Year 5, September 2020 - March 2021

Progress Report on Strategic Research Programme Delivery

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LEADING IDEAS
FOR BETTER LIVES

SEFARI, the Scottish Environment, Food and Agriculture Research Institutes, are responsible, with Higher Education Institute partners, for delivering the Scottish Government (Rural and Environment Science and Analytical Services, RESAS) funded Strategic Research Portfolio on environment, food, agriculture, land and communities.* The Portfolio includes the Strategic Research Programme 2016-2021 (SRP), the Centres of Expertise, Innovation partnerships and underpinning capacity funding for national resources within SEFARI.

The SEFARI Gateway is the knowledge exchange and impact hub for the Portfolio. The Gateway works to improve the flow of research-knowledge and expertise to and from the Portfolio to policy, industry-sector representatives and public audiences, and to improve the impacts of those activities.

The road back from the COVID-19 pandemic remains a long and difficult one at both individual and societal levels. The recovery is hugely intertwined with the twin priorities of the climate change and biodiversity loss and ensuring a fair and just economy and society that is accessible and valued by all within it. These are immense challenges but ones that science and research can and are responding to. In so doing, SEFARI Gateway remains fully committed to ensuring that stakeholder access to Portfolio expertise and partnership working continues unabated in addressing these priorities and delivering to Scotland's National Outcomes.

The SRP progress updates within this report continue to emphasise the breadth and depth of its contribution to Scotland's environment, land, agriculture, food, rural communities and economy research, informing policy and practice and building partnerships across Scotland, the UK and internationally. Key highlights include: how flood embankment lowering and natural recovery is helping to restore natural connections between a river and its floodplain; how a crucial focus on livestock health can contribute to a reduction in greenhouse gas emissions from livestock farming; work engaging the industry and researchers on the long term sustainability needs of the Scottish Barley sector; a wide ranging series of reports and targeted advice to Scotland and UK government and agricultural sectors on climate policy; and a new web resource bringing groundbreaking research on the role of food choice in influencing our gut microbes with and thereby our health.

The canvas on which this research is illustrated remains the imperative of tackling the consequences of the COVID-19 pandemic, establishing an effective green recovery, and tackling the climate and nature emergencies. Overcoming these challenges will require data-driven solutions and extensive collaboration. Later this year, the 26th session of the UN Climate Change Conference of the Parties (COP 26), and its vibrant fringe events, will take place in Glasgow and is already providing new cross-cutting opportunities. Whether within or outside the COP's "zones," it is a hugely promising opportunity for the Portfolio and its researchers to build collaborations and engage on their research and its value across society both here in Scotland, UK and globally.

Taking forward many aspects of the research and expertise reported here, SEFARI Gateway Fellowships, Specialist Advisory Groups and Responsive Knowledge Exchange projects are continuing to create new and strengthen existing collaborations:

- Working with NatureScot to review the use and application of nature-based solutions frameworks
- Collaborating with the Scottish Forum on Natural Capital on exploring Natural Capital uptake by Scotland's small and medium enterprise food sector
- Cooperating with the Food, Farming and Countryside Commission and Scottish Agricultural Organisation Society (SAOS) on the use of agroecology principles in Scotland's farming and crofting

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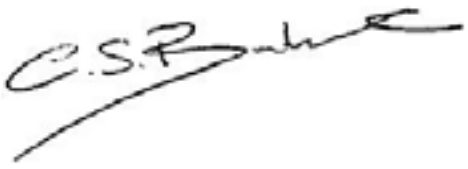
* You can find more information about the structure of the Strategic Research Portfolio and the partners involved (SEFARI, SEFARI Gateway and CoEs) here.

- Our sustainable (circular) economy work, with Zero Waste Scotland and Circular North East, will see reports on Agri-by-product use-and new opportunities in North East Scotland
- Working with Life Sciences Scotland to evaluate Animal Health, Agritech and Aquaculture capacity in Scotland to support the recognition of Scotland's considerable expertise and capacity for innovation across these fields
- A collaboration with SAOS has examined the wider societal-community advantages stemming from cooperation within farm and crofting sectors

In so many areas of work: data, its form, type, collection, accessibility, gaps and needs are featuring as urgent requests for Gateway assistance via Strategic Portfolio Expertise and a range of bespoke projects are now being instigated to meet these needs with stakeholders.

Very best wishes,



Director, SEFARI Gateway

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Summary

Theme 1 - Natural Assets

Funding success: There have been several significant funding successes recently by SEFARI researchers in WP1 that build on work funded through SRP Theme 1. In collaboration with Edinburgh University the researchers secured a £1m NERC capital grant to build an atmospheric research observatory tower. The new facility will measure greenhouse gas composition allowing scientists to model changes in Scotland's carbon sources and sinks. The facility, to be located at the Balruddery Research Farm (James Hutton Institute), west of Dundee, will also be used as a teaching resource. Soil researchers were also successful in winning funding for work on carbon sequestration in re-wetted peats (INSURE) and to develop a Fourier Transform Infrared Spectroscopy Tool to quantify soil organic carbon (funded by the Macaulay Development Trust).

