. This will improve policy-makers' knowledge of: diversification in Scottish agriculture and crofting; links between farmers, food producers and other local food-related rural enterprises, such as Community Supported Agriculture (CSA); and inform policy on the role of SFSNs in helping to promote rural development and innovation, empower resilient communities and enhance trust, equality, food sovereignty and sustainability.
- To co-construct, with stakeholders, proposals for policy mechanisms to support food sovereignty, SFSNs and the empowerment of resilient communities that are built on, and can enhance, trust, equality, and sustainability. Particular attention will be paid to adapting existing policy instruments (e.g. SRDP, Climate Challenge Fund) so as to maximise their effectiveness and additionality, reduce policy conflict and minimise costs.
- To contribute to international scholarly and policy debate through peer-reviewed publications, policy briefings etc. that will maintain and enhance the international standing of Scottish research and policy in this area.

These will be achieved through the completion of nine specific research objectives (**O1-9**). They are summarised below, along with the main anticipated knowledge exchange opportunities (KE1-7) and deliverables (D1-9).

O1: Structured literature review (months 1-9)

This review is necessary because there is a very limited evidence base for the RD. It will identify (using a protocol adapted from systematic review criteria) and review the academic and 'grey' literatures on practices, concepts and policies vital to this RD. It will critically assess SFSNs, considering their contribution to social inclusion and exclusion, and implications for local empowerment, resilience, sustainability, food sovereignty etc.

Key deliverables 1 & 2 generate a conceptual review of SFSNs for submission to (D1, month 9), and publication in (month 13), a peer-reviewed journal.

O2: Laying the groundwork for the large-scale survey (months 1-12)

To do this we will engage with stakeholders (from month 1) and engage in a round of KE (**KE1**, months 10-12) in order to 'ground' the findings of the literature review in the Scottish context. This will enable us to hone our understanding and to produce credible, coherent and methodologically sound definitions of key terms and questions for the survey to be undertaken in O3.

O3: Survey of local and locality food producers, processors and retailers in Scotland (months 13-24)

Building on the work in objective 2, we will, in consultation with RESAS, design, pilot and implement a large-scale representative survey of local and locality food producers, processors and retailers in Scotland. The survey will examine: geographical links with suppliers and customers; involvement with SFSNs; use and views of policy mechanisms. Survey findings will be presented to stakeholders and input sought on how to structure the following stages of the research (**KE2**, month 22).

Key deliverable 3 (by month 24): The analysis of the survey will be written up for submission to peer-reviewed journal (D3).

Milestones 4 & 5 (end of year 2)

Depending on the analysis of the survey, it is anticipated that the research will divide into separate streams for much of years 3 – 5. The final decision on this (M4) will be made at the end of year 2. The parallel streams are likely to focus on the distinction between 'local' and 'locality' food production and circulation. Though this may need to be complemented by a focus on individual 'systems of provision'. Decisions on the most appropriate framework for subsequent research, their associated Os, and which PIs will lead them will be taken at this point (month 24). The selection, in consultation with stakeholders, of a case study area for O4 will also be made at this time (M5).

O4: Qualitative research with food producers, processors and retailers in case study area (months 25-36)

Working in parallel with O6, food producers, processors and retailers from the case study area will be identified from O3, KE2 and public sources. Volunteers will be recruited to take part in qualitative research about their perceptions of:

concepts reviewed and developed in Os 1 & 2; their contribution to healthy diets (WP 3.2); how to improve food supply chain sustainability (WP 3.1); what should be the identifying policy priorities and mechanisms that could be adjusted or developed to enhance SFSNs, food sovereignty and community empowerment (this will feed in to RD 3.4.4).

O5: Comparing the cost of 'local' and 'non-local' foods (months 25-36)

Work here will compare price data for local and locality foods – gathered from survey work carried out in conjunction with O4 – with the costs of purchasing 'conventional' equivalents through multiple retailers, using Kantar World Panel data analysed in RD 3.3.1.

Findings from O4 & O5 will be presented to stakeholders (with a particular focus on those in the case study area) and input sought on how to structure the following stages of the research (**KE3**, month 35). These findings will be written up into a report for stakeholders (**key deliverable 4**, month 36) and for submission to a peer-reviewed journal (**key deliverable 5**, month 39).

O6: Longitudinal study of short food supply networks in practice (months 27-51)

Running in parallel with, and informed by, O4, here we will identify and monitor the work of a small number of SFSNs in order to examine their strategies for, and attempts to create, sustainable networks and local empowerment through food. By examining the operations of SFSNs as they unfold in real time, and exploring the reasons for key developments and events, work in this objective will build up a rich qualitative understanding of the factors that influence the success (and possibly failure) of SFSNs. Work in O6 will draw on, and help to inform, work on O3 of RD 2.4.3, with a view to maximising the environmental sustainability and circularity of SFSNs. In addition, it will enable us to co-develop relevant and robust methods for capturing their impact, thereby feeding into RD 3.4.4. Lastly, by drawing on O3 of RD 3.2.3, we will examine, with respondents and stakeholders, the implications for SFSNs of a move to a healthier, more sustainable, diet.

Key deliverable 6 (by month 51): Draft report on SFSNs in practice, including suggestions for methods to capture their impacts and proposals for improving them (q.v. O8). This will be co-produced with stakeholders (**KE4**).

O7: Development of evidence, and recommendations for policy and practical guidance, on Scottish locality foods (months 37-40)

Building on findings from O4, O5 & O6, we will – in consultation with colleagues from WP 3.1 & RD 3.3.1, and with national and regional stakeholders (**KE5**) – prepare policy recommendations and practical guidance on the issues of authenticating, protecting and supporting locality foods in Scotland. The intention of this objective is to lay the groundwork for the promotion and revivification of Scottish regional 'terroirs'.

Key deliverables 4 & 5 (by month 39): policy recommendations and practical guidance on the issues of authenticating, protecting and supporting locality foods in Scotland. **Key deliverable 6** (by month 40): paper on SFSNs and terroir for submission to peer-reviewed journal.

O8: Focus groups with community groups and consumers (months 41-58)

Working in parallel with O6, focus groups will be undertaken with community groups and consumers in four different types of area, identified from the mapping undertaken for O3 and for food access in RD 3.3.2. This will elicit data about their perceptions of concepts reviewed and developed in Os 1 & 2, and insights from Os 3, 4 & 6, with a view to identifying policy priorities and mechanisms that could be adjusted or developed to enhance SFSNs, food sovereignty, community empowerment, rural sustainability and resilience. This work will feed in to RD 3.4.4. Work in O8 will also liaise with work on O4 of RD 3.2.3, with a view to: assisting in the validation and communication of the tool which RD 3.2.3 intends to develop in order to encourage people to eat healthy and sustainable diets; and exploring its consequences for the use and enhancement of SFSNs.

Key deliverable 7 (by month 57): Draft report on policy mechanisms that could be adjusted or developed to enhance SFSNs, food sovereignty, community empowerment, rural sustainability and resilience.

O9: Synthesis and knowledge exchange (KE7) (months 58-60)

Here we will work with stakeholders and groups drawn from previous respondents to bring together insights and experience gathered, along with findings from Os 1-3, with a view to testing and refining policy priorities and mechanisms developed during Os 6-8 that could be adjusted or developed to enhance SFSNs, community empowerment, resilience and food sovereignty and that command support from food producers, community members and existing SFSN participants.

Key deliverable 8 (by month 60): Final report and synthesis.

Key deliverable 9 (by month 60): Paper on the relationship between policy and SFSNs (demand and supply sides) for submission to peer-reviewed journal.

Technical approach

There is currently relatively little evidence on local and locality food in Scotland, which means that the technical approach will be dominated by the gathering of primary quantitative and qualitative data, as outlined in the project summary above. The main quantitative data gathering technique will be a large-scale (n~3,000) stratified national survey; the design and implementation of which will be undertaken in collaboration with RESAS. A smaller-scale survey will also be undertaken in a specific area. The area to be surveyed will be decided on in conjunction with stakeholders, as will the areas selected for the qualitative research. The data gathered will be economic, social and cultural: predominantly numerical, textual and talk data. More detailed explanation of the kinds of analysis to be conducted on data gathered in years 1 & 2 are given below. Work in this RD will not involve animals, nor any dietary or medical study of humans. There is no reason to think that there will be any ethical considerations that cannot be dealt with using standard social scientific ethical procedures.

The first two years will be devoted primarily to building an evidence base from which to address the themes outlined in the SRP. As indicated in the project summary, this will comprise work on Os 1-3. These are described below, along with their accompanying deliverables (D1, D2) and knowledge exchange events (KE1-KE2), the timings of which are given in the Gantt charts. Milestones M1 and M2 mark the end of year 2 and is the point at which the direction and fine

detail of O4-O9, along with their associated deliverables and KE events, will be decided on.

O1 Watts will develop a protocol for (O1.1, M1), and will lead a structured review of the academic and 'grey' literatures on concepts and policies vital to this RD (trust, food sovereignty, authenticity etc.), SFSNs and on community empowerment through food (O1.2). This will test the continuing validity of the distinction often drawn between 'local' (typically face-to-face and spatially proximate) and 'locality' (where provenance is generally established 'at a distance' through product information and/or branding, such as EU protected name schemes) food networks. It will draw out the pros and cons of SFSNs, considering their contribution to social inclusion and exclusion, and implications for local empowerment, resilience, sustainability, food sovereignty etc. (months 1-9).

D1, D2 Conceptual review of SFSNs for submission to (month 9) and publication in a peer-reviewed journal (month 13).

O2 In parallel with, and building on O1, PIs (Watts as lead) will identify & engage with stakeholders (e.g. RESAS, Scotland Food & Drink, KE1 Nourish Scotland, Crofting Federation, Scottish Association of Farmers' Markets) from month 1 (O2.1, M2). Towards the end of the literature review, more intensive engagement (O2.2, KE1) will be undertaken to produce coherent and methodologically sound working definitions of key terms and survey questions (q.v. O3) for this RD that are appropriate to local and Scottish contexts (months 7-12, with the main KE taking place in months 10-12).

O3 Watts will lead the design and piloting of a large-scale survey (O3.1, M3). The survey instrument will build on Pangbourne and Roberts (2015) and a questionnaire developed by Watts in a previous pilot project, and will examine: geographical links with suppliers and customers; involvement with SFSNs; use and views of policy mechanisms. The survey will, in consultation with RESAS, be sent to ~3,000 Scottish farms, agriculturally-active crofts, fishing enterprises, fish farms, fish processors, community food-growing projects (data on the latter will come from publicly-available sources and one of Watts' PhD students), food processors and retailers (O3.2, M4). Data collected will be inputted, mapped and analysed using a variety of statistical techniques: such as non-parametric tests of association (e.g. Mann-Whitney U) and measures of spatial concentration (e.g. location quotients) (O3.3). The results will be written up for validation and dissemination (O3.4) (months 13-24).

KE2 Findings presented to stakeholders in workshop and discussion paper and input sought on how to structure the following stages of the research (month 22).

D3 Empirical paper on SFSNs for submission to peer-reviewed journal (month 24).

M5 At this point (month 24) it is anticipated that the research will divide into separate streams, on the basis of the findings from O3 (which builds on those of O1 and O2). This is most likely to take the form of a distinction between 'local' and 'regional' food production and circulation. However,

and given that one of the innovative features of this research is the inclusion of fish production, harvesting and processing, this may need to be complemented by a focus on individual 'systems of provision' (Fine 2002). Decisions on the most appropriate framework for subsequent research, their associated Os, and which PIs will lead them will be taken at this point. Selection of a case study area for O4 (Month 24).

Expertise

This RD draws on established qualitative and quantitative research expertise within the MRPs. The staff listed in the table above will lead on Os that reflect their specialisms, and all have expertise related to the topic of local food. The topic itself represents a broadening of social science expertise, and the development of a new research area, at RINH.

Key linkages, interdisciplinarity & collaboration

- Close links with RD 3.3.1 (Food trade & consumption), esp. through O5 & O7.
- Close links with RD 3.3.2 (Enhancing Food Security), esp. through O8 & O9.
- Close links with RD 3.4.4 (Local Assets), esp. through O2, O8 & O9.
- Links with RD 2.4.3 (Environmental sustainability and circularity of the rural economy) through O6.
- Links with RD 3.2.3 (Sustainability of Healthy Diets) through O6 & O8.
- Links with WP 3.1 (Improved food & drink production) through O4 & O6.
- Collaboration with Watts's PhD student working on "Rethinking food security", esp. re O1.
- Collaboration with Watts's PhD student working on "Urban Farming: Concepts and Practice", esp. re O3.

Added Scientific Value

Although there is considerable literature on local and regional foods, and on so-called 'alternative' food networks, much of it takes the form of conceptually-informed case studies. The work to be conducted in RD3.3.3 will make a significant and original contribution to scientific knowledge in this area, primarily through the publication of papers in high-impact peer-reviewed journals.

- There is, as Watts *et al.* (2011) argued, very little quantitative evidence on SFSNs. D2 (empirical paper on SFSNs in Scotland based on O3) will contribute to the evidence base and empirical development of this field.
- There has been little or no work that has sought to incorporate food from both land and water into scholarly debate over SFSNs. RD3.3.3 will therefore make a significant and original contribution to an enlarged understanding of the links and contrasts between SFSNs based on land and marine resources.
- D4 (paper on SFSNs and terroir) will contribute to scholarly debate over: the role of 'regional' foods in rural development in northern Europe (most EU protected name designations are located in Mediterranean countries); and as a means of addressing the documented vulnerabilities of single-product-focused approaches, which has received scant attention to date. issue
- D5 (paper on the relationship between policy and SFSNs) will contribute to scholarly debate on the connections between policy instruments (e.g. Pillar II of the CAP) and the promotion of local and regional foods, with a particular

focus on how useful they have been and could be in future.

- New understanding of barriers and routes to community empowerment through SFSNs.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview. KE is vital to this project. It will take four main forms.

First, although years 1 & 2 will be devoted primarily to data collection, stakeholders will be vital in helping to develop sound working definitions of key terms and survey questions (see KE1 and O3, above). Thus, the project team will be drawing on the expertise of stakeholders to inform the construction of its database. PIs will identify and target key stakeholders, such as RESAS, Scotland Food & Drink, Nourish Scotland, NFUS, STFA, the Crofting Federation, and the Scottish Association of Farmers' Markets. Similarly, KE5 will involve stakeholders in the co-creation of proposed mechanisms for improving SFSNs and the co-development of robust methods of capturing their impact.

Secondly, in KE2 & 3, preliminary results will be shared with stakeholders, who will be given the opportunity to critically review them. This, in turn, will inform and help to refine the findings in question and provide valuable insights into the construction of subsequent phases of the research.

Thirdly, in KE4, 6 & 7, stakeholders will play a key role in shaping the development of evidence-informed policy recommendations and practical guidance. For instance, in KE4 stakeholders will be given the opportunity to co-create guidance for SFSNs on issues of authenticating, protecting and supporting locality foods with the ambition of laying the groundwork for the promotion and revivification of Scottish regional 'terroirs'. Similarly, in KE6 & KE7, stakeholders will be contacted with a view to testing and refining policy recommendations developed during the project to enhance SFSNs, community empowerment, resilience and food sovereignty and that command support from food producers, community members and existing SFSN participants.

Fourthly, this RD will feed into KE activities organised at WP and Theme levels and through the Centre for Knowledge Exchange and Impact (CKEI) for the SRP. This will include participating in centrally organised KE events (e.g. 'joined-up KE meetings with stakeholders) and using the Theme web pages and electronic communications tools (e.g. e-zines and Twitter) to disseminate research findings and, where applicable, recruit research participants.

Audience

Research in this RD has the potential to both inform and be informed by stakeholders involved in SFSNs. The main audience for RD3.3.3 will be policy officers and representatives from bodies such as RESAS, Scotland Food &

Drink, the National Farmers' Union Scotland, the Scottish Fishermen's Federation, the Scottish Tenant Farmers Association, Scottish Salmon Producers Organisation, the Scottish Crofting Federation, regional food groups (e.g. Orkney Food and Drink), Scottish Association of Farmers' Markets, the 'Seafood - See here!' project, etc. One of the early stages of RD3.3.3 will be to identify relevant representative bodies who are interested in helping to shape the research.

High-level stakeholders, and key knowledge exchange events, will be identified and co-ordinated at the WP and Theme levels, as well as the Centre for Knowledge Exchange and Impact (CKEI)

Impact

RD3.3.3 will provide:

- Vital baseline data on local and regional food production to enable the Government to formulate evidence-informed policy.
- A survey instrument that will allow for that baseline data to be updated periodically (subject to further funding).
- Policy recommendations to enable SFSNs to be better supported so that they can achieve positive change for producers and rural communities.
- Insights into how producers and processors can work together with consumers to create SFSNs that foster trust, equality and food security.

Impact strategy and monitoring will be conducted in accordance with emerging best practice from Research Excellence Framework.

RESEARCH DELIVERABLE NUMBER: 3.3.3

Work planning and timetable for Year 1: Please include major milestones: key research milestones (M), deliverables (D), KE/impact events (KE) and their timing.

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1: Develop protocol for structured literature review	M1											
O2.1: Identify & engage with stakeholders						M2						
O1.2: Structured literature review									D1			
O2.2: Co-define key terms & questionnaire											KE1	
O3.1: Ethics, pilot and sampling frame												
Annual report (Year 1)												R

RESEARCH DELIVERABLE NUMBER: 3.3.3

Work planning and timetable for Year 2: Please include major milestones: key research milestones (M), deliverables (D), KE/impact events (KE) and their timing.

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1: Structured literature review	D2											
O3.1: Ethics, pilot and sampling frame			M3									
O3.2: Administer survey of food enterprises							M4					
O3.3: Input & analyse survey data												
O3.4: Write-up survey findings										KE2		D3
O4: Select case study area												M5
Annual report (Year 2)												R2

Work Package 3.4 Communities and Wellbeing

Work Package Information:

1. Overview: strategic relevance to policy and end users

The work within WP3.4 focuses on the resilience and wellbeing of Scotland's rural communities and provides the context within which work elsewhere in the SRP (on natural assets, land-based industries, and food and health) can be placed. The key links with other WPs within the Food, Health and Wellbeing Theme, and also with the other two research themes, are shown in Figure 1.

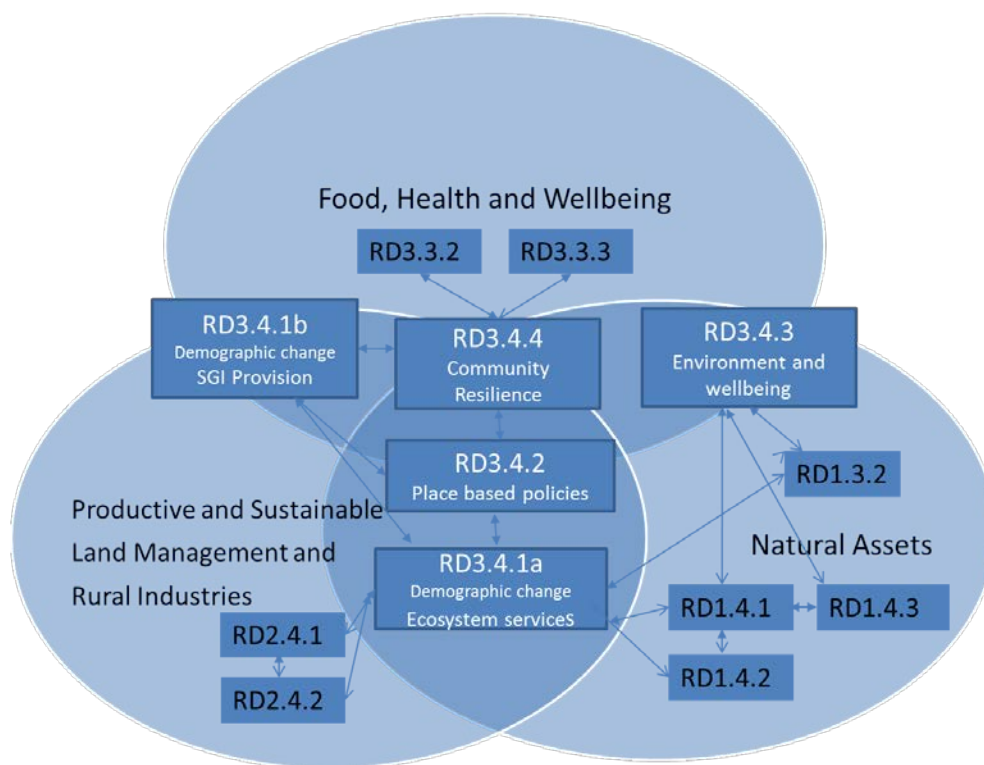


Figure 1: Links between WP3.4 and the wider strategic programme

Demographic, social, economic and environmental change is being experienced from remote through to accessible rural areas in Scotland; from rural towns and their hinterlands, to coastal areas and islands. This WP examines how such changes can be measured and what they mean for the wellbeing of rural residents. It will identify policies which can enhance community wellbeing and resilience and the role of empowerment, local participation and democracy in this process. It follows that issues of social inclusion and equality are cross-cutting themes for the WP.