Flood embankment lowering and natural recovery helps to restore natural connections between a river and its floodplain. A 70 m long flood embankment on the upper River Dee in Aberdeenshire was lowered in 2015 to restore habitat and floodplain connectivity (paper here). The monitoring demonstrated that improved river to floodplain connectivity can result from targeted flood embankment lowering and letting the 'river do the work'. Both the embankment lowering and natural changes in river shape due to a series of large floods resulted in large changes to floodplain connectivity. Floodplain water tables rose by 4-9 cm on average, the river flow required for spillage onto the floodplain lowered by 55% and the frequency of floodplain spillage doubled. Such approaches could help to improve catchment resilience to climate change by improving water storage and, hence, reducing downstream flooding.

You can read Theme 1 achievements in full here

Theme 2 - Productive and Sustainable Land Management and Rural Economies

A sustainable future for Scottish barley: Addressing the challenge of long-term sustainability, SEFARI researchers produced a podcast summarising the key messages from an event (held in February 2020) funded by SEFARI Gateway and SSCR where stakeholders in the barley industry were invited to learn about and discuss on-going and future barley research. The aim was to understand the main issues that industry stakeholders face, particularly in terms of priorities for future sustainability, and to explore how barley research can address these needs. The podcast, produced for the virtual Hutton Symposium in November 2020, reviewed the main findings of the event, covering agronomic, environmental and economic challenges associated with current and future barley breeding, cropping and processing, and examined potential solutions to those challenges.

Animal Health and Greenhouse Gas Emissions Study: Endemic production-limiting disease is a major constraint on efficient livestock production, both here in Scotland and globally. Reducing the burden of endemic disease will help improve the biological efficiency of livestock production and contribute to reducing the Carbon footprint of animal agriculture. In order to investigate the impact of natural liver

infections in Scottish cattle, we analysed kill data from ≥52,000 cattle slaughtered between 2014-2017, 3% of which had liver lesions classed as active fluke infection, 18% had lesions consistent with past infection (historic fluke) and 79% showed no evidence of infection. Animals with fluke were typically 14-18 days older at slaughter than those with no fluke and had 4% lower weight gain. We also estimated that the effect of fluke infection represents an approximate 2% increase in greenhouse gas Emissions Intensity (EI). Overall, we conclude that effects of liver fluke on cattle weight gain are substantial and that managing infections is important to improve animal performance and reduce associated greenhouse gas emissions.

Agricultural and climate policy analysis and advice: Agriculture is at the centre of the global debate on greenhouse gas emissions. SEFARI scientists have worked closely with Scottish Government policy, RESAS and the Farmer Led Groups on Climate Change to provide independent analytical evidence and policy support. Theme scientists are members of the Suckler Beef Climate Group Programme Board and the Hill, Upland and Crofting Group (as well as the independent Farming for 1.5 Degree Inquiry). Using methodologies developed in the programme, new analytical insights have been provided on the technical efficiency of the Scottish cattle herd and the distribution of CAP support to sectoral enterprises. In addition, working with scientists from Theme 1 and an independent consultancy, a concept paper was written on how embedding greater environmental conditionality within the existing Direct CAP support framework may evolve the existing support framework to deliver more for the environment. Working with external consultants funded through the SRP, Theme scientists also examined the climate mitigation potential of a number of suckler beef management options through AgReCalc, how management changes may impact on the greenhouse gas Smart Inventory for agriculture, and also what potential impacts on cattle numbers may be expected from adopting mitigation measures. A series of policy advisory notes were also produced including on advisory support and accreditation, Suckler Beef Climate Scheme draft metrics and implementation issues for the Suckler Beef Climate Group Programme Board with the collective aim of supporting industry to achieve both environmental and economic benefits.

You can read Theme 2 achievements in full here

Theme 3 - Food, Health and Wellbeing

Scottish Parliament Committees: Utilising the diverse expertise available within SEFARI and the SRP, researchers engaged with two Scottish Parliament committees. Evidence was given to two sessions of the Scottish Parliament Health and Sport Committee: a session in December 2020 considered the "Provisional UK Common Framework on Nutrition labelling, Composition and Standards nutrition and health claims made on foods", while a session in January 2021 considered the "Provisional UK Common Framework on Food and Feed Safety and Hygiene (FFSH)". The challenges facing Scotland and the UK in respect of the post-Brexit arrangements regarding food regulation were highlighted in written evidence and in extensive discussion in each session. SEFARI researchers also gave evidence at the Scottish Parliament Environment Climate Change and Land Reform Committee, discussing the definition of 'sustainable development' and 'community', as described in the draft Right to Buy Land to Further Sustainable Development (Eligible Land, Specified Types of Area and Restrictions on Transfers, Assignations and Dealing) (Scotland) Regulations 2020.