The research is structured around four Research Deliverables (RDs) which address the following high-level research questions:

1. How do changes in the population of remote rural areas of Scotland affect the

- social, economic and ecological resilience of these areas? (RD3.4.1);
2. Can place-based policies address differences in economic performance and social outcomes in Scotland's rural areas and small towns? (RD3.4.2);
 3. What are the links between the environmental and landscape qualities of rural areas and the wellbeing of those that visit or live in these areas? (RD3.4.3); and
 4. What does "success" in rural community resilience look like, and how can methodologies be developed which capture the impact and outcomes of policy and practice interventions? (RD3.4.4).

The proposed research builds on the 'Rural Communities' Theme (Theme 8) in the cSRP, and links with current research undertaken by others (such as the work by Carnegie UK Trust and partners on Understanding Scottish Places) to ensure value added to programme funding, but also introduces several new and innovative areas of research. Building in continuity from cSRP, Theme 8 provides a basis for analysis of community-level data over a 10-year period – unprecedented in this field of research where such analyses are usually time-limited due to short project lifecycles. The resulting longitudinal analysis will reveal new insights into the drivers of rural change, processes of community adaptation and the impact of policies. It also allows for the further testing and refinement of conceptual frameworks and measures developed in the previous programme including the conceptual model of rural urban interdependencies, the toolkit for measuring community resilience, and the socio-economic performance index used by Scottish Government to allocate LEADER funding in the latest Scottish Rural Development Programme.

However the focus of the WP includes new topic areas for the SRP, in particular:

- The analysis of human-ecological interactions (within RD 3.4.1);
- The role of small towns in rural development and service delivery (RD 3.4.2);
- The links between human wellbeing and the environment (RD 3.4.3);
- Methodologies for assessing policy outcomes and ways of capturing the impacts of interventions (RD 3.4.4).

Each of these provides potential for developing new methods and understanding of direct policy relevance at EU, national, and local level.

The research will incorporate reviews of evidence and practice from urban Scotland, which will provide valuable learning for the rural analyses (and, potentially vice versa). In addition, coastal communities will be a new point of focus, thus providing links with Marine Scotland and agencies working to enhance the resilience of such areas.

These new elements are particularly relevant to several key current and future policy developments in Scotland, including the Community Empowerment (Scotland) Act, the proposed Land Reform Bill, reforms of the Common Agricultural Policy (and particularly changes to the LEADER programme), the Scottish Government Economic Strategy, and ongoing developments relating to the Land Use Strategy, marine spatial planning, and the Christie Commission.

These policies signify the 'direction of travel' of current policy towards greater empowerment of citizens through national and local configurations of legislation, processes and structures. Increasing emphasis is also being placed on addressing

inequalities, social justice, inclusion, ownership of assets as a means of empowerment, participation and local democracy, and the prevention agenda (particularly in the health and social service contexts). Therefore, the research from WP3.4, will not only inform specific policies but will address meta-questions of relevance to policy, stakeholders charged with implementing policy and rural communities themselves.

The WP will directly inform the evidence base of a number of rural policies within the first two years of the programme (Land Reform, review of LFASS, Land Use Strategy, Community Empowerment). More generally the planned annual reviews of the progress and direction of the WP with Scottish Government and other key stakeholders will ensure it is sufficiently flexible to be able to address new policy priorities as they emerge. Additionally, we will highlight the relevance of our research findings for other broader policy portfolios which impact on rural areas (such as poverty/social justice, economic development and enterprise support, planning, energy, transport, telecommunications, health, education), thus enabling the research to feed into systemic, rather than simply sectoral, priorities.

The WP is underpinned by a transdisciplinary ethos and practice. This will mean that, throughout the five years of the SRP, we will be working regularly and collaboratively with stakeholders (rather than simply transferring outputs to them). The approach will build on networks and trust with stakeholders established in the cSRP Theme 8 which has already seen the research feed in to specific policy and practice work at national, regional and local levels but will need to be extended to allow for the change in research focus. Details will be finalised in months 0-3 of the SRP; monitoring and improvements will be made as the SRP progresses.

2. Coordination and Management

2.1 Within WP3.4 and across other WPs

The WP is based upon four interlinked RDs, each of which looks at a different aspect of wellbeing. Each RD will be delivered by a research team comprising researchers from both Hutton and SRUC. In order to ensure the four RDs (and their constituent research objectives) are linked in an efficient and strategic way, we are proposing the following management structure:

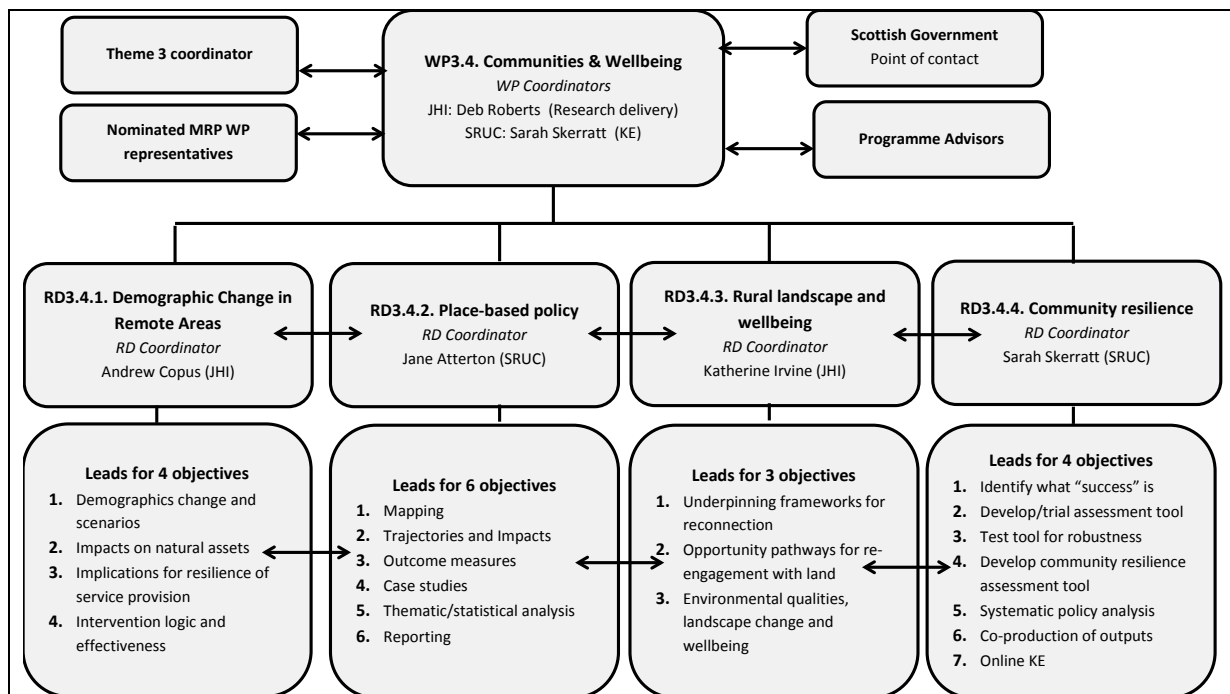


Figure 2: WP3.4. Management Structure

Figure 2 illustrates the dual point of contact between the Scottish Government (RESAS) and the two institutional (SRUC and Hutton) co-Coordiators of the WP. Roberts will lead on research delivery and Skerratt will lead the KE for the WP. It also shows the links between the WP Coordinators and: the Theme 3 Coordinator, nominated MRP WP Representatives, and Programme Advisors. In the first quarter of the new Programme, the WP co-Coordiators will establish frequency and type of contact required by RESAS and others involved in Programme/Theme/WP advice and management. The WP co-Coordiators are responsible for the performance of the WP and the ultimate delivery of all Milestones and Deliverables on time and within budget. Each RD has a single Coordinator, with the cross MRP teams being coordinated and managed by this lead. Within each RD, there is a range of objectives, and these are respectively managed by staff from the MRPs, depending on the time allocation of staff members to those objectives. As in cSRP Theme 8, there will be annual WP-level meetings, and 6-monthly RD-level meetings, supplemented by quarterly reports from RD Coordinators to the WP co-Coordiators. All of the researchers with leadership responsibilities have experience in planning and implementing interdisciplinary research projects, ensuring opportunities are identified and exploited, and remedial action is taken if progress is not as expected or there is a change in the direction of work.

As noted above, the WP has strong links to other parts of the SRP, particularly in WP1.3 (RD1.3.2), WP1.4 (RDs 1.4.1&2), WP2.4 (RD2.4.1&2), and WP3.3 (RD 3.3.2). This will be achieved by assigning an individual within the relevant RD the responsibility of keeping familiar with the activities in the linked RDs so as to ensure the transfer of expertise, data, analysis and interpretation as required. Statistical analysis will be conducted in collaboration with BioSS, their inputs being supported by BioSS funding for Underpinning Capacity, Function 7. We will also explore possibilities to link to the Centres of Expertise in particular the rural communities work within CREW and work on community renewables in ClimateXChange (CxC).

There will be particularly strong connections between this WP and the CKEI, largely due to the policy focus of WP3.4 and its use of transdisciplinary (co-construction) approaches. The WP leaders will keep the KE Sectorial Leads informed of progress and the latter will identify opportunities for adding value by wider engagement across the research programme or with stakeholder communities. WP3.4 is expected to have particularly close links with the Communities KE Sectorial Lead. There are also synergies with work being undertaken out with the SRP (such as the Understanding Scottish Places work by Carnegie UK Trust and partners, several EU FP7 projects, and other UK-funded research).

2.2 Working with partners beyond the MRPs

Given the centrality of co-construction and transdisciplinary working within WP3.4, it is critical that we continue our engagement with stakeholders as we have been doing in cSRP Theme 8, and also extend and evolve our engagement processes so that they deliver greatest benefit for practice and policy. The trans-disciplinary (co-constructed) and case study approach at the core of the WP will result in collaboration with a range of local, regional and national stakeholders, including local businesses, Local Authorities, NGOs, the third sector and communities themselves. Skype/VC-enabled meetings will be used as a means of ensuring that the objectives, outcomes and evaluation of the stakeholder engagement is coordinated. In addition, regular communication and dialogue will enable the strategic selection of case studies across the WP which will enhance their policy relevance and impact.

Figure 3 illustrates the range of stakeholders whom WP3.4. researchers anticipate continuing to have dialogue with, and co-construct the research with, as it progresses from 2016-2021:

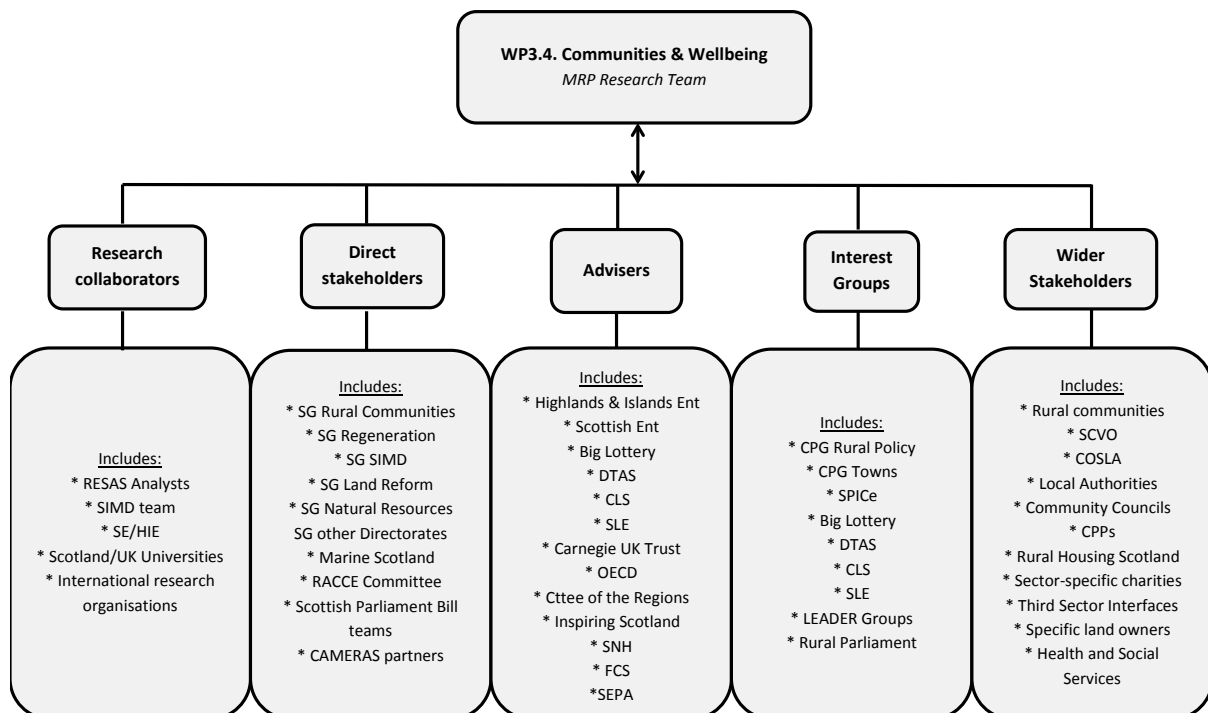


Figure 3: WP3.4. Stakeholder engagement

In addition, and as shown in Table 1, some the stakeholders will be involved across all four RDs, whilst others are specific to an RD reflecting its particular angle.

Table 1: Examples of Key Stakeholders by RD

RD 3.4.1 Demographic change in remote areas	RD3.4.2 Place based policy	RD3.4.3 Rural Landscape and wellbeing	RD3.4.4 Community Resilience
RESAS Analysts	RESAS Analysts	RESAS Analysts	RESAS Analysts
SIMD Team	SIMD Team	SIMD Team	SIMD Team
SG Natural Resources SG Land Reform	SG Regeneration	SG Land Reform	SG Land Reform
SE/HIE	SE/HIE	SE/HIE	SE/HIE
SNH	CPG Towns and Rural Policy	SNH	Big Lottery
SEPA	Carnegie UK Trust and partners	SLE	DTAS
SLE	Third Sector interfaces		CPPs

2.3 The Annual Reporting Cycle

The management structure described in section 2.1 will be used to meet the requirements for annual reporting. These will comply with the SRP-wide structures and procedures for reporting agreed with RESAS in the 6 months preceding the start of the new Programme. The reporting process will involve identifying high impact narratives relevant to policy, industry/innovation and examples of scientific excellence, including resilience (funding), collaboration and interdisciplinary working (with MRP and/or external partners). Ultimate responsibility for reporting will lie with the joint WP Coordinators. However responsibilities will be delegated from WP to RD Coordinators and specific objective team leads as a way to ensure that outputs and their impacts are achieved according to the proposed timeline. This will also provide the opportunity to review and adjust progress on each RD based on feedback from direct stakeholders, particularly RESAS policy teams. Annual reporting on progress will also take account of KE plans according to the Centre for Knowledge Exchange and Impact (CKEI) and its linkages to WP level and RD level KE activities.

2.4 Additionality

The WP leadership team is made up of researchers with considerable experience in both delivering to specified project objectives but at the same time adding value through their national and international networks. They have active policy links beyond Scotland (such as SRUC's role as Scottish convenor of the UK Rural Policy and Practitioners Group, Hutton/SRUC links into Defra's Rural Communities Policy Unit and SRUC/Hutton links with the OECD Rural Policy Team). These links, combined with international research links developed through several EU-funded projects, will allow them to add value of work conducted within WP3.4 while at the same time informing rural policies beyond Scotland.

Additional capacity will be achieved through leveraging external funding from both

EU and UK funders. The complementary strands of work in the RDs (some theoretically-driven, some policy-driven) will allow for researchers to apply across a broad portfolio of funding streams. Upcoming H2020 opportunities include: H2020-SC1: Health, demographic and well-being; H2020-SC3: Secure clean efficient energy; H2020-SC5 Climate action, environment, resource efficiency, raw materials H2020-SC6: Europe in a changing world. Other sources include European Spatial Planning Observatory Network (ESPON) funding; ISIB3-2015: Unlocking the growth potential of rural areas through enhanced governance and social innovation. ESRC, EPSRC, NERC funding if eligible; DEFRA; UK charities (e.g. JRF) and Non UK funding bodies (e.g. Norwegian Research Council).

Externally funded projects will also be used to consolidated links with researchers based in HEIs in Scotland and more widely. For example, researchers at SRUC (Skerratt, Atterton and Brodie) are part of the 'academic pool' for What Works Scotland which will enable the sharing of information (as appropriate) between the two projects. This is likely to be particularly relevant in RD 3.4.2. Also relevant in RD 3.4.2 will be close liaison with Carnegie UK Trust and partners (including the University of Stirling and the Centre for Local Economic Strategies) in relation to their ongoing Understanding Scottish Places work. At Hutton, Copus, Melo, Irvine and Roberts have strong links with Nordregio in Stockholm and with other academic institutes across Europe through recent relevant EU funded projects. These links will be drawn on to both inform the research undertaken (e.g. in 3.4.1 for the selection of European case study regions), and to disseminate the research findings to a wider non-Scottish/non-UK audience.

The proposed research is interdisciplinary reflecting the complexity of the underlying research questions. Each of the four RDs will involve researchers from a different social science background (economics, geography, environmental psychology, sociology, anthropology, political science), and RDs 3.4.1 and 3.4.3 also involving ecologists working in Theme 1. The researchers involved have previous experience of working successfully together and their host Institutes support interdisciplinary ways of working.

2.5 Risk Assessment

WP3.4. will establish a Risk Register. The risk management strategies (listed in Table 2 below) will link to, and be a component of, the Theme level risk management. The regular WP3.4. management meetings will allow for:

- The status of current risks to be assessed;
- New emerging risks to be identified and added to the register;
- Mitigation strategies to be proposed, taking into account the research implications for cross programme links and external collaborations including implications for stakeholders;
- Assessment to be agreed (e.g. tolerate, monitor, take action, including escalate);
- WP management committee to send risk register update to Theme Management Committee.

Table 2: Key risks and mitigation strategy

Risk Descriptor	Risk Assessment	Impact	Controls	Risk owner
Staff turnover	Medium	High	Regular WP and RD management meetings will be used to identify potential issues and plan solutions	WP Coordinators
Reduction in budgets	Medium	High	Research plans will be renegotiated with SG, and impacts will be agreed with partners	WP Coordinators
Changes in staff within stakeholder organisations	Medium	Medium	Regular WP management meetings will be help to minimise impact and avoid any potential disengagement with the research	WP Coordinators RD Coordinators
Divergence in stakeholder and research priorities	Low	Medium	Regular WP management meetings will be used to ensure communication and early identification of potential issues. Flexibility will be maintained in the planned work, without compromising coherence, to accommodate changes to policy etc. priorities where appropriate	WP Coordinators
Divergence in priorities between partner MRPs	Low	Medium	Regular WP management meetings will be used to ensure communication and early identification of potential issues	WP Coordinators
Linkage with other WPs	Low	Medium	We will maximise interaction through the selection of a number of common case studies across RDs in WP3.4. and WP1.3, WP1.4, WP2.4 and WP3.3. In addition, the individual charged with the responsibility for particular cross SRP linkages (see section 2.1) and the three researchers in WP3.4 who are also working in linked RDs will ensure effective collaboration and added value to research beyond WP3.4.	WP Coordinators RD Coordinators

3. Impact and KE

3.1 Key priorities for impact

The Coordinators of WP3.4 and each of its four RD leaders are very experienced and without exception have strong track records in delivering science-policy impact. They also have a very good understanding of EU and national policy and how it impacts on rural communities in Scotland. The key priority for WP3.4 is to continue delivery to SG policy teams. It will also aim to extend, and deepen, relationships to SG Land Reform policy team, other direct stakeholders in SG, wider stakeholders, and interest groups as listed in Figure 3.

3.2 Pathways to impact

The WP management structure (Figure 2) and stakeholder engagement plan (Figure 3) will ensure that work developed within each RD and across RDs in WP3.4 deliver the planned outcomes and impact. Regular engagement with key stakeholders (Figure 3 and Table 1) will ensure timely and effective interaction with the aim of maximising the benefit, and hence impact, of the research developed in the WP. Table 3 summarises some of the main anticipated benefits and impacts from WP3.4.