Microbe Safari: The role of gut microbes in human health has achieved widespread recent scientific and public recognition. SRP work has been at the forefront of internationally recognised research on the impact of food choice on the diversity and composition of such microbes. To respond to burgeoning educational and public interest, SEFARI researchers have established an educational website focussed on microbes, food and health. The interactive website, Microbe Safari ('from the field to the fork and further'), contains detailed information on microbes and how they relate to gut health, food safety, food production, and the environment, with an emphasis on how all these areas are connected. The Microbe Safari website engages the general public and is accessible for school children. The site hosts resources for use in classrooms, with new and topical material being added to the platform over time. This project benefitted from input and support from FSS.

You can read Theme 3 achievements in full here

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Theme 1 - Natural Assets

Work Package 1.1: Soils

Major Achievements

- **Policy publication:** A ClimateXChange funded report showed that Scotland has a significant, world-leading soil knowledge base. However, the existing evidence base on soils does not contain tools identified as appropriate for monitoring change in Scottish soils. The report, which was signed off by the cabinet secretary for Environment, Climate Change and Land Reform, has resulted in a follow up study being commissioned.
- **Root hairs for improved tolerance to drought and phosphorus deficiency:** SEFARI scientists and collaborators have demonstrated the importance of maintaining root hairs on crop plants designed to cope with the impacts of environmental change. In two recently published papers root hairs in barley were found to be critical in maintaining yield in the extremely dry growing season of 2018 and modelling work has demonstrated that root hairs are able to allow plants to acquire more of the phosphorus stored in soils following fertilisation.
- **COVID-19 impact on UK systems:** SEFARI researchers co-authored a recently published paper on the impact of covid-19 on UK food and nutrition security. The study provides an opportunity to place the initial lessons being learnt from the ongoing responses to the pandemic in respect of food and nutrition security in the context of other long-term challenges such as climate change and biodiversity loss.

Work Package 1.2: Water

Major Achievements

- **Researching the multiple benefits delivered by catchment partnerships:** Based on research in four catchment partnerships in the UK, a report explored if and how partnerships can help deliver multiple benefits. It suggests the work of partnerships can be valuable for helping to connect various priorities, not only from policy but also more local groups, going beyond what would otherwise be done to manage catchments. The benefits of partnerships largely arise from the coordination and communication aptitudes and efforts of individual representatives within partnerships, and especially coordinators, and these must be valued and recognised. However, partnerships cannot do it all, especially in a climate of austerity, so the report cautions against expecting partnerships to deliver against too many aspirations.
- **Understanding riparian zones provides catchment benefits:** Collaborations between SEFARI researchers, Irish colleagues (Teagasc Institute) and Irish EPA funded research (Smarter BufferZ) led to a paper reviewing the use of spatial datasets to represent riparian functions such as canopy shade effects on the stream, flood inundation effects on the land. The work shows that knowledge of the spatial location of soils, topography, water flows and vegetation is critical in order to understand riparian condition and functions and to enable effective targeting of restoration of riparian zones.
- **New research on diffuse pollution modelling:** International collaboration has built on past SRP work, to produce two papers (available here and here) published in special journal issues that help to advance the science on diffuse pollution modelling to inform water quality policy and management. Increased use of Bayesian network (BN) models, which are a tool for probabilistic and causal modelling, have been shown to improve environmental risk assessments for toxicology and water quality.

Work Package 1.3: Biodiversity

Major Achievements

- **Sustainable feedstock processing**: A SEFARI-scientist/industry collaboration has established an optimised method to process beans for brewing and distilling. Crop, product, and coproduct qualities demonstrate the environmental, nutritional, and commercial potential of the new method in support of more sustainable agri-feed and -food systems.

- **Enabling more sustainable food- and feed-systems:** As part of an EU-wide team, a SEFARI researcher has discerned twenty-one enabling approaches to increase the production and consumption of home-grown legumes. These practical approaches present integrated strategies to benefit the environment, society, and the economy.

- **Bere barley diversity contributes to sustainability and value chain diversification:** SEFARI scientists have made further discoveries related to the importance of maintaining Bere barley diversity for its value to sustainability. Scotland's traditional barley variety, Bere, has been shown to be particularly able to cope with micronutrient deficiency and traditional growth with seaweed as a fertiliser has driven the evolution of this ability. Genes associated with the ability of Bere to cope with manganese deficiency specifically have been identified. The importance of Bere as a heritage variety with value chain diversification credentials has been recognised in its inclusion in a successful bid for EU Horizon 2020 funding (RADIANT), which secured additional funding of €6M for the consortium.

- **Forest microclimates:** SEFARI scientists have identified the conditions under which forest expansion and management today can create microclimates that support the diversity of globally rare Scottish rainforest into the future (under climate change). This will assist spatial planning among the wide range of stakeholders tasked with meeting Scotland's reforestation targets, to benefit nature over the long-term.