Table 3: Key benefits and sources of impact from WP3.4

Science Quality	WP3.4. builds squarely on the expertise gained from cSRP Theme 8 and research from a number of leveraged external projects including two EU-funded projects (TIPSE and TESS). This means the proposed research team have a solid understanding of the state-of-the-art science and are in a good position to publish REF-submittable outputs within the SRP timeframe.
------------------------	--

Policy impact	Much of the proposed research is trans-disciplinary with the RDs co-constructed with (rural and where possible, other) policy and RESAS colleagues within the Scottish Government, and with other stakeholders. Research plans have been drawn up with specific policies in mind and with outputs timed to inform policy developments. Extensive and systematic co-construction and review will ensure impact will continue to be delivered throughout the duration of the programme. Impact will also be enhanced by the embedded KE strategies within each RD.
Delivery to Innovation/commercialisation	The research does not directly lend itself to industrial impacts or commercialisation. However it is likely to identify innovations in terms of (lower cost) public sector service delivery mechanisms and community governance arrangements. Both of these will enhance the overall resilience of rural communities.
Contribution to 'science agenda-setting' issues	The policy focus of the research will mean that science-policy interactions and pathways to impact are a key element of the research design, helping to ensure research contributes to policy and has other positive impacts.

3.3 Interaction with the Centre for Knowledge Exchange and Impact

Both WP-Level and RD-level KE activities will draw from and contribute to the proposed Centre for Knowledge Exchange and Impact (CKEI). The KE Director and CKEI will provide leadership, guidance on best practice, QA, evaluation and training in support of all KE based on the RESAS programme, whether delivered directly from the WP/RD or from the CKEI itself. KE activities to be led from the CKEI will be agreed by the Knowledge Exchange Planning and Implementation Group (formerly KEC), which includes five KE Sectorial Leads including a Communities Lead. The WP Coordinator will liaise closely with all of the Sectorial Leads to ensure appropriate contributions from this WP to CKEI-led activities, and to ensure effective delivery of WP-led KE. The following KE activities and events will integrate our KE plans to be delivered with the CKEI:

- Storage and communication of outputs from work within WP3.4 through dedicated website (i.e. 'resource hub');
- Events Management (e.g. workshops, seminar, etc.; in Scotland, UK and Brussels);
- Research outputs, particularly Research Briefings, Policy Briefings, etc.;
- Link to social media platforms (e.g. blog, Facebook, Twitter, etc.).

4. Finance and value for money

In addition to staff time, resources are requested for primary data collection via fieldwork (focus groups, surveys, interviews), the purchase of secondary data sets (as required), and on-going regular engagement with national, regional and local stakeholders.

Primary data from some of the case studies in the cSRP will be built on to allow for longitudinal analysis over 10 years (the two SRP periods) and efficiencies of fieldwork resource use. Researchers across the RDs in WP3.4 will work closely together (for example, through regular WP-level meetings) and with external stakeholders to identify case studies which will be appropriate for data collection across multiple RDs. Stakeholder engagement around the case studies will be an asset in the SRP, and will build on the trusted networks established under the cSRP.

It is possible that use could be made of some of the research platforms (such as the community renewables being developed at Hartwood). New to this SRP will be greater emphasis on integrating natural science within the WP (particularly in RD3.4.1) and links with WP2.4 and WP3.3 where shared approaches and case studies will be developed.

Quality Assurance (QA): The MRPs contributing to WP3.4. are dedicated to achieving and maintaining the highest possible standards of quality in order to meet the requirements of their work and the needs of their internal and external customers. To achieve this they will:

- Comply with the requirements of the BBSRC/Defra/FSA/NERC 'Joint Code of Practice for quality assurance' and the BBSRC 'Statement on Safeguarding Good Scientific Practice'.
- Operate a quality management system that meets the requirements of the ISO 9001:2008 and which is systematically maintained, reviewed and revised to ensure continuous improvement.
- The relevant Quality Management Systems, or equivalents in each Institute, will ensure:
 - Quality performance monitoring through internal and external auditing relating to the pertaining ISO standard;
 - Understanding of specific quality objectives and targets to staff;
 - Planning and developing of standard work processes by means of Standard Operating Procedures, where required;
 - Appointment of competent personnel to co-ordinate, implement and review quality management directives [existing MRP QA managers].
- Ensure adequate allocation of resources to achieve quality objectives and targets.
- Obtain and act upon feedback from key stakeholders and the Scottish Government.
- Develop and maintain competency of all staff through the provision of tailored training and the clear communication of quality assurance requirements.

5. **Ethical and regulatory issues:** The research in this WP will involve collecting data from both stakeholders and the public. Therefore, data collection methodologies will need to be approved by the Scottish Government Survey Control Unit and the appropriate MRP ethics committee.

6. **Contribution to the 3R's (reduction, refinement and replacement):** The research in this WP does not involve any animal experimentation.

Sustainable Development: The Scottish MRPs associated with WP 3.4 have Environmental Policy Statements which affirm that they are committed to preventing pollution, adopting and promoting environmental best practice in connection with operations and in support of sustainable and safe practices. This is managed via an ISO 14001 environmental management system. Video and teleconferencing are widely used as a way to reduce the need for travel, and sustainable transport is supported by Business Travel Policy (Hutton, SRUC).

Name of RD: 3.4.1 Demographic change in remote areas

Research aim and key drivers

This research deliverable addresses the following question: *What are the links between trends in farming/crofting/key rural industries and population change, and how do these affect the provision of ecosystem services, and threaten the resilience of rural communities?*

This RD reconsiders the rationale for supporting small scale farming and other land-based activities in remote rural areas as a means of preventing “desertification”, and ensuring the delivery of ecosystem services, in remote and sparsely populated areas of Scotland. This is particularly timely, given the discussion of Areas of Natural Constraint (ANC, formerly LFASS) policy together with the ongoing Land Reform debate. It will also build on recent SG-funded research on the diversity of land ownership.

The research addresses fundamental questions about the changing nature of peripherality and the role of local territorial capital. Most popular theories require at least part of the impetus for rural development to originate in the local population³, pointing to a range of (local) human and social capital characteristics as preconditions for positive local economic and social dynamics. The logical implication is that declining population may (once a certain threshold has been passed), trigger a downward spiral. However, more recently, the advocates of “organised proximity”⁴ and networked models of development have argued that increasing opportunities for external interaction may compensate for sparse and dwindling local capacity.

The key drivers for this research are:

(i) *Long-term demographic processes.* The dominant process in remote rural Scotland has been “desertification” through the selective out-migration of the younger and more highly educated segment of the workforce towards cities and towns. This has exacerbated the demographic ageing common to most of rural Western Europe. A second process involves a gradual drift of population from the most remote and sparsely populated areas into nearby villages and towns. Both of these have substantial implications for the demand for and cost of delivering “services of general interest”⁵ (SGI) and hence the equality agenda. They may also have more subtle effects on the “critical mass” of communities and their capacity for endogenous development.

(ii) These demographic changes have accompanied gradual but longstanding changes in crofting/farming *land use and intensity*, with associated implications for natural assets and provision of Ecosystem Services (ES).

(iii) Adding complexity to the picture, remote and sparsely populated areas, and their local economies, have to varying degrees participated in *diversification and restructuring*. Within the farming/crofting sector this has manifest itself in increasing links between farm businesses and the wider local economy, either through the incorporation of activities such as tourism/recreation, or through the participation of

³ Terluin I (2003) Differences in economic development in rural regions of advanced countries: an overview and critical analysis of theories. *Journal of Rural Studies* 19, 327-324. Atterton, J., Newbery, R., Bosworth, G. and Affleck, A. (2011) Rural enterprise and neo-endogenous development, in Alsos, G. A., Carter, S., Ljunggren, E. and Welter, F. (eds). *The Handbook of Research on Entrepreneurship in Agriculture and Rural Development*, Edward Elgar: Cheltenham, UK, pp. 256-280.

⁴ Boschma R A (2005) Proximity and Innovation: A Critical Assessment, *Regional Studies*, 39:1, 61–74. Torre A and Rallet A (2005) Proximity and Localization, *Regional Studies*, 39:1, 47-59

⁵ Use of this terminology serves to emphasise the fact that responsibility for service provision is increasingly shared between public bodies, commercial providers and the third sector. See for example: http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/SeGI.html [Accessed 20th March 2015]

farm household members in off-farm work. Established rural activities, such as forestry, fishing, aquaculture and tourism have adjusted, and new activities, such as renewable energy, have emerged.

These three key components of change in remote and sparsely populated areas have taken place against a changing backdrop of economic and social “framework conditions”. These include subtle, incremental and selective changes in the meaning of *peripherality*, *accessibility*, and *proximity*, driven by information and communications technology (ICT), improvements in infrastructure, and changing working practices and lifestyles. They also interact with a more immediate macro-economic context (crisis and recovery) and consequences in terms of local authority budgets.

The causal links between the drivers and outcomes described above are illustrated in Figure 1. Clearly the demographic changes are part of a very complex system, reflecting a range of social and economic processes. However in this research deliverable the focus will be upon the redistribution

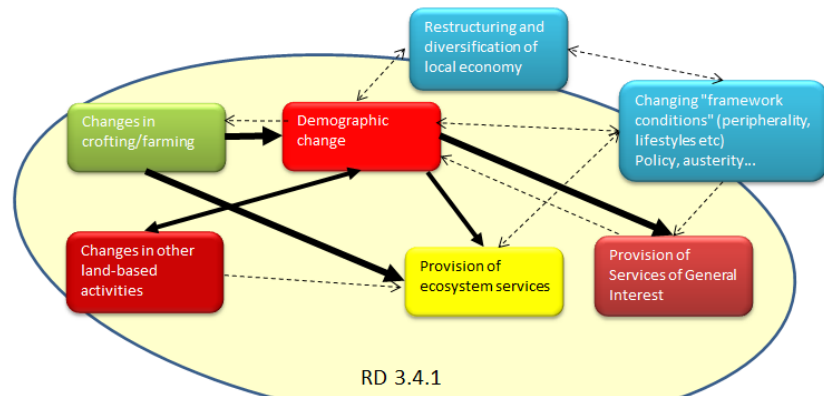


Figure 3: Causal relationships and research focus

Note: dashed arrows are not necessarily indicative of lesser importance in terms of cause and effect, but rather of a lower priority in RD3.4.1

of population as a consequence of changes in small scale farming, other key rural industries, and broader economic diversification.

It is assumed that changes in natural assets and provision of ES are partly a direct result of changes in farming and other key industries, and partly a “second round” effect of associated demographic changes, diversification of the economy, and broader social changes. Changes in provision of services of general interest are assumed to be driven in the medium term by changes in the distribution of population, but also strongly affected in the short term by policy expenditure priorities.

Stakeholders consulted: HIE, Scottish Enterprise, Argyll and Bute Council, and Highland Council have all reviewed the RD text and provided valuable feedback.

Summary of the proposal:

Objectives:

- To describe and explain recent demographic changes and economic trends in remote rural areas of Scotland, and to build scenarios describing likely developments in the immediate and medium-term future.
- To explore the implications in terms of impacts on natural assets, and the provision of ecosystems services.
- To consider the implications for the resilience of remote rural communities in general, and in terms of provision of services of general interest (SGI) in particular.
- To review the “intervention logics” associated with policies to support remote rural areas, and to consider the effectiveness of different approaches within this changing context.

Activities:

O1. Recent and Projected Demographic Change in Remote Rural Scotland

This tranche of work seeks to establish a clear picture of demographic and economic structures and trends in remote rural Scotland. It consists of two sub-tasks:

(i) An initial basic task will be to define the area of rural Scotland which will be the focus of this RD. In doing so it will be necessary to incorporate both sparsity (low population density) and remoteness. It is anticipated that the area identified will be an aggregation of output areas, constituting a sub-set of the “very remote rural” area of the 8-fold Scottish Government urban-rural classification.

(ii) The next step will be to carry out a thorough analysis of recent demographic trends, including shifts in age and gender profiles. Importantly this review will begin by tracing changes since 1991, but will proceed to consider projections of key demographic indicators for the medium and longer term (2025 and 2050).

(iii) A clearer picture of recent and anticipated trends, especially in terms of migration, will form the basis for an assessment of the key issue of motivation, and whether demographic change is jobs-led or people-led (i.e. the relative importance of employment and well-being).

O2. The Role of Agriculture and Key Rural Activities in Demographic Change

This group of tasks seeks to understand and quantify relationships between local economic activities/incomes and demographic changes, using evidence from the recent past as a basis for possible future scenarios.

(i) The first step will be to analyze recent changes in farming systems, land ownership and labour utilisation in the remote rural areas, over the past 25 years.

(ii) A broader focus will then be taken, with a review of recent developments in key rural industries, and incomes associated with them.

(iii) Based on the foregoing analysis, the final sub-task will be to identify key drivers of recent and (likely) future changes in economic activity, incomes, population, and demographic structure in remote rural Scotland. A better understanding of these will likely suggest a need to adjust the demographic forecasts established in O1.2. These improved demographic forecasts will form the starting points for a series of probabilistic scenarios for economic activity in 2025 and 2050.

O3. Implications of Demographic Change for Land Use, Natural assets and ES

This group of sub-tasks seeks to establish trends in agricultural and crofting land use, to consider implications for natural assets, to model future ES activity, and its likely impacts on the local economy of remote rural Scotland.

(i) Building on O2.1 the first step will be to establish recent trends in crofting/farming land use in the study area over the past 25 years.

(ii) Identification of key recent changes in ecosystems and natural assets, will be achieved in collaboration with researchers in theme 1.3, particularly RD1.3.2.

(iii) The Natural Assets Inventory proposed by RD1.4.1 will be examined as a potential baseline assessment of the status of environmental public goods.

(iv) A set of hypothetical scenarios for farming systems and land use changes by 2025 and 2050 will then be developed, based upon expert horizon scanning of likely technical and market trends, and a range of agricultural and rural development policy options.

(v) On the basis of these scenarios the likely future development in provision of ecosystems services in remote rural Scotland will be assessed in terms of changes to the Natural Assets Inventory.

(vi) Implications of such changes in Natural Assets in terms of environment-based activities, such as agritourism will be explored.

O4. Implications of Demographic Change for provision of SGI in Remote Rural areas

This element of the research deliverable explores the implications of demographic change for provision of SGI. The definition and classification of SGI will take account of the findings of RD3.4.2.

(i) The first step will be to review the full range of SGI provision (public, private and third sector) in the remote rural study area, in order to establish a classification of modes of delivery, and to select a representative set of services which are observed to be particularly sensitive to sparsity and remoteness.

- (ii) This subset of “exemplar” SGI will then be investigated in greater detail, to establish the narrative of recent changes in provision, examining the rationale offered for the changes made. This narrative will be set against objective demographic data, in order to assess the relative importance of sparsity and population trends compared with other factors.
- (iii) GIS analysis will be used to identify (current) patterns of service delivery/access within remote rural Scotland, focusing on the “exemplar” services only. The population projections and scenarios for 2025 and 2050 will then allow an assessment of how these patterns could change, and identify those areas under threat of poor access, or non-delivery.
- (iv) Finally, researchers will review novel approaches to SGI delivery in sparse and remote contexts, and consider how these could be used to improve provision of services in specific areas identified by the GIS analysis as “under threat”.

05. Implications of Demographic Change for Capacity for Endogenous Development.

This work aims to answer the question: “Is there a minimum critical mass (or rather density) for endogenous development processes, or can this limit be avoided by developing stronger exogenous networks?” It also sets the analysis of remote rural Scotland within an international context, by exploring different policy rationales from other EU Member States.

- (i) A review of international academic and policy literature relating to remote and sparsely populated areas, their demographic and economic structure and trends, theories regarding the changing role of such areas, and policy approaches, will be carried out.
- (ii) Using the “population potential” definition a small number of European case study regions with comparable degrees of remoteness and sparsity will be selected. These will be investigated, as a potential source of good practice ideas, and alternative approaches. Governance arrangements will be described as an important contextual aspect.
- (iii) The critical threshold question will be tackled by means of structured interviews with local institutions and organisations involved in different aspects of local development, designed to elicit their experiences, and in particular to assess the degree to which exogenous networks may compensate for sparse endogenous human and social capital.
- (iv) On the basis of the literature review and the case studies, a range of alternative intervention rationales to support the ecological and socio-economic resilience of remote rural Scotland will be formulated. These will form an important input into the 2025 and 2050 scenarios [O1.2, O2.3, O3.4].

Milestones

M	Objectives	Completion of:	Date
1	1.1	Definition of study area	Yr 1 Q2
2	1.2	Demographic analysis and forecasting	Yr 2 Q3
3	2.1, 2.2, 3.1	Agricultural and key rural industry trend analysis	Yr 2 Q3
4	5.1, 5.2	Review of literature and international case studies	Yr 2 Q4
5	2.3	Socio-economic scenarios	Yr 3 Q2
6	3.2, 3.3	Natural assets and ecosystems services analysis	Yr 3 Q2
7	4.1, 4.2	Initial SGI classification and exemplar analysis	Yr 3 Q2
8	3.5, 3.6	Ecosystems services scenarios	Yr 3 Q4
9	4.3, 4.4, 4.5	SGI GIS analysis and Scenarios	Yr 4 Q2
10	5.2, 5.3, 5.4, 5.5	Review of intervention rationales, costs and benefits	Yr 4 Q4

Deliverables (Years 1 and 2 only)

Deliverable /date	Objective	Type	Description
D1 (Yr1 Q3)	1.1	Working Paper	Population potential analysis, definition of study area
D2 (Yr1 Q4)	5.1	Working paper	Review of literature
D3 (Yr2 Q4)	1.1, 1.2	KE Workshop + working paper	Demographic profile of remote rural Scotland, 1991-2050
D4 (Yr 2 Q4)	2.1, 2.2, 2.3	Working paper	Recent trends and future prospects for remote rural areas of Scotland.
D5 (Yr2 Q4)	4.1, 4.2	Workshop	Stakeholder review of SGI classification and exemplar services.
D6 (Yr2 Q4)	5.1, 5.2, 5.3	Workshop	Stakeholder KE workshop- International case studies

Technical approach:

Experimental and Statistical Approaches

This RD is largely based on data which is in the public domain, it will not require special access or licences. A licence for the Stella systems modelling software will be required. The foresight element will require expert inputs from local stakeholders.

Population potential mapping. This is a technique developed by Gloersen *et al*⁶ which combines information on sparsity and remoteness. In essence it classifies areas in terms of the number of persons who reside within a certain distance. This approach takes account of both low density within the immediate area, and access to adjacent populations. Arguably this better represents the real economic and social implications of sparsity than a simple choropleth map of population density. It has the added advantage of smoothing out abrupt changes in density, and generating a “population potential” surface or gradient. The procedure will be applied to output area⁷ data from the 2011 census in order to develop a more detailed and up to date map than is available in the existing literature.

Analysis of 1991-2011 census data. Using output area data wherever feasible, the analysis will review age structure and gender changes over the full 30 year period, and key human capital characteristics for 2011. Findings for the remote and sparsely populated areas will be benchmarked against averages for different categories of the Scottish urban-rural classification. National Records for Scotland also publish estimates of population at the datazone level for intercensal years. These data will be explored as a source of information on change since 2011.

Disaggregation of Council Area Migration Statistics. Migration statistics are available only at a relatively aggregate level in Scotland. Estimates of the flows into and out of the remote and sparsely populated areas will use Council area data⁸ as a starting point, following procedures, tools and guidance provided by the National

⁶ Gløersen, E., Dubois, A., Copus A and Schürmann C (2005) Northern peripheral, sparsely populated regions in the European Union, Nordregio Report 2005:4, Stockholm. Available from <http://www.nordregio.se/en/Publications/Publications-2005/Northern-peripheral-sparsely-populated-regions-in-the-European-Union/> [Accessed 19th February 2015]

⁷ Data zones are too large in the area under study.

⁸ <http://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/migration/migration-statistics/local-area-migration>

Records of Scotland, and the Office for National Statistics.

Population Projections for 2025 and 2050. Similarly the “popgroup” methodology used by National Records for Scotland to produce projections⁹ will be adapted for the remote and sparsely populated areas. Estimates of total population, age and gender structures will allow comparisons with official projections for Council Areas and Scotland as a whole.

A simple systems model. It is anticipated that the above tasks may be brought together in a simple systems model of demographic change, implemented in Stella software¹⁰. This will greatly facilitate scenario analysis.

Review of Recent Employment Change in Key Rural Industries. This element of the work will of necessity adopt an eclectic and pragmatic approach, since no single source of data is sufficient or comprehensive. Key sources will be the population census, the Annual Business Inquiry, sector specific reports etc.

Analysis of Agricultural Change in Remote Rural Scotland. This will be based on June Agricultural Census (parish level data) and FAS data, and will focus particularly on the evolution of labour usage (O2), and land-use change (O3), in the remote and sparsely populated areas of Scotland, and associated farm types.