- **Liver fluke risk and agri-environment schemes:** Wetland birds are in decline but establishment of wetland areas to promote their conservation has previously been thought to be incompatible with grazing animals due to the risk of liver fluke. However, SEFARI scientists have shown that the risk to livestock of catching liver fluke in these wetlands would appear to be lower than in the neighbouring in-bye fields. Results are summarised in a SEFARI Case Study and associated podcast.

- **Biodiversity-function relationships in sustainable crop production:** SEFARI scientists have produced a review article that links fundamental ecological understanding of the role of biodiversity in delivering ecosystem functions to the pressing need for developing sustainable crop production systems. The article reviews the potential benefits to multiple ecosystem functions and services from enhancing diversity in crop systems, for example through intercropping, and is relevant to research, as well as those interested in the development of sustainable farming policy.

- **A New approach to assess carriage of antimicrobial resistance genes by a marine sentinel species:** SEFARI scientists have successfully applied cutting-edge DNA sequencing technologies to detect antimicrobial resistance (AMR) genes in faecal samples from the Scottish grey seal, which is an important indicator species of environmental contamination. The method employs Nanopore technology and allows rapid identification of the bacteria that carry the AMR genes, shedding light on potential routes of AMR genes at the wildlife–livestock interface. The work was presented at the 6th World One Health Congress (Virtual Edition).

- **Moult and climate change:** Research by SEFARI scientists in collaboration with colleagues in America showed increased camouflage mismatch in mountain hares due to climate change. Despite on average there being 35 fewer snow days per year compared to 70 years ago, mountain hares have not adapted the timing of either their autumn or spring moults.

- **Small mammal monitoring:** Working with colleagues from the RSPB and the Mammal Society, SEFARI scientists have developed an innovative camera trapping technique to study small mammal populations. The technique provides a low-cost survey method for small mammals that is labour-efficient and has minimal animal welfare implications.

Work Package 1.4: Integrated Land Use Systems

Major Achievements

- **Natural assets' contribution to community development and well-being:** Purchasing and managing community woodlands is one way rural communities push forward their own development through socially innovative projects. SEFARI researchers have studied the impact of social innovation in the context of community forestry on the sustainable development of rural communities. They found that social innovation in the context of community forestry leads to positive impacts in the environmental, social, economic and institutional/governance domains. In particular, community woodlands increased community cohesion, sense of place and well-being while at the same time creating local employment opportunities.

- **Cooperative approaches to water management:** A comprehensive 5-year study of water resources in the Lunan and Dee catchments has explored cooperative approaches to management of water flow and the linkages between land and water resources. Key findings are that land ownership, concerns over committing to long-term management of potential interventions, and the need for a stronger evidence base setting out benefits from interventions are important factors in establishing effective cooperative management schemes.

- **Landscape scale farm management:** Building on the results from Theme 1 work on the environmental benefits of collective landscape scale farm management, the work is now taking on an international dimension. Supported by funding from the EU, Farmer Clusters like the one established in the Balruddery Catchment are being established across Europe with the objective of developing and implementing biodiversity friendly farming and promoting Integrated Pest Management. This approach is also gaining ground in Scotland with farmers keen to form landscape scale Clusters in Inverness-shire, Aberdeenshire, and Strathmore.