Analysis of ecosystem and natural assets impacts of land use change. It is anticipated that the approach will be structured according to the principal habitat types present within the region, and adopt a simple qualitative scoring system similar to that of the UK National Ecosystem Assessment. It will draw on four sources of information:

- Expert inputs from the Ecosystems Science Group of the James Hutton Institute, including some joint work under RD1.3.2.
- Grazing and “rewilding” experiments being carried out by SRUC under RD1.3.2 at the Hill and Mountain Research Centre (HMRC), Crianlarich
- The Natural Assets Inventory, to be developed in RD1.4.1.
- A series of stakeholder workshops.

GIS Analysis of service provision/accessibility. This will be carried out in ARCGIS, and will build upon work carried out in the context of the ESPON SeGI project (see footnote 1).

Scenario Analysis – Scenarios for 2025 and 2050 will be developed in the context of Activities A, B and C. To a large extent these will be driven by population projections, the key scope for different outcomes will lie in assumptions about future migration. The scenarios of economic activity and land use/ecosystem change will also incorporate available forecasts and expert inputs from the study team and stakeholders. It will be necessary to consider multiple outcomes for 2025 and 2050. It may also be necessary to subdivide the study area into different zones (e.g. farming v crofting), with different prognoses. Another source of differentiation will be different assumptions about future policy, especially agricultural policy.

Interdisciplinary Collaboration

Whilst this RD is necessarily anchored in socio-economic approaches, Activity C depends heavily on collaboration with ecosystems and farming system expertise. This will be achieved partly through working closely with the HMRC (Prof Davy McCracken). This collaboration will result in at least two joint deliverables with RD1.3.2; the review of land use change (O3.1) and a stakeholder workshop to formulate land use change scenarios (O3.4). Ecosystem expertise will also be

⁹ <http://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-projections/small-area-population-projections>

¹⁰ <http://www.iseesystems.com/software/education/StellaSoftware.aspx> [accessed 19th March 2015]

contributed by senior researchers from the Ecological Science Group of the James Hutton Institute.

Location of planned fieldwork: O3: experiments carried out at the HMRC.

Detailed work plan for first two years:

O1.1: Mapping Population potential

This identifies the territorial context for the later analysis. It also benchmarks the study area objectively in relation to similar European areas, allowing direct comparisons of socio-economic trends and styles of intervention. Although the population potential measure is derived in a different way from the Scottish Government's urban-rural classification, and the study area is likely to be a sub-region of the very remote rural category, every effort will be made to maximise complementarity. The work will commence at the beginning of year 1 and should be completed within six months. The findings will be communicated in the form of a working paper (D1).

O1.1: Demographic patterns/trends/projections

The distinctive contribution of this work is that it focuses upon remote and sparsely populated areas, seeking to fully document key aspects of demographic trends over the past three decades, and to project trends to 2025 and 2050. Most published analysis presents results for administrative areas, (generally Council Areas), masking important detail and often combining territories with divergent trends¹¹. Our analysis will focus upon a relatively homogeneous study area, and use data for the smallest available spatial units (output areas).

Whilst the "natural increase" aspect of demographic change is relatively easy to project in a mechanical way, the "wild card" is migration, and it will be necessary to consider a limited number of alternative scenarios, each of which will be highly contingent not only upon what happens to economic activities within the study region, but also events and social trends in the rest of Scotland and beyond.

The analysis will highlight demographic trends in the study area with particular emphasis upon (a) local redistribution processes, which are thought to be resulting in a more "nucleated" settlement pattern, and (b) trends in the "human capital" characteristics of the population (age, gender, education, profession).

This activity will begin as soon as the study area is defined (Yr1 Q3) and will culminate in Yr2 Q4, with the publication of a working paper, which will be presented and discussed at a stakeholder workshop (D3).

O2.1 and O3.1: Agricultural trends

These tasks share a common information base (agricultural census and FAS) but face two ways in terms of cause and effect links. In O2.1 the focus is upon understanding trends in agricultural employment, and the link between this and migration from remote and sparsely populated areas. In O3.1 attention turns to land use change, which is of interest because of its impact upon ecosystem service provision.

The study area is far from homogenous in terms of land use or farming system, and it will be necessary to acknowledge internal differences within the region. An early

¹¹ The inherent dangers associated with this are dramatically illustrated by two recent Nordic analyses which showed that apparent evidence for counter-urbanisation trends is a consequence of too "coarse grained analysis" of a process of outward extension of the urban fringe. This illustrates the danger of assuming that processes of change observed in more densely populated contexts are also affecting remote and sparsely populated areas. Amcoff J (2006) Rural population growth in Sweden in the 1990s: Unexpected reality or spatial-statistical chimera?. *Population Space and Place* 12 171-185. Grimsrud, G., R. (2011) How well does the 'Counter-urbanisation story' travel to other countries? *The case of Norway. Population Space and Place* 17, 642-655.

challenge will be the need to reconcile different geographies (parishes and output areas) associated with agricultural/land use data and demographic data, which make a simple “overlay” approach impossible. The solution will probably lie in finding a common classification of local environments which can be operationalised in terms of each of the spatial units associated with the different data sources.

In the case of O2.1 it may be appropriate to sub-divide the study area into a number of broad farming/crofting system types, which will act as a framework for presentation of past trends in labour use, and (in O2.3) scenarios for 2025 and 2050. However in order to serve the analysis of land use and ecosystems services it may be that a framework relating to broad natural habitat types may be more appropriate. These simple classification grids of farming type and habitat will later become an important structural component of the scenario analyses of O2.3 and O3.4.

This task is scheduled between Yr1 Q2 and Yr2 Q3.

O2.2: Key rural industry trends

This task will establish trends in key rural activities such as forestry and timber processing, fishing and aquaculture, food and drink processing, tourism recreation and leisure. One of the first challenges here will be to arrive at an objective definition of “key rural industries”. The initial assumption will be that these have some kind of local/rural comparative advantage (a local raw material, a market for semi-processed products, or indeed, in the case of leisure, recreation and (agri)tourism, a direct dependence on ES). Clearly a pragmatic approach to data sources, and to spatial units will be required. Every effort will be made to examine internal differentiation within the study area, but inevitably for some activities it will only be feasible to describe trends affecting the whole area. This task is scheduled between Yr1 Q2 and Yr2 Q3.

O2.3: Economic Activity Scenario building

This task will build upon the foundations laid in O2.1-O2.2, to create a limited number of possible scenarios for the development of the economy and employment patterns (including agriculture, and key rural industries) of the study area in 2025 and 2050. These scenarios will require three principal inputs:

- (a) The trends established in O2.1-O2.2
- (b) A limited number of contrasting policy scenarios for agriculture and key rural industries
- (c) Expert stakeholder inputs.

The planned deliverable (D4) will be a working paper, drawing in O2.1-O2.3), on evolving economic activities in remote rural areas.

O3.2: Ecosystem change

This task will explore the broad implications of agricultural change for ecosystems in the study region. It will draw upon expertise at the HMRC, and the Hutton’s Ecological Sciences Group, partly through direct involvement of the latter in this RD, and partly through joint deliverables with RD1.3.2. It is anticipated that the approach will be structured according to the principal habitat types present within the region, and adopt a simple qualitative scoring system similar to that of the UK National Ecosystem Assessment. In-house expert judgements will be tested through a series of stakeholder expert workshops, each linking to different habitat types, and located in different parts of the study area to facilitate local involvement. This task will begin in Yr2 Q3 and continue into Yr3 (possibly Yr4). The deliverable will be a series of stakeholder workshops and a working paper.

O4.1: Classification of SGI provision, selection of exemplars

This work will be carried out in close collaboration with RD3.4.2. The range of services which has implications for rural resilience is very broad. The objective of this

task will be to develop a classification of services made available to residents and communities, and to identify a set of “exemplars” which are particularly challenged by the geographical characteristics of the study area. This will be achieved by a review of a variety of secondary data sources, and by interviews with key providers (councils, health boards, etc). The classification and the exemplars will provide a structure for subsequent analysis of the determinants of change in SGI provision/delivery. This work will begin as soon as the study area is defined (Yr 1 Q3) with the aim of having a classification of SGI in the study area one year later. This work will contribute to a stakeholder workshop (D5) and a working paper.

O4.2: Analysis of change in SGI provision/delivery

This task will build on O4.1, focusing on the “exemplar” subset of services. It will seek to understand the rationale for past changes in modes of delivery/provision, and to assess the relative importance of sparsity and remoteness in the decisions. In conjunction with what will be known about demographic change this should allow an assessment of the concept of demographic “tipping points”, beyond which a downward spiral sets in. Again this work will be heavily dependent upon qualitative interviews with practitioners from the public, private and third sector service providers. Work will begin during Yr2 Q4. It will contribute to a stakeholder workshop (D4) and a working paper.

O5.1: International review of intervention logics

This review of the international academic and policy literature relating to remote and sparsely populated areas, their demographic and economic structure and trends, theories regarding the changing role of such areas, and policy approaches, will begin in Yr1 Q1, and continue throughout the first year. This review will allow the development of a typology of policy paradigms. This work will contribute to a working paper (D2) and a stakeholder workshop on alternative policy paradigms (D6).

O5.2: European Case Studies

Using the “population potential” definition a small number of European case study regions with comparable degrees of remoteness and sparsity will be selected. Desk research and telephone interviews will explore demographic, structural, land-use and ecosystems aspects, along with current policy approaches and governance arrangements as important contextual aspects. These case studies will be a potential source of good practice ideas, or at least of alternative approaches. This work will contribute to a working paper (D2) and a stakeholder workshop on alternative policy paradigms (D6).

Expertise

The Hutton’s SEGS group has many relevant skills; in demographic and agricultural statistics analysis, GIS, systems modelling, economics, foresight/scenario analysis, policy evaluation, structured interviewing of stakeholders, ecological change and ecosystems services. SRUC will contribute expertise in policy evaluation, comparative case studies, ecological change and the natural assets inventory.

Key linkages, interdisciplinarity & collaboration

The most immediate linkages are with RD3.4.2, and RD1.3.2. In both cases the research teams have common members. In the case of RD1.3.2 joint deliverables will be produced, whilst in RD3.4.2 the teams will work together on common methodologies. Objectives 1 and 2 will acknowledge and maximise coherence with the contributions of RD2.4.1 and 2.4.2, especially with regard to operational concepts of resilience. Opportunities for this RD to interact with CAP (ANC) impact analysis in RD1.4.1-2 will be explored. Interdisciplinarity is achieved mainly in the context of Objective 3, where ecosystems, natural assets and farming systems expertise

(RD1.3.2, and 1.4.1) will integrate with socio-economic approaches.

Added Scientific Value

The study area envisaged for this RD probably has more in common with the Nordic Countries, or Iberia, than other parts of the UK (hence the emphasis placed upon international literature and comparative case studies). The research will draw on several bodies of literature/theoretical perspectives, including studies of rural policy approaches, crofting and land ownership, rural service provision (especially health and social services), land use change, ecosystems services and environmental public goods, and even the debate in regional science about the changing nature of proximity. The distinctive contribution will be its interdisciplinary and holistic approach grounded in a specific and distinctive regional context, a combination with proven capacity to deliver considerable leverage of external funding.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview. Stakeholder workshops and dissemination events form an important structural component of the proposed research, delivering expert inputs, especially to future scenarios building. Active involvement of local authorities and sectoral representative bodies will be sought. This will deepen research team awareness of current policy issues and ongoing developments in terms of migration and local economic activity.

Workshop	Description	Date/ Deliverable	Objectives
KE1	Disseminate demographic profile	Yr2 Q4 (D3)	1.1, 1.2
KE2	Stakeholder review - scenarios of economic activity	Yr3 Q1	2.3
KE3	Stakeholder review of draft land use scenarios	Yr3 Q4	3.3, 3.4
KE4	Stakeholder review - SGI classification + exemplars	Yr2 Q4 (D5)	4.1, 4.2
KE5	Stakeholder review - SGI scenarios	Yr3 Q4	4.3, 4.4
KE6	Disseminate findings - international case studies	Yr2 Q4 (D6)	5.1, 5.2, 5.3
KE7	Stakeholder review - intervention rationales	Yr4 Q2	5.4, 5.5

The “audience” for this work will include policy practitioners at the Scottish Government, local authorities, relevant NDPBs, third sector organisations active in community development and environmental conservation.

The KE events will foster genuine co-production, leading to the following impacts:

- (i) A better evidence base for policies to support sparsely populated and remote areas.
- (ii) Raised awareness of alternative approaches used in similar areas elsewhere.
- (iii) An overview of the evidence for better decision making and planning of SGI provision.
- (iv) A better basis for strategic planning for sparsely populated remote areas.

The KE events will be an effective way to ensure. Findings will be shared through the KE workshops and the planned Working Papers. A simple impact indicator might be constructed from the number of downloads of the working papers, or attendees at KE workshops.

RESEARCH DELIVERABLE NUMBER: 3.4.1

Work planning and timetable for Year 1: Please include major milestones, (key research activities, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, KE=KE event, R=Reporting to RESAS

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1: Mapping population potential/Defining the study area						M1			D1			
O1.2: Demographic patterns/trends												
O2.1/O3.1: Agricultural trends												
O2.2: Key rural industry trends												
O4.1: Classification of SGI provision												
O5.1: International policy review												D2
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.4.1

Work planning and timetable for Year 2: Please include major milestones, (key research activities, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, KE=KE event, R=Reporting to RESAS

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.2: Demographic trends/projections									M2			D3
O2.1/O3.1: Agricultural trends									M3			
O2.2: Key rural industry trends									M3			
O2.3: Econ. Activ. Scenario building												D4
O3.2: Ecosystem change												
O4.1: Classification of SGI provision												
O4.2: Analysis of SGI exemplars												D5
O5.2: European Case Studies												M4 D6
KE Event: Stakeholder workshop												KE1
Annual Report (Year 2)												R2

Name of RD: RD3.4.2 Place-based policy and its implications for policy and service delivery

Research aim and key drivers

Aim: To improve our current understanding of (i) the main reasons for differences in economic performance and social outcomes across rural areas and small towns of Scotland, and (ii) how policies can help to deliver positive outcomes and address these disparities. The key research question to be explored is: Can place-based policies address differences in economic performance and social outcomes in Scotland's rural areas and small towns?

Drivers

- Persistent differences in the socio-economic performance of rural areas and small towns across Scotland, despite a range of policy and practice interventions, leading to severe and, in some instances, growing, inequalities between people and places (e.g. the 'Vulnerability Index' in SRUC's [2012 Rural Scotland in Focus Report](#), the small settlements growth/decline work in the [2014 Rural Scotland in Focus Report and Hutton's recent mapping socio-economic performance work](#)).
- Ongoing structural changes across rural Scotland (e.g. the increasing importance of service sector activities and the knowledge-based economy, changing commuting patterns and increased home working) leading to changes in the functional relationships between small towns and their hinterlands.
- Continuing emphasis on 'bottom-up', 'place-based' and 'asset-based' approaches to local development in policy, for example, through the Community Empowerment (Scotland) Bill and proposals for the Land Reform (Scotland) Bill; an emerging policy and practice emphasis on wellbeing (see e.g. the OECD Better Life Index) alongside the Scottish Government's overarching purpose of sustainable economic growth.
- New economic opportunities and challenges for rural areas encouraged through the Scottish Government's Economic Strategy and the Low Carbon Economic Strategy, and in the context of a fast changing economy.
- Research and policy initiatives directed at Scotland's towns (e.g. the Town Centre Action Plan), often with a focus on town centres rather than their interactions with their hinterlands or with city regions (the current/planned work led by Carnegie UK Trust on Understanding Scottish Places is an exception).
- A concern that some towns fall into a gap between spatial (i.e. rural and urban) and/or sectoral policies; coastal towns are one such example. At the same time, National Planning Framework 3 underlines the significance of towns and Scotland's Towns Partnership is undertaking various activities to improve their performance and raise their profile.
- Ongoing pressure on public sector finance and changes in the landscape of service provision and the delivery of services at regional and local level (e.g. see the Christie Commission Report), and delivering to National Outcomes, such as reducing inequalities, realising individuals' full economic potential and delivering responsive, high quality public services.

The proposed research addresses all of these policy and practice drivers and provides a significant opportunity to deepen and expand the research and evidence base relating to economic performance and social outcomes across rural Scotland.

Consultation: The following have been consulted in preparing this RD:

- Scottish Government RESAS staff (Liz Hawkins)
- Highlands and Islands Enterprise (Alastair Nicolson)
- Scottish Enterprise (Julian Pace)
- Scotland's Towns Partnership (Phil Prentice)
- Carnegie UK Trust (Jim Metcalfe)

Summary of the proposal:

This RD will explore the reasons for the persistent inequalities in economic and social outcomes across Scotland and how they can be addressed through different policy and service delivery responses. Emphasis will be placed on understanding Scotland's towns, and how they interrelate with rural and urban areas, providing a particularly novel aspect to this research. The work will improve our understanding of the current service delivery landscape and inform the design and delivery of services at a time when public sector budgets are constrained, but new drivers and demands are emerging, such as the prevention agenda, inequality and social justice, and demographic ageing. The research will lead to a better understanding of how different policy interventions can help improve social and economic outcomes across rural and small town Scotland – and why some existing policy/practice responses are not making a positive difference. The team has extensive experience and expertise in rural and regional development (Atterton, Copus, Roberts, Melo, Currie, Markantoni, Steiner), rural policy (Atterton, Roberts, Copus), towns and their inter-relationships (Roberts, Copus, Atterton) and policy analysis (Copus, Brodie, Atterton) in Scottish, UK and EU contexts.

Objectives

1. Map the landscape of rural policy and service delivery (i.e. the instruments through which economic and social outcomes may be delivered) to help understand the range of actors, institutional levels, and geographies at which place-based policy and service delivery may be most useful.
2. Review and build on existing typologies and classifications of rural-urban from Scotland and elsewhere (e.g. SG's 6-fold rural-urban classification, the conceptual model of rural-urban linkages developed in WP8.3 of the cSRP and existing literature, to better understand rural/town/urban interdependencies.
3. Assess the suitability of different data sources and map the disparities in economic performance and social outcomes across rural and small towns and present these at community level.
4. Explore, through case studies, the relationship between economic performance and social outcomes, rural/town/urban interdependencies and the lived experience of policy implementation and service delivery.
5. Develop thematic analyses of all data to create a typology which is broad and yet meaningful enough to incorporate any rural/small town in Scotland based on their socio-economic outcomes and regional interdependencies with associated prioritised areas for policy and service delivery intervention.
6. Make recommendations for the most needed interventions across different policy and service domains, in different types of rural communities.

Major Activities (M = Milestone)

Objective 1: Mapping the policy and service delivery landscape

- 1.1 Carry out a desk-based review of place-based and 'spatially blind' policies, with particular reference to Scotland, to understand policy coherence and

implementation.

- 1.2 Create a summary matrix of the policy landscape in Scotland, including rural and small town policies, and other policies of relevance such as city regions [M2] [M1 is the creation of the RD's dedicated web area].
- 1.3 Carry out a desk-based review and mapping of the service delivery landscape in rural and small town Scotland, and of the guiding principles for the service delivery framework across Scotland [M3].

Objective 2: Understanding small town/rural trajectories and linkages

- 2.1 Carry out a desk-based review of existing definitions and classifications of rural and small towns in the European and international contexts, and comparison with the approach used by the SG [M4]. This will inform the modelling in O5.1.
- 2.2 Carry out a desk-based review of literature and main contemporary theories on the interdependencies and co-dependencies between urban/small town/rural areas (e.g. core-periphery models, agglomeration economies), from the perspective of rural areas. The review will build on and extend existing evidence on the interdependencies and co-dependencies between small towns and surrounding rural areas in Scotland (e.g. 2005 report by SAC et al.) [M5]. This will inform the modelling in O5.1.
- 2.3 Carry out a desk-based review of existing typologies of rural and small towns in the Scottish, UK and European context. The review will highlight the limitations and advantages of existing typologies in terms of the methodologies used and impact on policy making. It will consider recent/ongoing initiatives such as the Understanding Scottish Places toolkit by the Carnegie UK Trust and partners, to be launched in April 2015 (with further work planned) and 2008 work by Scottish Enterprise on city regions and rural areas [M6]. The review will inform the design of the typology to be developed in O5.3.

Objective 3: Identifying suitable measures of socio-economic outcomes and mapping geographical disparities

- 3.1 Identify different data sources and indices of economic performance and social outcomes in addition to those used by the Socio-Economic Performance (SEP) Index (cWP8.1), and of potential/actual data sources (e.g. travel to work areas, retail market areas and housing market areas) used to map rural-town-urban interdependencies.
- 3.2 Assess their suitability/fit as measures for rural/small town Scotland based on the work carried out under O2.
- 3.3 Map the disparities in economic performance and social outcomes across rural and small town Scotland, and present at community level, with a particular focus on small towns [M7]. This will build on work under cWP8.1 on SEP Index (Thomson et al., 2014; Copus and Hopkins, 2015) and rural-urban earnings inequalities in Scotland (Melo, 2015).

Objective 4: Case study work

- 4.1 Using the groupings of rural areas and small towns developed in O3, a sampling framework will be created from which up to 10 case studies will be selected. These will reflect different types of rural areas (e.g. interdependencies with town/urban areas, coastal) and a range of socio-economic outcomes [M8].
- 4.2 Case study work will question, through participative and in-depth techniques with a range of local community actors, the three key elements of this RD: the relationship and interdependencies between rural/small town/urban places; the explanatory factors behind high/low socioeconomic outcomes; the lived experience of local policy implementation and service delivery [M9].

Objective 5: Thematic and statistical analysis

- 5.1 Development of econometric models to explore how socio-economic outcomes in rural areas are affected by the increased degree of spatial integration of urban and rural areas (i.e. city regions). This will include analysis of the different types of interdependencies they have with their surrounding rural hinterlands/nearest urban centres and more distant rural areas or urban centres (this will link with typology undertaken in cWP8.3) [M10].
- 5.2 Thematic analysis of the effects of specific national and local level policies as identified in O1 and explored in O4 [M11].
- 5.3 Analysis of all data identified and analysed in O3 to create a typology which can incorporate any rural/small town in Scotland based on their socioeconomic outcomes and regional interdependencies with associated prioritised areas for policy and service delivery intervention [M12].

Objective 6: Reporting

- 6.1 Synthesise the research findings thematically and the research outputs created throughout the programme in O1-O5 to assess how bottom-up place-based policies can contribute to achieving economic and social outcomes [M13]. Inputs from RD3.4.4 will also be considered here with a focus on the impact of community capacity on place.
- 6.2 Make policy recommendations for intervention(s) across different policy and service domains, in different types of rural communities [M14]. Costs and benefits of the different interventions will be assessed using a range of sources including comparative international and national literature and data (e.g. from the PSSRU's *Unit Costs of Health and Social Care*) on the cost savings of a preventative and bottom-up approach to public service delivery.

Key deliverables

Table 1: Summary of key deliverables

Objective	Deliverable	Description	Date
1.1	D1	Review report, Blog post	Yr1Q3
1.2	D2	Matrix, Blog post	Yr1Q3
1.3	D3	Review report, Blog post	Yr1Q4
2.1	D4	Conference presentation, Journal article, Blog	Yr2Q2
2.2	D5	Review report, Blog post	Yr2Q2
2.3	D6	Review report, Blog post	Yr2Q4
3.1, 3.2, 3.3	D7a/b	Research report, Blog post	Yr3Q1
4.1	D8	Research report, Blog post	Yr2Q3
4.2	D9	Research briefings, Blog post	Yr4Q3
4.2	D10	Conference presentation, Journal article, Blog	Yr4Q4
5.1	D11	Conference presentation, Journal article, Blog	Yr3Q3
5.2	D12	Thematic review report, Blog post	Yr4Q2
5.3	D13	Conference presentation, Journal article, Blog	Yr4Q1
6.1, 6.2	D14	Research report, Journal article, Blog post	Yr5Q3
6.2, 6.2	D15	Policy briefing, Blog post	Yr5Q3

References

- Copus, A. and Hopkins, J. (2015) Mapping Rural Socio-Economic Performance (SEP), Report for the Rural Communities Team, Food Drink and Rural Communities Division, The Scottish Government. Funded by PAWSE J101915 - Support Delivery of LEADER).
- Melo, P.C. (2015) People, Places and Earnings in Scotland. *Regional Studies* (in press, DOI 10.1080/00.43404.2015.1100286).

Personal Social Services Research Unit, *Unit Costs of Health and Social Care* (2014), University of Kent and London School of Economics. Available at: <http://www.pssru.ac.uk/project-pages/unit-costs/2014/index.php>

SAC/SRUC (2012/2014) *Rural Scotland in Focus Reports*, SAC/SRUC Rural Policy Centre, Edinburgh.

Scottish Agricultural College, The Arkleton Institute, University of Gloucestershire (2005) *Economic linkages between small towns and surrounding rural areas in Scotland*. Available at: <http://www.gov.scot/Resource/Doc/37428/0009554.pdf> (accessed on 23-02-2015).

Scottish Enterprise (2008) *Understanding the role of places in city regions and urban Scotland*, Scottish Enterprise, Glasgow.

Thomson, K., Vellinga, N., Slee, B., and Ibiyemia, A. (2014) Mapping Socio-Economic Performance in Rural Scotland, *Scottish Geographical Journal*, Vol. 130 (1): 1-21.

Technical approach

This RD consists of a combination of desk-based and field-based work, and draws on both quantitative and qualitative approaches, including:

- *Policy analysis, impact and process evaluation* in activities 1.1-1.2 of O1 and 6.1-6.2 of O6.
- *Literature reviews* in activities 1.1 and 1.3 of O1, and activities 2.1-2.3 of O2.
- *Spatial analysis and GIS-based techniques* in activities 3.1-3.3 of O3. This will include secondary data analysis and mapping.
- *Statistical modelling*. Parametric techniques, such as panel data econometric modelling, and non-parametric techniques, such as principal component and clustering analysis, will be developed in activities 5.1 and 5.3 of O5.
- *Case study work*, including in-depth interviews and participatory workshops with key local stakeholders and community members, in activities 4.1-4.2 of O4.

Planned fieldwork locations

The final decision on fieldwork locations will be taken in consultation with the SG and other stakeholders (e.g. Scotland's Towns Partnership, Carnegie UK Trust). It is anticipated that the sampling framework will be based on the selection of up to 5 'matched pairs' of well performing and less well performing locations using the remote/accessible rural/small town categories from the SG 6-fold classification, plus an additional category for coastal locations). However, a number of factors will inform the decision, including: a framework for WP3.4 which will ensure efficiency and coherence in the case study work across all four RDs and will link to case study work in cWP 8.2; ongoing discussion with staff in other related WPs (e.g. WP 2.4), again to ensure coherence; evolving policy and research priorities (e.g. coastal locations); ongoing research work, such as the Carnegie UK Trust led work on Understanding Scottish Places and the ESRC/SG-funded What Works Scotland project; and developments in practice, e.g. the activities of Scotland's Towns Partnership. The selection process will be written up in a short paper for clarity (see O4.1, D8) and to ensure that accurate conclusions can be drawn regarding the transferability of case study findings to other parts of Scotland (and beyond), and the overarching strategic messages for policy and practice.

The in-depth work in the locations will focus on the three key elements of this RD: (i) the relationship and interdependencies between rural/town/urban places; (ii) the explanatory factors behind high/low socio-economic outcomes; and (iii) the lived experience of local policy implementation and service delivery. The work will have a number of stages:

1. A desk-based review of local/regional strategies, policy documents (e.g. Local Economic Development Strategies, Local Plans) and the local/regional institutional

infrastructure (e.g. Third Sector Interface, Community Development Trusts, Community Planning Partnerships). This will provide background information on the rural-town-urban places within the community and the factors that are regarded as important in generating low/high socio-economic outcomes.

2. Interviews with local decision-makers to explore their responses to all three elements (e.g. representatives of local authorities, NHS, CPPs, enterprise companies, and the third sector). This stage of the work will also be critical to ensure buy-in from these key actors, who will also form a local stakeholder network through which information generated in the project will be exchanged and discussed (see KE section for more information).
3. Ethnographic data collection with individual community members to explore responses to all three key elements, but particularly focusing on their lived experiences of local/regional policy and service delivery, including its coherence, implementation and impact. These questions could be phrased for data collection purposes as, for example, how does 'good' delivery look? what are 'good' outcomes? This stage of the work is likely to involve a variety of data collection techniques depending on the research questions, including visual data collection, such as photography, attending community events, textual analysis of the content of local community noticeboards and newspapers/newsletters, etc.
4. Face-to-face work with communities to discuss emerging findings and cross-check policy recommendations, typology, and other 'tools' emerging from the research. This will involve deliberative workshops focusing on a particular service, or on specific groups (e.g. pre-retired, those in 'older old age', children, young adults, long-term residents and in-migrants, those reliant on welfare payments). Mirroring the approach in RD3.4.1 to ensure complementarity, the classification of 'services of general interest' will be used to select services on which to focus, which is likely to include education, health and social care, and transport.

Ethical considerations. These will include obtaining permission from the relevant MRP ethics committees, particularly if qualitative fieldwork involves groups such as children/young people.

Detailed work plan for first two years

Seven main activities and deliverables will be developed in the first two years, and relate to O1.1-O1.3, O2.1-O2.3 and O4.1. A detailed description is provided below; with a brief description provided for the remaining activities in Objectives 3-6.

Objective 1: Mapping the policy and service delivery landscape

First, a state of the art review of the relative merits of place-based and 'spatially blind' policies will be undertaken to understand policy coherence and implementation. The review will consider the UK, Europe and other OECD countries, but with particular reference to Scotland [D1]. Second, a summary matrix will be created to describe the policy landscape in Scotland [D2, M2]. Third, a review of the service delivery landscape in rural and small town Scotland will be undertaken. This will include details on guiding principles such as prevention, addressing inequalities and improving social justice. The changing public sector budget situation will be reviewed, as will key social changes, such as demographic ageing and changes to the welfare system. This Scotland-wide review will feed into O4 in RD3.4.1 which will focus specifically on service delivery in remote rural areas [D3, M3].

Objective 2: Understanding small town/rural trajectories and linkages

First, a review of definitions, classifications and measurement approaches to rural areas and small towns across Europe and other OECD countries will be undertaken. Comparisons will be drawn, and limitations and advantages discussed, with the approaches used in Scotland [D4, M4]. Second, a review of literature on key theories

(e.g. the interdependencies between rural, town and urban areas, core-periphery models, and agglomeration economies) from a rural perspective will be undertaken [D5, M5]. Third, a review of existing typologies of towns and rural areas in Scottish, UK and European contexts will be carried out [D6, M6]. This is critical to the development of a new typology in O5.

Objective 3: Identifying suitable measures of socio-economic outcomes and mapping geographical disparities

The main tasks are to identify and map measures of economic performance and social outcomes and of rural-town-urban interdependencies. This will build on work in cWP8.1 and cWP8.3 and undertaken by others, including the Carnegie UK Trust, and will draw conclusions on 'best practice' for Scotland. Several secondary data sources will be explored (e.g. Census, Scottish Neighbourhood Statistics, National Records of Scotland, Scottish Household Survey, Scottish Longitudinal Study). The analysis will date back to 1991, to mirror the approach taken in RD3.4.1.

Objective 4: Case study work

The main task in the first two years is to develop the framework to identify and select case study locations [D8, M8]. This will draw heavily on, and be informed by, the desk-based and quantitative work in earlier Objectives, and case study selection within other RDs and WPs, case study work in the cSRP, and work undertaken by SRUC and Hutton in other related projects, where appropriate (e.g. LEADER evaluations and Local Development Strategy preparation work in the Cairngorms, Ayrshire and Aberdeenshire). Matched pairs of case studies will be selected (using the 6-fold rural-urban classification) to reflect different 'levels' of economic performance and social outcomes, based on the spatial analysis in O3. We will also purposively sample to ensure good coverage of other factors of interest that emerge from the reviews in O2 (e.g. variations between remote towns and those within immediate reach of an urban area).

Objective 5: Thematic and statistical analysis

This work will apply a range of statistical techniques (e.g. econometric modelling, principal component and clustering analysis), to the data collected and described in O3. The theoretical context for the empirical analyses is provided in O2. The novel feature of this work is its longitudinal nature, which allows investigation of medium and long term changes in the trajectories of different rural areas and small towns. It will also carry out a desk-based thematic review of the effects of specific national and local level policies, thereby recognising past/existing policy interventions in rural areas and small towns (this would link with work in RD3.4.4 focusing on capturing the 'success' of interventions).

Objective 6: Reporting

The final stage is the Reporting phase which will be primarily desk-based, synthesising the quantitative and qualitative findings in a thematic way, and bringing together the research outputs from the duration of the SRP. The results will be brought together to answer RD3.4.2's key question and assess how bottom-up place-based policies can contribute to achieving positive economic and social outcomes in Scotland's rural areas and small towns. The key part of this report will be clearly explaining the recommendations for the most needed intervention(s) across different policy and service domains, in different types of rural communities, in order to maximise their potential. It will also provide descriptions of 'best practice' service delivery models in different places (e.g. healthcare).

Interdisciplinary and multidisciplinary collaborations

The research team is *multidisciplinary*, involving geographers (Atterton, Copus,

Currie, Hopkins, Markantoni), political scientists (Brodie), and economists (Melo, Roberts). Through the qualitative, in-depth fieldwork with the case study communities described above, the approach will be *transdisciplinary*. It will ensure that communities are involved in the project in terms of ‘providing’ data, and that they have a major role working alongside the research team to define the shape of the research, including the key questions, approach to be taken, KE approaches, etc.

Expertise

The research team has a strong and growing reputation in rural and regional development research, including in relation to inequalities in economic performance and resilience across different rural regions, changing aspects of service delivery and role of different actors and institutions, and the current and future role of towns. Researchers have undertaken work for the Scottish Government (both in terms of the CSR and in other projects), a number of LEADER groups (e.g. Dumfries and Galloway, Ayrshire, Aberdeenshire and the Cairngorms) and local authorities (e.g. Ayrshire), and are also very active at EU level, participating in several 6th/7th Framework projects (e.g. EDORA [Copus], DERREG [Copus], TIPSE [Copus, Melo], CAPIRE [Roberts], TERA [Roberts]) and proposals (e.g. SINBAD [Atterton], focusing on social innovation (submitted to Stage 1 in February 2015).

Researchers in this RD (including Roberts, Copus, Melo, Atterton) have done work outwith the CSR (and previous SRP) on towns and their interdependencies and this will be drawn on for RD 3.4.2. Examples include:

- Roberts’ work on the economic linkages between small towns and rural areas produced for the Scottish Government (see the report here: <http://www.gov.scot/Resource/Doc/37428/0009554.pdf>).
- Copus’ work in cWP8.1 and cWP8.3 on Socio-Economic Performance (SEP) index for rural Scotland, supported partly by PAWSA, for the 2014-20 LEADER LAG areas.
- Melo’s work in cWP8.1 on the role of ‘people’ and ‘place’ on earnings inequalities in Scotland with particular reference to the 6-fold urban-rural classification.
- Atterton’s work on the Vulnerability index (see the [Rural Scotland in Focus 2012 report](#)), and on [City Regions and Rural Areas in the North East of England](#).

The team has wide-ranging expertise across a variety of research methods, particularly content analysis of policy documents (Atterton, Brodie, Copus, Currie), economic modelling (Melo, Roberts), and case study work using a mix of quantitative and qualitative methods (Atterton, Brodie, Markantoni, Currie, Hopkins, Steiner), including participatory approaches (Brodie).

Key linkages, interdisciplinarity & collaboration

This RD links particularly closely with RD3.4.1, in the following ways: (i) the review of place-based and spatially blind policies and other approaches to rural development (O1) will inform O5 in RD3.4.1; (ii) the review of the service delivery landscape in rural and small town Scotland (O1) will feed into O4 in RD3.4.1, where the focus is on remote/sparse rural areas; and (iii) both RDs will propose evidence-based policy recommendations towards the end of the SRP and will ensure that these are complementary. The work in RD3.4.2 also links strongly with RD3.4.4. Steiner (SRUC) and Currie (Hutton) will act as the key liaison points between these two RDs. The work will contribute to CAMERAS Evidence Plan, particularly topic 1 on “Improved understanding of the spatial distribution of rural disadvantage (socio-

economic and by protected equalities characteristics)". In addition, linkages to WP2.4 Rural Industries and WP3.3 Food Security will be made through the spatial analysis in O3, which will also consider the relationship between socio-economic outcomes and spatial differences in industrial profiles of rural and small town areas, paying particular attention to the role of key industries as considered in WP2.4 and WP3.3 (e.g. farming and forestry, food and drink, energy, nature-based tourism). Atterton and Markantoni (SRUC) will help to develop strong complementarities as both are working here and in WP2.4.

Added Scientific Value

- Develop a comprehensive longitudinal database of indicators of economic and social outcomes for rural and small towns in Scotland (also drawing on data generated in other WPs, e.g. 2.4), which will be made available and accessible to a wider community of researchers and practitioners through the RD's dedicated website.
- Adopt a novel approach including quantitative and qualitative analysis of characteristics and inter-relationships, combined with detailed policy/service delivery mapping, to understand why some places develop 'better' than others and how policy and service delivery can better support positive and appropriate local development across all places.
- Discussion with Carnegie and Scotland's Towns Partnership colleagues has revealed that the work will generate particular added value in terms of its robust messages for a range of policy domains, including community empowerment, equalities and social justice, and the development and performance of towns.
- Links will be made with ongoing/new research projects (e.g. Horizon 2020) to maximise knowledge generation and exchange across all related work.
- Working closely with the Understanding Scottish Places team will ensure RD3.4.2 work is complementary and contributes towards a comprehensive knowledge base on economic performance and social outcomes across rural and small town Scotland.

KE, Audiences and Impact

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

KE: The team will participate in a series of regular events including the Scottish Rural Parliament and Scotland's Towns Conference (and other events organised by Scotland's Towns Partnership). In addition, the team will organise an annual workshop/seminar for key national and regional stakeholders including practitioners working to support rural Scotland and small towns (e.g. local authorities, Community Planning Partners, CAMERAS partners, Scottish Towns Partnership) and individuals including business owners and local entrepreneurs.

Audience: Target audiences include policy-makers (at local and national level in Scotland and beyond); researchers (in Scotland and beyond); practitioners working to support rural Scotland at regional and local levels (i.e. those involved in service delivery, the delivery of funding streams, etc. such as local authorities and other Community Planning Partners); and individuals (including business owners) and community groups across Scotland's rural areas and small towns.

Impact & pathways to impact: The work will inform and improve policies seeking to address instances where socio-economic performance is lagging across Scotland's

rural areas and small towns. We will produce an annual 'impact report' for the RD which will consider the key audiences and provide a detailed account of how our work has impacted on them, and ways in which this impact could be improved. We will ensure impacts reach intended targets in the following ways:

Policy-makers (at local and national level in Scotland and beyond)

Quarterly progress meetings (beginning with an inception meeting in April 2016) with SG RESAS and Policy staff (e.g. in Rural Communities, Regeneration, EU Rural Development, Inequalities and Social Inclusion, etc.) to discuss links with the CSRP and other externally-funded research, update on progress with the research, discuss emerging findings, review relevant policy developments, etc.. RD3.4.2 will have a dedicated web area, appropriately named (M1). This will serve as the 'central hub' for all project documentation and information. Regular blog posts will be written and published on the project website to provide regular 'readable' updates on progress with the research (see Table 1). Each year of the SRP we will organise a workshop/seminar for key national and regional stakeholders (as identified earlier) to update them on progress with the project; this will provide a key opportunity for input on how the work is developing. Regular review papers, briefings, research reports, etc. will be produced throughout the SRP, all written in accessible language and made available on the project website. Each output will have at least a 'soft launch' i.e. key stakeholders (in Scotland, UK, EU, OECD, etc.) will be emailed a project update when a new output is available.

Researchers (in Scotland and beyond)

The team will produce five peer-reviewed academic journal articles, and attend several relevant national/international conferences to present papers on the research undertaken (details to be confirmed). Relevant researchers based outwith the core research team will be invited to attend the annual stakeholders update meeting (e.g. researchers from What Works Scotland, Carnegie UK Trust). This will ensure synergies with other relevant research are maximised.

Practitioners, individuals and community groups

Knowledge exchange will be geographically focused in the case study locations, although outputs will be made available across Scotland (and beyond). We will set up a local stakeholder group in each case study location, which will meet on a six monthly basis to discuss project progress, provide local contextual information, feedback on outputs, etc. Securing early buy-in from this group will be important and this group will be critical to KE throughout the project, as they will be able to draw on their own networks to widen information exchange. We also plan to work with a local partner (to be decided) in each case study area to use an existing local web portal – e.g. Community Development Trust, LEADER group or third sector interface – to be the conduit 'local' KE. This will help to ensure value-for-money and maximise traffic to the RD website by raising the profile of the project.