Theme 2 - Productive and Sustainable Land Management and Rural Economies

Work Package 2.1: Crop and Grassland Production and Disease Control

Major Achievements

- **Development of barley varieties with improved quality, yield and resilience:** SEFARI scientists, as part of an international collaboration, have identified natural genetic variation in a gene, HKT1;5, that allows barley plants to accumulate high concentrations of sodium without any adverse impacts on plant growth. These findings advance our understanding of sodium transport throughout the plant and aid in the development of barley varieties with improved yield and resilience. The genetic basis of barley malting quality has been studied using new genomic approaches which have identified genetic factors that will be important for breeding improved barley varieties.
- **Accelerating breeding of disease resistant potato varieties**: SEFARI scientists, as part of an international collaboration, have developed and applied diagnostic resistance gene enrichment sequencing (dRenSeq) and identified functional and effective disease resistance genes against late blight, PCN, and viruses in existing potato varieties and breeding clones. Importantly, we have developed informative markers for all major late blight resistance genes that are important for breeding improved potato varieties. These findings have informed potato breeding programs that aim to prolong the longevity of existing pathogen control strategies.
- **New findings about stem-lesion nematodes:** SEFARI researchers have generated data to underpin studies on the emerging problem of stem lesion nematode on several crops. This work has been reflected in a recent peer-reviewed manuscript and an invitation to participate in an EuPhresco project to characterize stem lesion nematodes within Europe and populations moving in trade. Furthermore, this supports work in a recently funded UKRI project on bacteria-nematode disease complexes. Information generated was disseminated in two virtual meetings, AHDB Agronomy Week (Dec 2020) and AAB Nematology conference (Dec 2020) with delegates from UK, Europe, Asia and Oceania.
- **Sustainable feedstock processing:** A SEFARI-scientist/industry collaboration has established an optimised method to process beans for brewing and distilling. Crop, product, and co~product qualities demonstrate the environmental, nutritional, and commercial potential of the new method in support more sustainable agri-feed and food systems.
- **Hemp Futures**: SEFARI scientists co-hosted an online art/science gathering which showcased the importance of hemp and in particular its net zero benefit. The workshop was part of the ROF SEFARI Gateway project, Hemp for 45 (Hemp Project). The SEFARI scientists engaged with craft makers and craft food producers to understand the demand for hemp for craft and materials or products in Scotland.
- **IPM for potato late and early blight:** The Hutton criteria, a tool for the prediction of late blight according to weather conditions, was previously developed through SRP research. We used this predictive tool to demonstrate the control of potato late blight in a sustainable management programme at the Centre for Sustainable Cropping, resulting in effective targeting of fungicide applications in periods of low disease risk. A SEFARI member will build upon this research through the coordination of a recently funded EU SusCrop project 'ECOSOIL' (2021-24, €800k). The consortium of scientists, with extensive stakeholder involvement, aims to identify effective alternatives to conventional pesticides and to integrate these, with other measures, into practical and effective IPM strategies for late blight and early blight of potato.

Work Package 2.2: Livestock Production, Health, Welfare and Disease Control

Major Achievements

- **Appropriate antimicrobial usage (AMU) in the sheep industry**: The monitoring of appropriate AMU is an important part of efforts to address the global challenge of the development of antimicrobial resistance. In 2019, the Sheep Antibiotic Guardian Group published a set of flock-level core metrics that could be used for flock-level benchmarking and to estimate AMU in the wider sheep sector. In 2020, two online questionnaires were used to gather evidence about the recording of these core metrics by Scottish Sheep farmers and their veterinary surgeons. The results, which are likely to describe the 'best-case' scenario due to self-selection of respondents, have provided evidence to support anecdotal understanding that neither of these communities can provide all of the core metrics required. A joint approach with flock-owners providing the flock structure and productivity metrics, working in conjunction with their vet to calculate and validate the appropriate measure for the amount of antibiotic used (total mg/flock/calendar year) is required. A number of industry initiatives are being developed to provide the core metrics for AMU in sheep flocks.
- **Bayesian inference of on farm disease dynamics from mortality data:** Pathogens such as African swine fever virus (ASFV) are an increasing threat to global livestock production. Quantification of epidemiological parameters, such as within-farm transmission rates and latent and infectious periods is critical to inform efficient disease control. Routinely collected livestock mortality data is a potential source of readily available and representative information regarding disease transmission early in outbreaks. We developed methodology to make use of such data and tested it by inferring epidemiological parameters for ASFV using data from outbreaks on 9 farms in the Russian Federation. Our methodology performs better than current methods, quantifies transmission within-farm and from external sources, and allows combination of data across multiple herds, improving inference, and can be applied to other outbreaks or pathogens in the future.
- **Managing beef cattle body condition in pregnancy to improve calf viability and growth:** Body condition scoring is a rapid way to assess fat coverage of cows. Previous Scottish Government funded work suggested that only around 4% of beef farmers used the recommended condition scoring approach. Maternal stress can affect pre- and post-natal development, but this work studied for the first time whether obesity, leanness, or a change in condition in pregnant cows could harm calf welfare and growth. We condition scored 2366 cows on 21 beef farms twice during pregnancy, thereby creating the largest dataset of its kind. Results indicate that obesity during the earlier stages of pregnancy, especially if followed by substantial condition loss as pregnancy progresses, is likely to reduce the size of calves at birth, together with their neonatal vigour and growth rate up to weaning. The work suggests much scope to better manage body condition and that calf viability and growth are improved by a moderate condition score and avoiding large swings in condition over time. The project leveraged additional funding for creation of models with which to train farmers in condition scoring.
- **CT rumen volumes of sheep to predict methane emissions:** Initial work confirmed international research findings that rumen morphology, measured by CT, was associated with methane emissions from sheep. Larger rumen volumes are linked to increased methane emissions. Using CT image archives, statistically significant breed differences in rumen volume were identified between Scottish Blackface (hill breed) and Texel (terminal sire breed) lambs, reared together on lowground pastures. At the same live weight, Blackface lambs had average rumen volumes 26% higher than those of Texels, with males having larger volumes than females. Significant sire differences were identified, suggesting genetic control of rumen volumes within breed. Moderate to high negative correlations were estimated with muscling and muscularity (implying that more muscled lambs have smaller rumens). These measurements have been taken forward into the Grass To Gas (ERA-Net) project to further investigate strategies to reduce GHG emissions from sheep.