RESEARCH DELIVERABLE NUMBER: 3.4.2

Work planning and timetable for Year 1: Please include major milestones, (key research activities, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, SGM = Scottish Government Meeting, SHW = Stakeholder Workshop, KE=KE event, R=Reporting to RESAS

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Establish/maintain dedicated web area	M1											
Objective 1.1: 'State of the art' review of place based and spatially blind policies									D1			
Objective 1.2: Summary matrix of the policy landscape in Scotland									D2 M2			
Objective 1.3: Review and mapping of service delivery landscape in rural and small town Scotland												D3 M3
KE Events: annual workshop/seminar for key national and regional stakeholders (Year 1)												KE1
KE Events: Scottish Rural Parliament (Year 1)								KE2				
KE Events: Scotland's Towns Conference (Year 1)								KE3				

Stakeholder meetings with RESAS	SGM1			SGM2			SGM3			SGM4		
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.4.2

Work planning and timetable for Year 2: Please include major milestones, (key research activities, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, SGM = Scottish Government Meeting, SHW = Stakeholder Workshop, KE=KE event, R=Reporting to RESAS

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Establish/maintain dedicated web area												
Objective 2.1: Review of national and international definitions and measurement approaches to rural/small towns						D4 M4						
Objective 2.2: Review of literature on the inter-dependencies between rural/town/urban						D5 M5						
Objective 2.3: Review of existing typologies of rural areas and small towns in Scotland/UK/EU												D6 M6
Objective 3.1,3.2 and 3.3: Report summarising suitable data sources to measure economic and social outcomes												
Objective 4.1: Research report describing sampling framework for case study selection									M8			

KE Events: annual workshop/seminar for key national and regional stakeholders (Year 2)												KE4
KE Events: Scottish Rural Parliament (Year 2)								KE5				
KE Events: Scotland's Towns Conference (Year 2)								KE6				
Stakeholder meetings with RESAS	SGM 5			SGM6			SGM7			SGM8		
Annual Report (Year 2)												R2

Name of RD: 3.4.3 Rural Landscapes and Community wellbeing

Research aim and key drivers

Aim: This research deliverable (RD) aims to improve understanding of issues around (re)-engagement of people with Scotland's rural landscapes and natural environment. Specifically it seeks to: (i) examine and evaluate pathways to community wellbeing through use, and management of, natural landscapes and resources; and (ii) consider implications of landscape changes for wellbeing and future land use / management policy.

Key Question: What are the links between environmental and landscape qualities, use and enjoyment of the landscape and the wellbeing of visitors and residents?

Key Drivers:

Evidence: An international literature exists on wellbeing benefits of engagement with natural environments:

- Investigation has primarily focused on urban settings with less known about mechanisms linking rural landscapes and wellbeing.
- Wellbeing benefits largely depend upon engagement with the landscape. Little is known about: (i) inequalities in access across the Scottish population, (ii) what barriers exist to use, and (iii) how objective landscape qualities and related subjective qualities (e.g. perceptions of wildness) influence engagement.

Policy: EU and Scottish Government (SG) policy promote landscape and wellbeing:

- EU: The EU Landscape Convention supports a people-centered focus on landscape protection, management and planning, viewing landscapes as human environments that influence quality of life. It aims to deliver high quality environments for people and promote re-connection of people with place.
- Scotland: Use of Scotland's outdoors is a National Indicator to track progress towards strategic objectives of creating a wealthier, fairer, healthier, safer, stronger, smarter, and greener Scotland. Within the Land Use Strategy a key objective is for communities (rural and urban) to be better connected to and more people enjoying the land. Use of the outdoors also has relevance to delivery of the Physical Activity Implementation Plan and National Walking Strategy.

Other drivers include future changes in ownership or landscape/land use changes to address loss of biodiversity (e.g. through ecological restoration) and promote the mitigation of and adaptation to climate change (e.g. woodland expansion). Such changes could alter perceptions of and engagement with local landscapes.

The strategically focused research within this RD will generate important scientific and policy-relevant insight for the above drivers at multiple scales. By building on previous and current RESAS Programme (cSRP) research, it will advance understanding of the patterns and mechanisms underpinning engagement with Scotland's landscapes, which will also contribute needed evidence to the international literature on the relationship between rural landscapes and wellbeing. Policies that promote the re-connection of people and landscape as well as those that consider landscape change will benefit through identification of how engagement with the outdoors differs across population groups, understanding what barriers to engagement people face, and how objective and subjective landscape qualities influence engagement.

Consultation: SG research and policy staff (Liz Hawkins); Central Scotland Green Network (CSGN; Stephen Hughes); Paths for All (Francis Bain); Cairngorms National Park Authority (CNPA; David Clyne); Scottish Natural Heritage (Bridget Finton; Richard Davison); Scottish Waterways Trust (Katie O'Donnell; Cairngorms Local Outdoor Access Forum. Outreach to: Scottish Environmental Protection Agency; Botanical Gardens.

Summary of the proposal: Scotland's landscapes represent a wealth of natural capital for human wellbeing. Social values associated with these landscapes include goods relating to e.g. recreation/tourism, health/wellbeing, belongingness, education/environmental literacy, place- and cultural- identity, cultural heritage, inspiration and spiritual fulfilment. Such landscape functions have an important role in underpinning community wellbeing. Changes in landscapes (intended or unintended) through use, land use/management, etc can have implications for communities and the natural environment, thereby affecting community wellbeing. A foundation for this research is a 'taken as given' perspective that increased use of and engagement with the natural environment can promote wellbeing. Thus the emphasis here is on investigating use patterns, motivations for and barriers to access alongside characteristics of the 'environmental setting' - e.g. landscape; waterscape - that might influence use and how land use change might affect these patterns. To further understand these linkages and implications, this RD will undertake a number of activities to address three interconnected objectives:

Objective 1 – Underpinning Framework for re-Connection

- Develop a conceptual framework for understanding access to, engagement with and perceptions of landscapes in order to situate findings, maximize transferability, and provide a focal point for knowledge exchange.
- Use this framework to structure delivery of evidence to support future policy making and practice aiming to re-engage communities with the land in light of landscape change and wellbeing considerations.

Objective 2 – Opportunity Pathways for (re)-Engagement with the Land:

- Assess access to and use of a variety of landscapes by different population groups (e.g. socio-economic) within Scotland.
- Enhance understanding of barriers to and motivations for engaging with natural environments.

Objective 3 – Environmental Qualities, Landscape Change and Wellbeing

- Understand relationships between objectively and subjectively assessed aspects and experiences of rural landscapes.

Research in this RD will be coordinated with elements of work within WPs 1.3 and 1.4. Specific linkages are noted in descriptions of major activities.

Major activities to be undertaken for entire funding period.

Objective 1 (O1) – Underpinning Framework for re-Connection

O1 (O1.1) - Develop a framework of access capabilities. This conceptual framework will bring together understanding of barriers, motivations and enablers to use of the landscape by reframing access and engagement as a four-part set of capabilities

incorporating physical (e.g. route availability, mobility), mental (e.g. knowing where to go), sociocultural (e.g. companions, status) and emotional (e.g. feeling safe; emotional connections to places). Development of the framework will occur in conjunction with and be informed by activities in Yrs 1-2 and will underpin empirical work in activity 2.2 (Yrs 3-5). It will build on research undertaken in the cSRP (Themes 1 and 8), findings from RD1.4.1 on cultural ecosystem services (CES) and will purposely examine complementarity with the framework for ecosystem assessment to be developed in RD1.3.2. [Yrs 1-5]

O1 (O1.2) - Stakeholder engagement and knowledge exchange (KE). This will provide mechanisms for engagement and connection with a wide range of stakeholders (policy, managers, practitioners, community, scientific) at multiple scales (national, local) to inform the framework, and research, as well through which to share findings throughout the five years. [Yrs 1-5]

Objective 2 (O2) – Opportunity Pathways for (re)-Engagement with the Land

O2 (O2.1) - Use patterns and equality of access. Secondary analysis of existing data will seek to identify broad patterns of use at population-scale and to develop understandings of barriers to inclusive access at smaller scales (e.g. region, community). [Yrs 1-2]

O2 (O2.2) - Motivations and barriers to use. This seeks to ‘unpack’ the nuances underlying (non-)use of rural landscapes to inform deeper understanding of mechanisms or pathways that might facilitate increased access to and engagement with nature. A case study approach will examine barriers, motivations and enablers to landscape access/use. The ‘Access Capabilities Framework’ (O1.1) will be used to, where possible, identify the interplay of different capabilities with key established axes of exclusion/protected characteristics (e.g. ethnicity, gender) through integration with O2.1. Coordination with RD1.4.1’s research using visual and participatory methods to map and understand cultural ecosystem services will incorporate innovative visual methodology for exploring matters of motivation for and barriers to use. Study sites for fieldwork will be identified in collaboration with local stakeholders and RDs 1.3.2 and 1.4.3. [Yrs 3-5]

Objective 3 (O3) – Environmental Qualities, Landscape Change and Wellbeing

O3 (O3.1) - Landscape qualities, nature engagement and access. This will examine linkages among objective landscape qualities (including change), access to and engagement with rural landscapes, and subjective experiences that contribute to wellbeing. One strand of work could explore these relationships through combining appropriately scaled use and access data with landscape quality data (drawn from existing and new datasets). A second strand could undertake a focused case study approach to glean an enriched understanding of the linkages between objective and subjective landscape qualities and wellbeing. O3.1 will build on and be informed by work conducted in Yrs 1-2 within this RD (e.g. O2.1) and findings from other RDs (1.3.1, 1.4.1, 1.4.3). [Yrs 3-5]

Research already undertaken in this area, track record of researchers: The proposed activities build on cSRP, on the RESAS funded GreenHealth project and

on findings about inequalities in access to rural amenities (e.g. research for CAMERAS partners). Findings from relevant externally funded research on outdoor recreation, engagement with natural environments, the nature-wellbeing relationship (including the influence of objective qualities), shared values, and behaviour change (Scottish, UK, EU and international contexts as well as a variety of different natural environment/landscape settings) will also be integrated.

The research will draw on the team's previous work in: (i) Understanding the contribution of natural environments to human wellbeing (*all*); (ii) Outdoor recreation and access across the urban-rural gradient including evaluation of interventions to promote access and physical activity (*all*); (iii) Motivations and barriers to engagement with the outdoors and greenspace, and the role of individual, social and cultural factors in influencing engagement and participation (*all*); (iv) Mapping and measuring relationships between environmental qualities (e.g. biodiversity), user perceptions, behaviour, and wellbeing outcomes (*Irvine, Gilchrist*); (v) The development of frameworks for understanding and incorporating shared values and cultural ecosystem services into decision-making (*Irvine*); (vi) Policy and practice to promote behaviour change at the individual and community levels (*Irvine, Gilchrist*); (vii) Use and development of innovative methodologies and research design (*all*).

Table 1: Summary of key deliverables (D) & milestones (MS) Year 1-2

[Y = Year; Q = quarter within the year; KE = Knowledge Exchange]

Activity	M or D	Description	Date
O1.1a	M1	Develop framework review protocol	Y1Q2
O1.2b	M2/KE1	Annual stakeholder meeting	Y1Q2
O2.1a	M3/M8	Manuscript submissions from cSRP	Y1Q2/Y1Q4
O2.2a	M4	Initial list of case study sites	Y1Q3
O1.1	M5	Review complete & outline synthesis	Y1Q4
O2.2b	M6	Initial study design outline	Y1Q4
O3.1a	M7	List of potential objective data sources	Y1Q4
O2.1d	M9	Preliminary data analysis complete	Y1Q4
O1.2c	D1/D2	Review and annual reporting	Y1Q2/Y1Q4
O1.1e	M10	Draft working paper/report	Y2Q1
O2.1e	D3/D8	Journal articles from year 1 submission	Y2Q1/Y2Q4
O1.2e	KE2	Annual stakeholder meeting	Y2Q2
O1.2f	D4/D7	Review and annual reporting	Y2Q2/Y2Q4
O1.1g	M11/D6	Refine framework; Research note	Y2Q3/Y2Q4
O1.1f	D5	Conference presentation	Y2Q3
O2.1f	M12	Refined analysis	Y2Q2
O2.2.c	M13	Revise and finalise case study sites	Y2Q2
O2.2d	M14	Final design; ethics; start recruiting	Y2Q3
O3.1c	M15	Refine objective data for use	Y2Q4
O2.1h	M16	Draft working paper/report	Y2Q4
Outline Key Deliverables & KE for Years 3-5			
1.2	KE3/KE4	Annual Stakeholder & KE Meeting	Y3-4Q2
1.2	D	Review and annual report	Y3-5Q2,Q4
2.1	D	Research report(s) or note(s)	Y3Q1
2.1	D	Conference presentation	Y3Q2
1.1	D	Journal article	Y4Q1

3.1	D	Conference presentation	Y4Q2
2.2	D	Research report(s) or note(s)	Y4Q3
3.1	D	Research report(s) or note(s)	Y5Q3
1.2	KE5	Final KE event	Y5Q3

Technical approach: A pragmatic, multi-level and mixed method approach is proposed for understanding and evaluating pathways to wellbeing from landscapes. It builds on previous case-study based research to gain further insights into the pathways by which landscapes can contribute to community wellbeing through: (a) development and application of a capabilities-based framework for understanding barriers and enablers to local landscape engagement; (b) capitalising on existing nationally-representative data on use of the outdoors; and (c) drawing together evidence on environment-behaviour-wellbeing links from case studies spanning geographies (accessible rural to remote rural areas) and various forms of outdoor activity (e.g. walking, cycling). This approach will maximise opportunities for interdisciplinary collaborations with natural scientists, visualisation and spatial modelling experts through integration of the proposed research with other parts of the SRP including GIS mapping of cultural ecosystem services (RD1.4.1), in evidencing the impact of woodland creation and restoration on ecosystem services (RD1.3.2) and land use change in peri-urban areas (RD1.4.3). Further details are provided for each activity below.

Objective 1 – Underpinning Framework for re-Connection

O1.1 [Years 1-2] - Develop a framework of access capabilities. A conceptual framework of capabilities, incorporating physical, mental, socio-cultural and emotional factors influencing recreational access, will be developed through a desk-based review. An appropriate review protocol (e.g. rapid evidence assessment) will be identified to draw together theoretical frameworks, empirical research and grey literature. Relevant findings from previous and cSRP will be sought for incorporation through engagement with key researchers (e.g. Brown, Dinnie from cSRP Theme 8) and stakeholders (e.g. CNPA). The framework will be informed by research conducted concurrently in O2.1. RD activities will utilise and extend the framework.

O1.2 [Years 1-5] - Stakeholder engagement and knowledge exchange. This will be ongoing through various channels, e.g.: a) Formal stakeholder engagement conducted at WP level; b) Informal engagement of local stakeholders in relation to on-the-ground case studies; c) Sharing of written outputs (e.g. short reports, research notes) with RESAS and relevant agencies (e.g. SNH). An initial scoping meeting will be held in year 1; subsequent stakeholder and knowledge exchange meetings/workshops will be held annually for continued dialogue and engagement with respect to findings and forward planning.

Objective 2 (O2) – Opportunity Pathways for (re)-Engagement with the Land

O2.1 [Years 1-2] - Use patterns and equality of access. This will investigate patterns of access and use of the outdoors through analysis of existing datasets, focusing on inequalities in access in relation to particular population groups (e.g. ethnicity). Findings will inform activities in subsequent years.

To understand population-scale differences in engagement with the outdoors across different groups we will conduct secondary analyses of existing data gathered through large-scale surveys yielding samples representative of the Scottish population. For example, the Scottish Household Survey (SHS) has, since 2012, gathered data on visit frequency to the outdoors to utilise in monitoring performance against the National Indicator 'Increase people's use of Scotland's outdoors' in the National Performance Framework, and to track progress on delivery of the Land Use Strategy (indicator 9 – Visits to the Outdoors). These data provide opportunities to investigate potential use inequalities amongst particular population groups with protected characteristics (e.g. according to gender, ethnicity, religion, sexuality), across income and education levels, and urban-rural gradients (per SG's urban-rural classification). Other potential influencing factors (e.g. household characteristics, neighbourhood satisfaction, car ownership) will be explored. Statistical models (e.g. binary logit) will be used to understand the ways in which such individual differences are associated with outdoor use at the population level which may identify key target groups to inform future policy interventions. We will conduct statistical analysis in collaboration with BioSS (Underpinning Capacity, Function 7).

Availability of existing case study and/or qualitative datasets on outdoor access and inclusion will be sought from the cSRP (e.g. Theme 8) and external organisations (e.g. CSGNT) in order to more closely explore barriers to outdoor access faced by particular groups. Appropriate qualitative analysis techniques (e.g. thematic) will be utilised to characterise and contextualise barriers to inclusive access.

O2.2 [Years 3-5] - Motivations and barriers to use. This aims to gain a deeper understanding of the issues surrounding (non-)use of a variety of different landscapes (and the concomitant lack of nature engagement experiences) through development and application of innovative methodologies. These methodological approaches may include: walking interviews and 'walkshops' (developed in cWP8.3), touch table (in collaboration with RD1.4.1), ethnographic mini-cam methodologies (pioneered at Hutton) or participatory landscape engagement activities. These will be used to explore the harder-to-capture mechanisms that facilitate (or otherwise) uptake of engagement with outdoor activity.

Consideration will be given to a spectrum of activities from the less (e.g. sitting) to more active (e.g. nature conservation) and incidental (whereby experiencing nature is a by-product of another activity such as a group walk) to the intentional (purposeful interaction with nature such as viewing wildlife or stars). Identification and understanding of motivations and barriers will be informed using the Access Capabilities Framework (from O1.1) to consider e.g. physical infrastructure, institutional, cultural and individual constraints and opportunities.

Objective 3 (O3) – Environmental Qualities, Landscape Change and Wellbeing

O3.1 [Years 3-5] - Landscape qualities, nature engagement and access. This will incorporate both objective and subjective assessments of landscape qualities (including change), local natural resources and land management practices into understanding access to and engagement with nature. The specific questions will be informed by findings from Yrs 1-2 in this RD (e.g. O2.1) and others (e.g. 1.3.2's review on biodiversity enhancement and CES; 1.4.1's findings on local communities perceptions of CES in the landscape).

The research design and methodological approach will also be informed by findings from Yrs 1-2. A community- or place-level in-depth case study is one possibility, with site selection for fieldwork coordinated with other RDs (e.g. 1.3.2, 1.4.3, within WP3.4) and in collaboration with local stakeholders. Site selection will also be based on availability of appropriate-scaled objective data on qualities and change (to be informed by e.g. RD1.4.3). Visual and participatory methods (e.g. Touch Table) could be used to explore links between objective landscape qualities, subjective perceptions, outdoor use and behaviour, and wellbeing. Macro-scale insight might be obtained through combining use, access and objective landscape quality data. landscape change, such as through restoration, will be considered. While no new economic analysis will be carried out in this RD, the team will collaborate with the environmental economist in RD1.4.1 working on a natural assets register to investigate linkages between objective and subjective qualities of landscape, wellbeing, values and valuation.

Planned fieldwork locations: Case study areas will be selected in collaboration with stakeholders and other RDs (1.3.2, 1.4.3, other 3.4 RDs) to ensure coherence and efficiency for policy relevance and across/within the themes. Selection will also be informed by RD findings as well as available objective environmental data.

Ethical considerations: Research will be subject to standard quality assurance protocols adopted by the Hutton's ethics committee.

Detailed work plan for first two years: Activities consist primarily of desk-based research, fieldwork preparation and final development of output from the cSRP.

O1.1 – Develop a framework of access capabilities

Year 1:

- O1.1a: Develop framework review protocol (Q2; M1)
- O1.1b: Literature search (Q2-Q3)
- O1.1c: Literature review and synthesis with outline framework (Q3-4; M5)
- O1.1d: Linkages with other relevant RDs (Q1-Q4)

Year 2:

- O1.1e: Draft literature review and framework (Q1; M10)
- O1.1f: Conference presentation (Q3; D5)
- O1.1g: Refine framework in response to ongoing research activity (O2.1; other RDs) and stakeholder engagement (O1.2) (Q3, M11; Q4, D6)

O1.2 – Stakeholder engagement and knowledge exchange

Year 1:

- O1.2a: Interaction with stakeholders related to study area (Q1-Q4)
- O1.2b: Initial scoping meeting with wider stakeholder arena (Q2; M2/KE1)
- O1.2c: Review and annual reporting (Q2, D1; Q4, D2)

Year 2:

- O1.2d: Interaction with stakeholders related to study area (Q1-Q4)
- O1.2e Update meeting: Wider stakeholder arena / KE event (Q2; KE2)
- O1.2f: Review and annual reporting (Q2, D4; Q4, D7)

O2.1 – Use patterns and equality of access.

Year 1:

- O2.1a: Manuscript submissions from the cSRP (Q2,M3; Q4M8)
- O2.1b: Accessing data for analysis (Q1-Q2)
- O2.1c: Data management and cleaning (Q2-Q3)
- O2.1d: Preliminary data analysis (Q3-Q4; M9)

Year 2:

- O2.1e: Manuscript revisions & publication - Yr 1 submission (Q1,D3; Q4,D8)
- O2.1f: Refined analysis (Q1-Q2; M12)
- O2.1g: Follow-up analysis with other data sets to examine patterns (Q2-Q3)
- O2.1h: Manuscript development and draft research report (Q2-Q4; M16)

O2.2, 3.1:

Year 1:

- O2.2a: Scope case study sites to develop preliminary list (Q1-Q2; M4)
- O2.2b: Initial study design outline (Q2-Q3; M6)
- O3.1a: List of possible objective data sources from RDs (Q1-Q4; M7)

Year 2:

- O2.2c: Revise and finalise case study sites (Q1-Q2; M13)
- O2.2d: Finalise study design; ethics; start recruitment (Q1-Q4; Q3,M14)
- O3.1c: Refine objective data for use (Q1-Q3; M15)

Expertise: The research team brings complementary strengths and growing reputations in topics related to use of the natural environment (including inequalities), wellbeing benefits from nature-interaction, and rural-urban relationships. Disciplinary perspectives cut across several substantive areas including environmental psychology, natural resource management and spatial planning. The team has expertise in numerous research methods such as multivariate statistical techniques (*Irvine, Gilchrist*), visualisation (*all*) and field-based case study work using both quantitative and qualitative (e.g. interviewing) methods (*all*). Irvine's collaboration with ecologists in 2007 provided seminal research on biodiversity-wellbeing benefits from recreational use of natural environments and she brings extensive leadership experience. Individual team members have undertaken work for the SG (e.g. cSRP), and are active in policy-facing research (e.g. SG's ClimateXChange) and EU initiatives (e.g. TESS). The work undertaken will facilitate new interdisciplinary collaborations within the Hutton (via cross RD collaboration) and with external academic institutions in the rural landscapes-wellbeing relationship which will enhance capacity to attract external funding in key emerging research areas.

Key linkages, interdisciplinarity & collaboration: Collaboration with the other WP3.4 RDs will identify linkages related to e.g. frameworks, case study selection

and consideration of land use and community change. The RD has key interdisciplinary integrative links with WP1.3 and WP1.4 while at the same time providing stand-alone outputs that are largely independent from the input of others, which reduces risk to the work programme. These include maximising opportunity to coordinate case study location (e.g. CSGN) with RD1.3.2 and RD1.4.3 in order to engage with natural scientists' surveys and modelling of particular landscapes for exploration of users' perceptual experience of such objective qualities and to landscape change. Additional collaboration will be undertaken with 1.4.1's economic valuation to bring an economic lens to issues considered within this RD. Similar effort will be taken to link with visualisation and spatial modelling experts through integration of the proposed research with GIS mapping of cultural ecosystem services (RD1.4.1); there may also be scope to link with visualisation work being done in RD1.3.2. Additional linkages will be explored with regard to transferability of analytical frameworks developed (e.g. this RD's 'Access Capabilities Framework', RD1.3.2's Ecosystem Services Coproduction framework). A third area for integrative work is methodological, e.g. combining the participatory mapping and touch table methodology (RD1.4.1) with exploration of access and engagement with the natural environment (this RD). Collaboration and linkages will enhance and facilitate stakeholder engagement and KE and be managed through the co-location of researchers within both this RD and others; e.g. within RD1.4.1 (*Irvine*); within RD1.3.2 (*Irvine, Gilchrist*) and within RD1.4.3 (*Lackova*).

Added Scientific Value: In the past decade, research on nature-health relationship has rapidly increased as has interest in designing nature-based health interventions (e.g. green exercise, nature prescriptions). There remains however a lack of integration among insights gained from studies at different scales (e.g. large scale population and small scale psychology studies), a continued focus on single disciplinary research, and few primary studies that explore the effects of – and motivation for – engagement with nature for different population subgroups, for different types of natural environments, and for different types of contact with nature. This RD will seek to fill some of these gaps in understanding the people-environment-wellbeing nexus within changing contexts. Use of existing data sets at multiple scales combined with in-depth case studies embedded in the Scottish context will generate key insight into the contribution of rural landscapes and objective qualities of landscape to use of and engagement with the outdoors and wellbeing and equality of such access. Coordinated case study selection across RDs will integrate multiple disciplinary perspectives (e.g. economic, ecological). Methodological innovation will be undertaken to investigate hard-to-capture insight on landscape and community wellbeing which will contribute further scientific tools for use within other contexts. Several high-impact scientific publications are likely. Links will be made with ongoing/new research projects (e.g. Horizon 2020; Valuing Nature Programme) to maximise knowledge generation and exchange across all related work. Aside from major European initiatives and projects (e.g. OpenNESS, BioDivERsA, PHENOTYPE, URBES), the team is aware of (a) work by Forest Research on the Central Scotland Green Network, (b) the GreenHealth project and follow-up research on urban greenspace and human health and wellbeing (c) the NERC-funded BESS project on trade-offs between ES in urban ecosystems, and (d) the Forestry Commission's Woods In and Around Towns (WIAT) programme.

Knowledge Exchange (KE):

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview. An annual workshop/seminar will be held with a cross-section of policy-makers and practitioners from national, regional and local scale (e.g. CAMERAs partners, SNH, local authority). These will focus on insight and challenges to-date, and proposed next steps for collaborative discussion. Coordinated events with other RDs will be sought to share cross-RD findings.

Audiences: These include policy-makers (in Scotland [e.g. Land Use Strategy] and beyond); researchers (within & outwith Scotland); agencies (e.g. SNH), practitioners (e.g. PfA,) and individuals (e.g. outdoor activity leaders, those in GP and Council referral schemes) seeking to promote outdoor access, to better connect people with the land and to positively influence land use.

Impacts & Pathways to Impact: Strategic issues requiring understanding of pathways for (re-)engagement with Scotland's landscapes and natural capital for wellbeing and how landscape changes might influence these pathways will benefit. For example, the RD is directly relevant to the SBS Step 3's Priority Projects 5 (More people experiencing and enjoying nature). Evidence could inform: (i) current and future land reform initiatives and policy (e.g. findings on perceptions and experience of specific landscape features); (ii) question development for national-scale surveys (administered by e.g. SNH) could draw on e.g. motivations/barriers to engagement, drivers of inequalities and perceptions of rural landscapes; (iii) Land Use Strategy annual progress statements e.g. engagement with outdoor indicator). The RD lead will participate in the CNP research event (20/21 October 2015) and SNH's Mainstreaming Green Exercise (16 November 2015) to further explore opportunities.

Policy-makers (at local and national level in Scotland and beyond)

- Bi-annual reporting to Scottish Government RESAS.
- Annual workshop/seminar for key stakeholders for progress update and opportunity for input on how the work is developing.
- Regular reports, etc. produced throughout, all written in accessible language. Each output will have at least a 'soft launch' i.e. key stakeholders (in Scotland, UK, EU, etc.) will be emailed a project update when a new output is available.

Researchers (in Scotland and beyond)

- Five peer-reviewed academic journal articles will be produced.
- Research papers at relevant national/international conferences.
- Researchers outwith this RD will be invited to join stakeholder meetings to maximize synergies with other research.

Practitioners, individuals and community groups

- Case study specific stakeholders will be included in annual stakeholder meetings.
- The wider public will predominantly be addressed through news releases and social media mechanisms (e.g. blog, twitter).

RESEARCH DELIVERABLE NUMBER: 3.4.3

Work planning and timetable for Year 1: Please include major milestones (key research Objectives, deliverables, KE/impact events) and their timing.

M = Milestone, D = Deliverable, KE = KE event, R = Reporting to RESAS

Year 1: 2016/17	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1a: Framework review protocol Develop search protocol for literature to inform access capabilities framework				M1								
O1.1b: Framework literature search Identify relevant literature												
O1.1c: Framework synthesis Literature integration and framework development										M5		
O1.1d: Framework linkages Link with other relevant RDs efforts (e.g. 1.3.2) to inform framework development												
O1.2a: Stakeholder & KE Interaction with stakeholders related to RD-specific topic, data potential case study sites & participants												
O1.2b: Stakeholder & KE Initial scoping meeting with wider stakeholder arena				M2/ KE1								
O1.2c: Stakeholder & KE Review						D1						D2
O2.1a: Use patterns and equality of access Manuscripts from cSRP submitted				M3								M8
O2.1b: Use patterns and equality of access												

Accessing appropriate data												
O2.1c: Use patterns and equality of access Data management & cleaning												
O2.1d: Use patterns and equality of access Preliminary data analysis												M9
O2.2a: Motivations and barriers to use Scoping potential case study sites (in collaboration with other RDs)									M4			
O2.2b: Motivations and barriers to use Develop initial set of research questions, methods, nature-engagement activities, participants											M6	
O3.1a: Landscape qualities, nature engagement and access Liaise with relevant RDs with regard to objective landscape data (available & to be generated)											M7	
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.4.3

Work planning and timetable for Year 2: Please include major milestones (key research Objectives, deliverables, KE/impact events) and their timing.

M = Milestone, D = Deliverable, KE = KE event, R = Report to RESAS

Year 2: 2017/18	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
O1.1e: Framework Draft framework & literature review		M10										
O1.1f: Framework Conference presentation								D5				
O1.1g: Framework Framework refinement & research note						M11				D6		
O1.2d: Stakeholder & KE Interaction with stakeholders related to RD-specific topic, data, case study sites & participants												
O1.2e: Stakeholder & KE Update meeting				KE2								
O1.2f: Stakeholder & KE Review						D4						D7
O2.1e: Use patterns and equality of access Revise & resubmit manuscripts from Yr1			D3									D8
O2.1f: Use patterns and equality of access Refined analysis						M12						
O2.1g: Use patterns and equality of access Follow-up analysis using additional data sets to examine patterns												
O2.1h: Use patterns and equality of access Manuscript preparation & draft research report											M16	

O2.2c: Motivations and barriers to use Revise case study sites based on Yr1						M13						
O2.2d: Motivations and barriers to use Refine field-based research based on Yr1; ethics; recruitment								M14				
O3.1a: Landscape qualities, nature engagement and access Refine objective landscape data for use in social science field work									M15			
Annual Report (Year 2)												R2

Name of RD: 3.4.4 Local assets, local decisions and community resilience

Research aim and key drivers

The aims of this Research Deliverable (RD) are: (i) to assess how communities have been, or can be, empowered to generate local economic development, shape service provision, directly address poverty, or influence key land use decisions over the long term; (ii) to understand how these processes can play a key (rural) development role in enhancing community resilience and wellbeing; and (iii) the costs and benefits of a community-led approach to addressing systemic challenges and maximising opportunities.

The RD will build directly on the learning from the current Programme (cSRP) (specifically current work package 8.2 (cSRPWP) “Governance and Decision-Making for Community Empowerment”). cSRPWP8.2 research has generated a thorough understanding of processes which enhance, and reduce, community engagement, empowerment, and their links to resilience (as well as the complexities of ‘resilience’ as a concept). The research has generated evidence from different geographical locations and in relation to different policies and interventions, as well as from “home-grown” community activities and processes. This evidence, and papers and reports from these cSRPWP8.2 case studies, will be built on so that projects’ impact on/with communities can continue to be assessed in a longitudinal way. As well as being empirically-based, this research will be conceptually driven, building on – and extending - the community resilience framework and synthesis developed in cSRPWP8.2. This means that the RD will examine the interconnection of rural community resilience with, for example: capacity, readiness, wellbeing, social capital, governance, thus also building on links with RD 2.4.2.

By continuing this work seamlessly from cSRPWP8.2, RD3.4.4 will build on our strong stakeholder and user networks, enhancing impacts of the next, critical stage of this research. New research in this RD comprises two key themes, both of which have very high policy relevance:

- i. Developing methodologies to create a better understanding of how policy outcomes can be captured, particularly over the longer term, i.e. how is it possible to know a policy has “worked”, what does “success” look like (to whom) and why? How transferable (or place-specific) are these successful outcomes?
- ii. How community resilience (including economic development) can be enhanced in key economic sectors, including: tourism, local community service provision, allotments, forestry and woodlands, other rural industries, as well as collective working around flood prevention (linking with WP1.2). The selection of cases will be integrated across WP3.4 as well as with WP3.3. [RD3.3.2.] and, RD2.4.1 and RD2.4.4. to ensure efficient use of resources. These exemplars will be selected in order to illustrate a range of models of community ownership/management/influence of assets on resilience. The role of “community anchors” will specifically be examined. The analysis of community resilience will also encompass poverty as one key element of the “vulnerability/resources” mix.

There is a number of substantial drivers for this new research:

Firstly, RD3.4.4 will address issues of inequalities within rural communities, identifying the underlying reasons for different ‘empowerment outcomes’ between and within communities. This brings in the notion of “Darwinian development” (developed under cSRPWP8.2.), where those communities able to make use of development resources continue to do so, leaving behind those who do not have such capacity – resulting in “two-speed” development. Given the Scottish Government’s overarching commitment to equality, inclusion and poverty reduction irrespective of geographical location, this differential starting point for communities,

and their resultant trajectories, is of key concern to Government.

Secondly, the need to target resources effectively and efficiently, particularly due to the on-going pressure on public sector finances, and the increasing need for active public/private/third sector partnerships, means that the 'readiness' or otherwise of communities, and indeed of partnership bodies (including local authorities and other agencies), becomes more critical in ensuring inclusive development. This RD will therefore develop approaches for stakeholders – communities and agencies (public/private/third) - to be able to assess changes, impact and outcomes, thus directly and indirectly enhancing communities' resilience and wellbeing.

Thirdly, this RD will also develop innovative research by bringing together the learning from community development practice, policy and research in urban areas. This will both generate new understanding (from the wealth of evaluations and data available from charities and funding distributors such as Big Lottery, Scottish Community Development Centre and Development Trusts Association Scotland); and will allow us to identify what is distinctly "rural" about the interventions and associated costs, benefits and outcomes. We will also learn from urban practitioners' models of assessing "success", capacity and resilience. This urban/rural focus is policy-critical, given the Scottish Government's development of policies covering the whole of Scotland – such as the Community Empowerment (Scotland) Bill and Land Reform, and their need to target (as appropriate) to enhance outcomes.

Fourthly, RD3.4.4 will link with policy and wider Scottish Government-funded developments in the area of "resilience", such as the National Centre for Resilience (NCR). NCR focuses primarily on managing disaster, such as flooding and other extreme weather, and includes "building community resilience" within its remit. Links will be made with the Resilience Team within Scottish Government, and other NCR stakeholders, to ensure dialogue continues post cSRPWP8.2, to enhance policy impact of RD3.4.4 research. Additional important policy drivers for this research include:

- The legacy of Christie Commission (Public Service Commission, 2011): recommendations for public service reform, e.g. interventions for prevention;
- The focus on regenerating local democracy, as called for by the Commission on Strengthening Local Democracy (2014);
- Continuing emphasis on 'bottom-up', 'place-based' and 'asset-based' approaches to local development in policy, for example, through the Community Empowerment (Scotland) Bill, proposals within the Land Reform (Scotland) Bill (including draft Land Rights and Responsibilities policy) and extensions to the Scottish Land Fund (Scottish Government, 2014);
- Opportunities for support and partnership working between land managers and rural communities as a result of the new Common Agricultural Policy and Scottish Rural Development Programme (SRDP) and LEADER;
- The adoption of the Ecosystem Approach in the Land Use Strategy (Scottish Government, 2011), which recognises that people (and local communities) with their cultural and varied social needs are an integral part of ecosystems;
- Increasing interest in coastal communities and resilience, e.g. Marine Scotland;
- The Scottish Government's support for enhancing 'the rural voice' through the Rural Parliament (Oban, November 2014 and on-going);
- On-going, systemic challenges facing rural community economic development, including: access to high-speed broadband; access to land and affordable housing; planning system constraints; and social welfare concerns, such as fuel poverty and underemployment.

This RD has been developed through initial, high-level consultation with the following

organisations, who (as a minimum) will continue to be consulted and engaged with during the lifetime of the research: Scottish Government research and policy staff; Carnegie UK Trust; Scottish Community Alliance; Rural Housing Scotland; SCVO; NHS Highland; Scottish Land & Estates; Citizen’s Advice Scotland; COSLA (Relevant) Local Authorities and Community Planning Partnerships; LEADER Coordinators; Orkney Housing Association Ltd; Community Land Scotland; Big Lottery Fund; Scottish Enterprise; Highlands and Islands Enterprise – Strengthening Communities; Scottish Community Development Centre and Community Health Exchange; Development Trusts Association Scotland; Big Lottery; Nourish Scotland; Inspiring Scotland; Anti-poverty organisations and charities.

Summary of the proposal

As outlined above, a key driver for this new focus of the research is to develop methodologies which allow the Scottish Government, and wider stakeholders (including communities), to identify and capture “success” in enhancing the resilience of rural communities. Therefore, learning from existing knowledge, exchanging that knowledge, and building fit-for-purpose outputs are at the core of this RD. The research objectives - and associated research, knowledge exchange and co-construction activities - are summarised in the following table:

Objectives (O)	Activities and timings
1	<p>Generate a coherent learning output on “what success does and does not look like”, and how it is achieved from cSRPWP8.2 and other relevant materials. Co-produce next steps with stakeholders.</p> <p>Months 1-6: Collate and bring into a coherent whole the learning from cSRPWP8.2 and new trawling of the relevant international academic literature, as well as grey literature from national and international policy and practice sources to: (i) identify “success” in rural community resilience; (ii) how it is achieved, (iii) how it is assessed. It will be important to examine what success looks like for different stakeholders/parties.</p> <p>Months 7-9: Stakeholder knowledge exchange workshops (separately [and together where appropriate] with policy, practitioners, communities) on this “state-of the art” learning on what leads to “success”, with a focus on how then to measure/assess this.</p>
2	<p>Develop and trial first version of methodologies with <i>existing</i> RD3.4.4 case studies, to: (i) assess what success looks like and (ii) capture outcomes. Co-produce next steps with stakeholders.</p> <p>Months 9-18: “Trial” the assessment approaches proposed by stakeholders, merging these – where possible and appropriate – with those approaches generated through trawling the national and international literature.</p> <p>Build the RD3.4.4 case studies from cSRPWP8.2 to allow for longitudinal analysis.</p> <p>Month 18: Stakeholder knowledge exchange workshops (separately [and together where appropriate] with policy, practitioners, communities) on identifying key learning from trial of assessment processes with <i>existing</i> case studies. Identifying what needs to change to increase “fit” and robustness.</p>
3	<p>Test robustness of O2 outputs in <i>new</i> settings still within RD3.4.4. Co-</p> <p>Months 18-30: Test the robustness of these assessment approaches in <i>new</i> settings: (i) different economic development sectors (e.g. tourism, service provision, natural resources and local food initiatives,</p>

	produce next steps with stakeholders.	<p>local businesses and industries); (ii) different policy priorities (e.g. land use/reform, coastal); and (iii) with different case studies and geographic locations. It is anticipated that the RD will include themes of: community schemes to ameliorate poverty, inequality and disadvantage; innovative service delivery; co-production; asset transfer; community capacity and governance mechanisms.</p> <p>Case study analysis will involve working with communities with different degrees/length of time in poverty, stages of empowerment and engagement (and for whom), identifying lessons and pathways that can be learned from different stages.</p> <p>Months 28-30: Stakeholder knowledge exchange workshops (separately [and together where appropriate] with policy, practitioners, communities) on identifying key learning from trialling assessment processes with new case studies and what needs to be done next to refine the tool.</p>
4	Trial a Community Resilience Assessment Tool (CRAT) in <i>new cases beyond</i> RD3.4.4.	<p>Months 30-40: Trial the CRAT in cases <i>beyond</i> RD3.4.4, e.g. from WP3.4, WP4.2, and potential other cases in the SRP and/or CoEs.</p> <p>Potentially link with other externally-funded research being carried out by MRPs (and possibly other HEIs) including: FP7 TESS project; CREW; Macaulay Development Trust Fellowships; and H2020 projects. Where resources allow, work with stakeholders to trial the CRAT in cases proposed by stakeholders.</p> <p>Months 40-42: Stakeholder knowledge exchange workshops (separately [and together where appropriate] with policy, practitioners, communities) on: (i) assessing robustness of tool in different settings and for different uses, and identifying necessary changes; (ii) identifying how the CRAT can feed into systematic challenges across policy portfolios; (iii) identifying other processes/outputs alongside CRAT.</p>
5	“Up-scale” the Community Resilience Assessment Tool to identify how, where and by whom it can be used to assess interventions which are addressing <i>systemic challenges</i> in rural areas (poverty, health, housing etc.), i.e. across portfolios.	<p>Months 42-44: close consultation with policy colleagues at national, regional and local levels (in public sector, and also private and third where policies are being made and implemented). Focusing on how CRAT can be used cross-portfolio.</p> <p>Months 45-51: systematic assessment of how the Community Resilience Assessment Tool can support the delivery of Scottish Government Outcomes in rural Scotland.</p>
6	Co-production of	Months 51-60: continuing with <i>co-production</i> of

	final project outputs with policy and practice stakeholders.	outputs for use by a range of stakeholders from across public, private and third sectors, and communities, and at different levels (central/regional/local). Focusing on specific, <i>and</i> cross-portfolio, outputs.
7	Sharing learning with stakeholders throughout the programme	Months 1-60: Using online media, through shared website, blogs (with forum), and Twitter.