Work Package 2.3: Productive and Sustainable Land Management

Major Achievements

- **Land management effecting soil biology:** SEFARI researchers from WP2.3 have generated datasets that have explored the impact of land management on soil biological communities. For example, liming was shown to have a limited effect on nematode and microbial community structure; long-term application of organic fertilizers resulted in nematodes having higher enriched levels of Antimicrobial Resistance Genes (ARGs) than earthworms undergoing the same treatment and that the transfer of ARGs in the soil-nematode-earthworm food chain is a potential mechanism for a wider dissemination of ARGs in the soil ecosystem; and land use and season were the main drivers of soil nematode communities in fragile Machair habitats. Integrated with work from WP1.1 and WP2.1, knowledge generated in WP2.3 was disseminated in two virtual meetings, AHDB Agronomy Week (Dec 2020) and AAB Nematology conference (Dec 2020) with delegates from UK, Europe, Asia and Oceania.
- **Reducing greenhouse gas emission from grassland production systems**: SEFARI scientists published a paper in Agriculture, Ecosystems and Environment entitled 'Use of a nitrification inhibitor reduces nitrous oxide (N_2O) emissions from compacted grassland withdifferent soil textures and climatic conditions' related to the controlled traffic work on soil compaction. The economic assessment of the controlled traffic system incorporating red clover in the sward showed the benefits of the increased protein from the clover and the associated reducing in imported soya in the dairy cows' diet. Additionally, the increased yield from the reduction in soil compaction of the controlled traffic provided further reductions in cost for the implementation of the guidance systems. These data are feeding into the AHDB GreatSoils Partnership. New funding to SEFARI researchers is helping to explore future GHG reduction technologies in ruminant agriculture, including Defra funding to review of net impacts, barriers to success and consumer acceptance of methane-inhibiting livestock feed supplementation and Horizon 2020 programme to elucidate the role of ruminant-associated microbiomes and their interplay with the host in early life and throughout fundamental life event. These projects will help develop future solutions for further improving ruminant sustainability.
- **Data driven solutions for livestock sustainability and decision support tools:** The importance of data to drive decision makig processes in farms and food chains has been recognised through recent funding success. A new Horizon 2020 project (Data-driven control and prioritisation

of non-EU-regulated contagious animal diseases) will develop data-driven decision support tools and workflows that enable farmers, veterinarians and other animal health managers to improve control of prevalent non-EU-regulated contagious animal diseases based on a multidimensional burden of disease metric. Further, AHDB have awarded a project to help specify for prototype data dashboards for farmer based on the statutory cattle data. SEFARI researchers will help to identify and characterise key data and methods of integration leading to the development of future decision support tools based on real time industry data capture.

- **The potential of pulse supply chains in Scotland:** SEFARI researchers were successful in establishing a Rural Innovation Support Service (RISS) group, facilitated by Soil Association Scotland, on the potential of pulse supply chains in Scotland. The group comprises 10-15 stakeholders and researchers across the supply and value chain with a focus on legume and pulse production, processing and consumption. The group provided expert input regarding the contribution of legumes to climate mitigation in the Farmer-led Arable Climate Change Group consultation. The pulse RISS group intends to continue as a forum for legume growers, processors, value chain actors and researchers to discuss and address knowledge, technical and policy gaps. A Friends of the Scotsman article 'National protein plans could benefit our health and the environment' was published on 11th February 2021 to coincide with World Pulse Day.

Work Package 2.4: Rural Industries

Major Achievements

- **UKRI COVID-19:** Food and Nutrition Security during and after the COVID-19 Pandemic: This SEFARI led and UKRI funded project has drawn on expertise from across the SRP to look at the rapidly changing short/medium term economic and social consequences of COVID-19 for food security. It considers impacts on the four pillars of food security: availability, access, utilisation and stability. Particular emphasis has focused on economic access and the potential for disruptions to supply chains.

- **Peatlands and Payments:** Geospatial data on land use and ownership from Theme 2 were combined with new data on peatlands extent developed in Theme 1 to provide Scottish Government with insights into the degree of exposure of land-based businesses to peatlands, using the peatland typology developed for the UK GHG inventory. This is helping the Scottish Government better understand the spatial dimension of different types of degraded peatland and emissions in relation to agricultural practices and agricultural support payments. This information will allow agriculture and peatland restoration policy decision makers to make more informed choices about the preferred areas for targeting peatland restoration offers. The analysis specifically informs policy options for the Climate Change Plan update.

- **Farmer Intentions**: Four further research notes were produced based on analyses of the 2018 Farmer Intentions Survey and the 2013 CAP Intentions Survey.

  1. Data from both surveys was used to analyse how well actual (self-reported) farm management behaviour matched previously expressed intentions, for different farm activities. The research notes evidence regarding unexpected changes suggest that farmers can underestimate their potential to adapt.