Table 1: Objectives, activities and timings for RD3.4.4

References:

Commission on Strengthening Local Democracy (2014) *Effective Democracy: Reconnecting with Communities*, Available online: <http://www.localdemocracy.info/wp-content/uploads/2014/08/Final-Report-August-2014.pdf>; Last updated: 14.08.2014; Accessed: 06.03.15.

Public Service Commission (2011) *Commission on the Future Delivery of Public Services*, Produced by APS Group Scotland, June 2011.

Scottish Government (2011) *Getting the best from our land - A land use strategy for Scotland*, The Scottish Government, Edinburgh, March 2011.

Scottish Government (2014) *Programme for Government*. Available online: <http://news.scotland.gov.uk/News/Programme-for-Government-12b0.aspx>; Last updated: 26.11.14; Accessed: 06.03.15.

Key deliverables

Table 2: Summary of key deliverables (Deliverable = D)

Objective	D	Description	Date
O1	D1	Review report, Blog post	Month 6
	D2	Stakeholder KE report, blog post	Month 9
O2	D3	Review report, Blog post, Academic papers	Month 18
	D4	Stakeholder KE report, blog post	Month 18
O3	D5	Review report, Blog post, Academic papers	Month 30
	D6	Stakeholder KE report, Blog post	Month 30
	D7	First version of CRAT	Month 30
O4	D8	Report from trial of CRAT, blog post, academic papers (including reflection piece on policy and stakeholder co-production).	Month 40
	D9	Stakeholder KE Report, refined CRAT	Month 42
O5	D10	Consultation report on use of CRAT cross-portfolio; blog	Month 44
	D11	Assessment report and academic papers	Month 51
O6	D12	Range of outputs through co-production: CRAT and support tools	Month 60
	D13	Academic papers relating to D12 Papers co-produced with other RDs	Month 60
O7	D14	Online media outputs: shaped, co-designed.	1-60
	D15	Policy briefings	40,51,60

Table 3 – Milestones (M):

M	Activities	Completion of:	Date
M1	Review	Report: What “success” in rural community resilience looks like, and how it is assessed	30.09.16

M2	KE	Stakeholder KE workshops	31.12.16
M3	Methodology	Development of methodology and trial with <i>existing</i> cases	30.09.17
M4	KE	Stakeholder KE workshops	30.09.17
M5	Test	Robustness with <i>new</i> cases <i>in</i> RD3.4.4. completed	30.09.18
M6	KE	Stakeholder KE workshops	30.09.18
M7	Test tool	Robustness with <i>new</i> cases <i>beyond</i> RD3.4.4. completed	31.07.19
M8	KE	Stakeholder KE workshops	30.09.19
M9	Upscale	Cross-portfolio consultation completed	30.11.19
M10	Test tool	Cross-portfolio testing completed	30.06.20
M11	Final outputs	Co-production of final outputs completed	31.03.21

Technical approach:

The RD combines a range of qualitative approaches, using mixed methods of: desk research, content analysis of key documents (academic and grey literature, analysis of multi-media outputs etc.), one-to-one semi-structured interviews, focus groups, stakeholder consultation and KE events, and co-production through transdisciplinary approaches. The RD will also use quantitative techniques, both in terms of analysis of secondary statistical data, and in assessment approaches for the Community Resilience Assessment Tool which will itself combine qualitative and quantitative components. There are two underpinning elements: transdisciplinary working, and case study focus. These are now briefly discussed.

Transdisciplinary working: key to this RD is co-construction both of research and investigation processes and of the research outputs (including the Community Resilience Assessment Tool [CRAT]). It is critical to unpack the normative associations around “success”, what it looks like and for whom, how it is achieved (again, for whom), and whether and how it is part of resilience and wellbeing. Stakeholders will have different perceptions of success, and its sources, hindrances and how to achieve it. Further, the Scottish Government, and other partners in the private, public and third sectors, are increasingly concerned with how, meaningfully, to assess “success” *per se*, and to understand better how their interventions do or do not generate (lasting) success, as well as the costs/benefits of a community-led approach. The conceptual framework of this RD is resilience and wellbeing, so “success” will be explored within this context. Resilience and wellbeing are two concepts with rich academic pedigree which have been explored under the cSRPWP8.2 and this learning will be brought to this RD. They are also two concepts central to the Scottish Government’s Purpose and policies, and thus have high policy and practice relevance, particularly in times of straitened economic public sector finances where targeting of scarcer resources becomes even more critical, particularly in rural areas with dispersed populations. So, navigating through these normative understandings, and their implications for policies, budget allocations, assessments of outcomes etc. will all be a critical part of the research, and will require close working with the range of stakeholders engaged in this field. The WP3.4 document identifies the stakeholders with whom this RD will engage, and some have also been listed earlier in this RD document. Such engagement is necessarily repeated within each of the Objectives listed above, and we will expect it to shape the way that the research and its outputs develop. This will enable the research to maximise its usefulness and impact.

Case study focus: As outlined above, in the introductory text and in Table 1, case studies will be selected for continuity and to allow for longitudinal analysis. There is a

series of cases from cSRPWP8.2 in Dumfries and Galloway, Aberdeenshire and Orkney, and work will continue in these areas. In addition to allowing for longitudinal analysis, they will enable efficiencies in generation and analysis of data, and working through established and trusted links. Additional case studies during the lifetime of the programme will be selected in consultation with colleagues across WP3.4 and other identified parts of the Programme, again to ensure efficiencies and to lend coherence to the analyses taking place across the different RDs. Based on previous research, it is clear that case studies are extremely useful illustrations for policy colleagues; however, to maximise their usefulness, they need to be set against a backdrop of the 'bigger picture', such as statistical (performance) data and other larger sets of information, which enable policy colleagues to identify the significance and meaning of the selected cases. This policy need will be a key driver in case study selection.

Ethical considerations: This is described in the WP3.4 document.

Detailed workplan for the first two years

O1 [months 1-9]: The RD will begin with a desk study which will bring into a coherent whole the learning from cSRPWP WP8.2 and new evidence from the relevant international academic literature. Grey literature from national and international policy and practice sources will also be analysed using content analysis in order to: (i) *identify "success" in rural community resilience;* (ii) *how it is achieved,* (iii) *how it is assessed.* A typology will be constructed based on the content analysis which allows the range of meanings to be identified and presented in a digestible format. This typology will also recognise the differential meanings and interpretations of success from the perspective of types of stakeholders and will specify the implications of these varying interpretations. As with all phases of the research, this Objective will conclude with a series of stakeholder knowledge exchange workshops (separately [and together where appropriate] with policy, practitioners, communities) on this "state-of the art" learning on what leads to "success" (or not), with a focus on how then to measure/assess this.

O2 [months 9-18]: The next stage will firstly collate the assessment approaches proposed by stakeholders, which will have been analysed using thematic analysis (Patton) and Word clouds. These approaches will be compared with those generated through the analysis of the national and international (academic and grey) literature. The two sources (stakeholder and literature) will be synthesised, where appropriate and feasible, into a first iteration of an assessment set of criteria and will be "tried" in the cSRPWP8.2 case study areas. This will be initiated through contact with existing stakeholder "gatekeepers" for the projects which have been researched under the cSRPWP8.2. The approaches will be carefully co-constructed in a pilot way, so as not to jeopardise the subsequent phases of the research, either through over-surveying the case study participants, or by shaping their subsequent responses due to our initial investigations. Due ethical procedures will of course be implemented in line with SRUC/Hutton ethics standards, RESAS Social Science ethics and the ESRC's Ethical Standards approaches. As with O1, this Objective will conclude with a series of stakeholder workshops to allow for reporting back on the key learning from this initial scoping phase. Stakeholders will be consulted on what needs to change, in terms of defining, and then capturing, "success" within the overarching conceptual framework of resilience and wellbeing. They will also be consulted in terms of potential case study areas to capture key aspects of this research. Again, a thematic analysis of the findings from the workshops will be undertaken and incorporated into Objective 3.

O3 [months 18-30]: In this period of the RD, the analysis will be expanded to test the robustness of the assessment approaches in new community settings. Through

close consultation with WP3.4 colleagues (as outlined above) and with stakeholders (O2 workshops), the research will identify: (i) different economic development sectors (e.g. tourism, service provision, natural resources and local food initiatives, local businesses and industries); (ii) different policy priorities (e.g. land use/reform, coastal); and (iii) different case studies and geographic locations. It is anticipated that the RD will include themes of: community schemes to ameliorate poverty, inequality and disadvantage; innovative service delivery; co-production; asset transfer; community capacity and governance mechanisms. Case study analysis will involve working with communities with different degrees/length of time in poverty, stages of empowerment and engagement (and for whom), identifying lessons that can be learned from different stages, including pathways in and out of poverty. As with cSRPWP8.2, case study selection will be undertaken through gatekeepers in public agencies, communities and/or the private sector, depending on the nature of the case study. All ethical procedures will be followed, and the rationale and methodological and conceptual underpinning for case study selection will be traceable and well documented. Interview and focus group schedules/formats will be subject to RESAS approval. The data acquisition will primarily be qualitative, through interviews and focus groups. However, secondary data analysis will also be undertaken, to give the contextual backdrop to the analysis. Thematic analysis of the findings will be carried out by the researchers undertaking the interviews and focus groups. Data storage protocols, including maintenance of confidentiality and safety of source documents, will be part of normal procedure. The stakeholder workshops will take place in months 28-30, so fall out with the timeframe of this detailed workplan.

O4 [months 30-40] and O5 [months 42-51] comprise the development, testing and refining of a new Community Resilience Assessment Tool (CRAT) in community-level cases, and through “up-scaling” to a range of appropriate policy domains beyond “rural” *per se*, such as housing, health and poverty. This is because much national (UK and Scotland) policy affects rural areas, but remains under-researched, with the focus being primarily on the effects of rural policy. This RD will therefore be breaking new ground by researching and testing cross-portfolio. **O6 [months 51-60]** comprises the co-production of final project outputs with policy and practice stakeholders from across public, private and third sector organisation, and at different levels (central, regional, local). **O7 [months 1-60]:** throughout this RD, online media will be used, through shared WP/SRP website, blogs (with forum), and Twitter. This will enable the research to be spread to a wider range of stakeholders and to gain their feedback on the research findings.

Expertise: The RD team has extensive experience in rural community research, which means a strong working knowledge of: carrying out research in small communities; maintaining confidentiality of findings; maintaining trust in communication; and ensuring anonymity of discussions/interviews and results. The team also have a thorough understanding of how to work in rural settings: gaining access through gatekeepers whilst ensuring the interview samples are not biased by this process; and maintaining objectivity whilst being drawn into discussions about local issues etc. The team, in the cSRPWP, has been productive in terms of ensuring high quality academic outputs from the research into rural community resilience. This will continue in this RD.

The RD team is trusted by Scottish Government policy and analyst colleagues, in relation to the production of robust findings from diverse case study areas. Some of the team are active on Scottish Government advisory committees, are retained as Ministerial Advisers, and input both formally and informally to policy formulation. This is in relation to both rural directorate work, and wider directorate input e.g. in local

government, empowerment and regeneration. The team is extremely well networked and respected by a range of stakeholder (organisations) within (and beyond) Scotland, who will be important for ensuring co-production of processes and outputs, and thus greatly enhancing impact. Many of the research team have been working in rural Scotland for at least 10-15 years, (some 20+ years) and thus have access to influential networks which will support the co-construction central to this RD. Members of the team are active on Twitter and the web, and will continue to use these skills in engaging with stakeholders during the RD's lifetime.

Key linkages, interdisciplinarity & collaboration

RD3.4.4. provides the foundation for integration not only within WP3.4. but more importantly, across the Programme; this integration role is reflected in the budget. Case studies in RD3.4.4. have been selected to maximise efficiencies in primary data collection, focusing on the following specific WPs and RDs:

- Theme 1, WP1.4.
- Theme 2, WP 2.4 Rural Industries (specifically RD2.4.1. and RD2.4.4.)
- Theme 3, WP 3.3 Food Security (specifically RD3.3.2.)
- Other parts of the SRP (e.g. CREW [Sustainable Rural Communities])
- Links with external projects: FP7 TESS project, Macaulay Dev Trust Fellowships.

Added scientific value

- A tool does not exist for assessing “success” in terms of rural community resilience and wellbeing. This RD will produce this tool, for use by policy and other stakeholders. Further, the RD will build on cSRPWP8.2 thus making this ambition realizable, since much of the conceptual and modelling groundwork for assessing *change* (not necessarily *success*) has been successfully carried out.
- Such a tool has not been applied and tested across multiple settings. Rural Scotland is diverse and it is known that “one size does not fit all”, so the intelligence and guidance which will be produced in this RD will directly support the testing for robustness which will in turn lead to high impact academic papers, since typically this theme, where it is analysed, is addressed on a case by case basis, rather than being subject to rigorous systematic analysis.
- Resilience and wellbeing remain contested terms across a number of disciplines with the dominant paradigm being ‘bounce back from external shock’. cSRPWP8.2 research has demonstrated that this approach, for rural community resilience, is not fit for purpose, and so this RD will build on publications which critique and offer alternatives to that dominant paradigm. The main orientation of this RD is “human agency” models, incorporating communities’ proactive planning rather than simply passive bounce-back.
- This RD will bring in learning from urban Scotland. This will be innovative and systematic. It is an atypical, but hugely rich, approach.
- We will be working cross portfolio, i.e. within and beyond rural. This is innovative in terms of identifying the extent of specificities of *rural* resilience and wellbeing, identifying ways in which national issues impact on rural in particular ways, and opportunities for rural to contribute to national resilience/wellbeing outcomes.

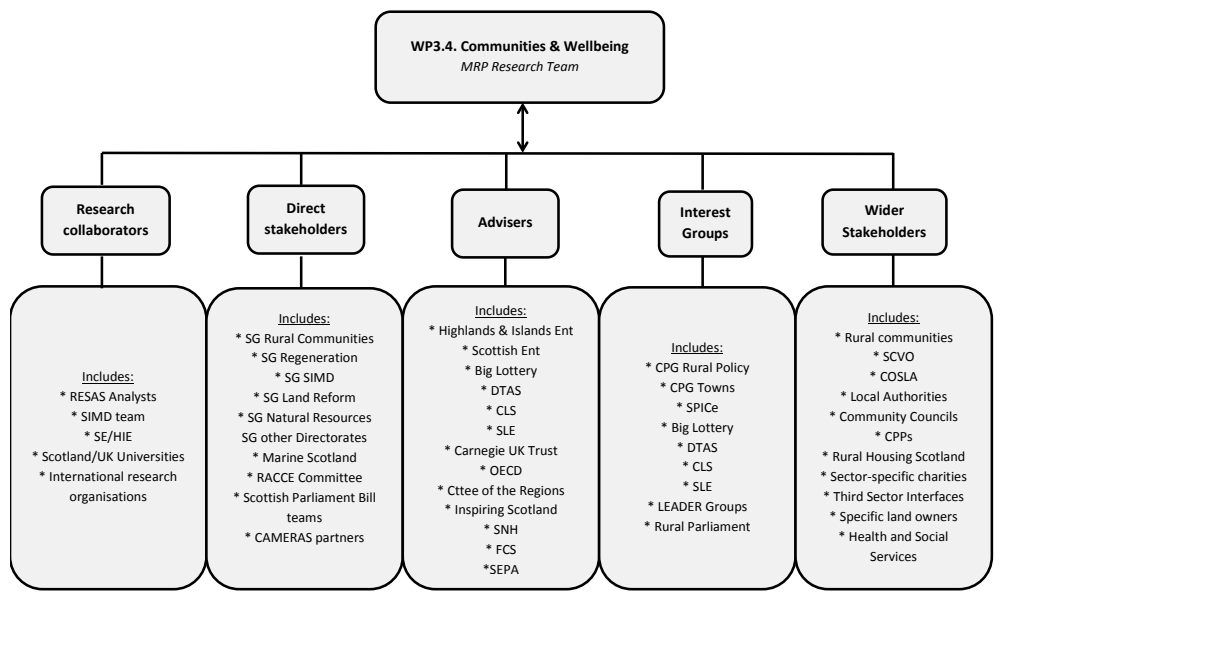
KE, Audiences and Impact

The Figure shows the audiences with which we have already been engaging (in cSRPWP8.2 and in the preparation of this RD), as detailed in the WP3.4 document. Engagement will be tailored to the audience types specified here. Plus, as outlined, given the centrality of co-construction through transdisciplinary working, RD3.4.4 will be engaging with stakeholders throughout the RD's lifetime. As outlined above, the RD is case study focused, which of necessity also involves KE throughout the

research process. Underpinning this engagement will be O7 which will allow RD researchers to work with stakeholders through online media (see above). In addition, the RD team will work with the Centre for Knowledge Exchange and Impact (CKEI) and Underpinning functions alongside the SRP. (See WP3.4 document for more detail on this, plus see management diagram showing links to KE).

The Centre for Knowledge Exchange and Impact (CKEI), together with the relevant KE Sectorial Leads, will be responsible for delivering KE events and integrative activities across the Theme and wider areas. At the RD/WP level more bespoke activities and events will be delivered with specific stakeholders. To assess KE impact we will monitor stakeholder feedback on an event basis with periodic overview.

This RD is highly policy relevant and is of high priority for policy colleagues. In months 1-3, effort will be spent confirming the key, influential individuals with whom the RD team should be engaging in dialogue. A number of these are colleagues already closely consulted for the cSRPWP8.2. However, given that the research will involve urban studies, and cross-portfolio testing of the Community Resilience Assessment Tool, “mapping” of the key contacts will be essential. In addition, the team will spend time ensuring that KE processes are co-constructed with policy colleagues, to ensure that the research outputs, and their timing, have maximum impact. Policy colleagues themselves will also be differentiated (analysts, policy support, Parliamentarians, Parliamentary researchers, cross-Party committees etc.) in order to enhance impact of the research findings.



RESEARCH DELIVERABLE NUMBER: 3.4.4.

Work planning and timetable for Year 1: Includes major milestones, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, SGM = Scottish Government Meeting, SHW = Stakeholder Workshop, KE=KE event, R=Reporting to RESAS

Year 1: 2016/17	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Establish/maintain dedicated web area												
O1. Generate a coherent learning output on “what success does and does not look like”, and how it is achieved from cSRPWP8.2 and other relevant materials. Co-produce next steps with stakeholders.						D1 M1			D2 M2			
O2: Develop and trial first version of methodologies with <i>existing</i> RD3.4.4 case studies, to: (i) assess what success looks like and (ii) capture outcomes. Co-produce next steps with stakeholders												
O7: Sharing learning with stakeholders throughout the programme												
KE Events: annual workshop/seminar for key national and regional									KE1			

stakeholders (Year 1)												
KE Events: Scottish Rural Parliament (Year 1)								KE2				
Stakeholder meetings with RESAS	SGM1			SGM2			SGM3			SGM4		
Annual Report (Year 1)												R1

RESEARCH DELIVERABLE NUMBER: 3.4.4.

Work planning and timetable for Year 2: Includes major milestones, deliverables, KE/impact events) and their timing.

M = milestone, D = deliverable, SGM = Scottish Government Meeting, SHW = Stakeholder Workshop, KE=KE event, R=Reporting to RESAS

Year 2: 2017/18	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Establish/maintain dedicated web area												
O2: Develop and trial first version of methodologies with <i>existing</i> RD3.4.4 case studies, to: (i) assess what success looks like and (ii) capture outcomes. Co-produce next steps with stakeholders						D3 D4						
O3: Test robustness of O2 outputs in <i>new</i> settings still within RD3.4.4. Co-produce next steps with stakeholders.												
O7: Sharing learning with stakeholders throughout the programme												
KE Events: annual workshop/seminar for key national and regional stakeholders (Year 2)						M3 M4 KE3						
Stakeholder meetings with RESAS	SGM1			SGM2			SGM3			SGM4		

Annual Report (Year 2)													R2
------------------------	--	--	--	--	--	--	--	--	--	--	--	--	-----------