  2. Comparison between commercial female and male farmers highlighted that female farmers were more likely to collaborate, to have not inherited their business, to have higher education qualifications and often to have different income generation strategies.

  3. Analysis of social media and internet access in Scottish farming demonstrates that poor internet connectivity remains a significant barrier to both diversification activities and farm management by new entrant farmers. Social media and the internet were found to be of little help as information sources by established farmers, but to be of more helpful to new entrant farmers.

  4. Considering Scottish farmers' attitude to perceived risk, we found that around 20% of farmers were risk takers, with the remainder being classed as more cautious or risk averse. There was a fairly even spread of risk perceptions across farming types, with risk takers

more likely to emerge from very large farms, and risk averse farmers from very small farms. Older farmers were found to be more risk averse, and a higher proportion of risk cautious and risk takers are under 45. This led to several press reports on the work in the farming press.

- **Women in Farming and the Agricultural Sector:** Further to the Scottish Government commissioned research (2017), four online focus groups have been held to gather views and experiences of the changing role of women in agriculture in Scotland. The focus groups, involving women and men who had originally participated in focus groups contributing to the 2017 report, have indicated that awareness of gender issues has increased within farming and crofting communities. New training initiatives to support women in agriculture have been met positively, although there is debate on whether the social norm of male succession in farm businesses has shifted.

- **Policy integration in delivering the EU sustainability and climate change goals:** Theme 2 SEFARI scientists along with Theme 1 researchers contributed to the completion of the H2020 MAGIC project – using societal metabolism methods to assess the need for greater policy integration in delivering the EU sustainability and climate change goals. The report on the interactions between CAP and the delivery of the UN Sustainable Development Goal 2 (Zero Hunger) highlighted the need to consider the negative externalities that imports of livestock feeds may be having on greenhouse gas emissions and habitat loss. The analyses underpinned several briefings, and an online mapping application which were deliberated on at events with European Commission staff and European parliamentarians and formed the basis for a seminar with SG analysts and policy makers.

- **The future of the EU livestock sector:** How to contribute to a sustainable agricultural sector? Linked to their work in Theme 2, SEFARI researchers authored a report for the European Commission (EC-JRC and DG AGRI) on the Future of EU Livestock in October 2020. The work examined climate and biodiversity impacts of the livestock sector, and provided opinion on potential pathways to improved livestock sustainability. The scientists also presented the work at a workshop organised to discuss the future of EU livestock along with other scientists and policy and industry stakeholders in March 2021, attended by over 200.

Theme 3 - Food, Health and Wellbeing

Work Package 3.1: Improved Food & Drink Production

Major Achievements

- **Soft fruit compounds**: Components in raspberries exhibited genoprotective effects in the human digestive tract in vivo, possibly reducing risk of colonic cancer. A model study identified positive impacts of raspberry compounds and their digestion metabolites on neuroprotection (e.g. protection against Alzheimer's or Parkinson's diseases) via neuroinflammatory pathways.
- **Food reformulation:** A paper reported the nutritional implications of trade-offs between fresh and processed potato products, where price reductions in processed potatoes increased weekly intake of calories, saturated fat and sodium, implicated in cardiovascular diseases and certain cancers.
- **Food safety:** A method was developed for the detection of important food borne pathogenic bacteria (STEC O157:H7) from horticultural crops allowing low level detection of pathogens in a high-throughput screen. Researchers set up an interactive educational website focussed on microbes, food and health, 'Microbe Safari', with detailed information on these microbes and how they relate to human gut health, food safety, food production and the environment. The website engages the public and school children, with input and support from Food Standards Scotland.
- **Food waste:** Reflecting SRP expertise, invited talks were given at the Defra & Agricultural Economics Society meeting 'Strengthening resilience in the food supply chain' (Dec-20), and the International Society for Economics and Social Science on Animal Health meeting (Nov-20), on "Tackling food waste and improving food safety to boost resilience" and "Reconciling health, welfare and the environment. Economics of surveillance and beyond", respectively.
- **Vertical farming:** Theme researchers and a consortium of Liberty Produce, a UK vertical farming company, and LivFresh, a Singaporean company, were awarded £421k by Innovate UK for "Hybrid Advanced Research Vertical-Farming Environment Systems and Technology (HARVEST)" as part of the EUREKA GlobalStars Singapore programme. This offers the opportunity to transform the safe production of food world-wide, despite the scarcity of land.

Work Package 3.2: Healthy Diets and Dietary Choice

Major Achievements

- **Scottish Parliament Health and Sport Committee:** A Theme researcher gave written evidence to two committee sessions on behalf of SEFARI. The session in Dec-20 considered the "Provisional UK Common Framework on Nutrition labelling, Composition and Standards" and that in January 2021 considered the "Provisional UK Common Framework on Food and Feed Safety and Hygiene (FFSH)". Extensive discussion highlighted the challenges facing Scotland and the UK in respect of the post-Brexit arrangements regarding food regulation.

- **Publications:** Theme researchers published papers on (i) epigenetic imprinting and the change with age, describing the use of cutting-edge molecular techniques to understand the basis for the transgenerational persistence of disadvantage that is increasingly seen in Scotland and globally, and mechanisms by which processes set in train in early life can influence brain health in later life; (ii) the public health rationale for promoting plant protein as an important part of a sustainable and healthy diet; (iii) the important role that lactate-utilising bacteria play for maintenance of stability within the microbial community in the human gut, and (iv) identifying human gut bacteria that are involved in mycotoxin metabolism.

- **Food swaps for an improved diet:** Theme researchers updated their NDNS Nutribank+ dataset with nutritional, 2021 cost and greenhouse gas emission (GHGE) data for almost 6000 food items from the British diet, identifying food swaps to make individual shopping lists healthier, greener and more affordable. New exploratory analysis revealed that within EatWell food categories, such as, for example, dairy and alternative items, very strong significant negative correlations exist between nutritional quality and cost, nutritional quality and GHGE, and cost and GHGE, across individual food products. This suggests that, with the right tools, there is scope for further improvement in diets, based on food swaps within EatWell categories.

Work Package 3.3: Food Security

Major Achievements

- **Impact of the COVID-19 crisis on food and nutrition security in the UK:** A paper in Nutrition Bulletin reviewed the effect of the COVID-19 crisis on food and nutrition security, with ESRC funding, arguing that COVID-19 is part of a worsening 'perfect storm' for UK food and nutrition security. Globally, the impacts of economic pressures arising from COVID-19 have been relatively mild, but in the UK have highlighted burgeoning inequalities in access to nutritious food. It recommends emphasizing resilience over efficiency in food supply systems, combining agroecological measures to improve biodiversity with behavioural change to offset reduced yields, and potential benefits of increasing home-grown protein supply through legumes.

- **Agent based global trade model:** The FeedUs model was published in Royal Society Open Science, demonstrating that increasing opportunities for trade have an important role in securing global macro- and micronutrient security. The model simulates countries as agents and uses the FAO Food Balance Sheet and Comtrade data for calibration and validation. To simulate the effect of trade, the model uses a 'trade saturation' parameter representing the proportion of possible exchanges of food between pairs of countries that are actually realized. The results suggest that high trade saturation enables all countries to theoretically meet their populations' requirements for calories and zinc, but not fat, vitamin A, or iron. Low trade saturation predominantly affects countries in Africa, Central America, and the near East.

- **Publications:** Theme researchers published a paper entitled "Nutritional and environmental assessment of increasing the content of fruit and vegetables in the UK diet", organised journal issues on "Marketing Environment and Nutrition Quality" and "Household Food Purchases and Sustainable Diets", and published a blog "Should food standards be left to the market in post-Brexit Britain?" in the London School of Economics blog, LSE Business Review.

These highlighted the importance of specific changes to the diet (increasing fruit and vegetables). Another paper "Food ideals, food rules and the subjective construction of a healthy diet" reported that those individuals who employed both food rules and rules for breaking their food rules appear more likely to be able to maintain eating patterns that they considered healthful.

Work Package 3.4: Communities and Wellbeing

Major Achievements

- **Scottish Parliament Environment Climate Change and Land Reform Committee:** Theme researchers gave evidence to the ECCLR committee on the definition of 'sustainable development' and 'community', as described in the draft Right to Buy Land to Further Sustainable Development (Eligible Land, Specified Types of Area and Restrictions on Transfers, Assignations and Dealing) (Scotland) Regulations 2020.
- **COVID-19:** Planned research to understand the impacts of COVID-19 on rural and island communities has been carried out, and has just reported, including the impact of the pandemic, factors that have promoted resilience and the prospects for a rural and island recovery.
- **Flooding:** A presentation to over 400 delegates on 'The long-term impacts of flooding: understanding individuals' wellbeing and resilience in the years after flood happens' was a Keynote speech at the SNIFFER flood-risk management conference (Feb-21).
- **Place-based policy:** A Theme researcher gave a presentation on demographic change and place-based policy at a webinar entitled 'Rural and Thriving: Scottish and Nordic Lessons on Reversing Depopulation' organised by the Scottish Government's Nordic and Arctic Unit.
- **Demographic foresight:** Theme researchers published a report entitled 'Population projections and an introduction to economic-demographic foresight for Scotland's sparsely populated areas (2018-43)'. A press release included a quote from Rural Economy Secretary, Fergus Ewing emphasising the importance of the sustainability of rural communities.
- **Agenda setting framework for biodiversity and health:** Theme researchers were involved in the development of an integrated framework, drawing on social, natural and health sciences, to identify the pathways for how biodiversity might influence human health. Understanding these pathways can inform policy and practice.

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