Year 6, February 2021 to August 2021

Progress Report on Strategic Research Programme Delivery

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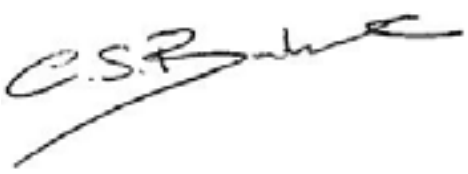
The Scottish Government's Strategic Research Programme (SRP) for environment, land, agriculture, food and rural communities 2016-2022 is delivered by the Scottish Environment, Food and Agriculture Research Institutes (SEFARI). The SRP is the mid to long term research component of the Scottish Government Strategic Research Portfolio*, which, in addition to the SRP, includes the underpinning of SEFARI national capability resources and, in partnership between SEFARI, Scottish Universities and Agencies, the policy facing Centres of Expertise. SEFARI Gateway is the Knowledge Exchange and Innovation Centre for the Strategic Portfolio. Gateway works to enhance access to the Portfolio's individual and interdisciplinary expertise, strengthening and building new partnerships with policy, agencies, sector organizations and across civic society.

This report provides a snapshot of SRP research and allied knowledge exchange covering the period between February 2021 to August 2021. Society and economies continue to be drastically affected by the COVID-19 pandemic and intertwined by challenges from the altering and often difficult international trading relationships. The report continues to reflect the ongoing contribution of SEFARI's strategic research, expertise, and resources to the COVID-19 response and to support Scotland's rural economy and communities. Looking forward into the autumn, the contents of this report are hugely relevant for the first phase of the UN Biodiversity Conference (October 11-15, in Kunming, China) and the crucial UN Climate Change Conference (COP26; October 31 – November 12, in Glasgow). Both conferences will provide a global and intense focus on the climate and nature crises, and the complex array of challenges these threats pose and are causing to our natural environment, food systems, economic and social fabrics, and our daily lives. The science is clear and there is an undeniable and urgent need to act at pace and scale to achieve net zero targets (by Scotland in 2045) and limit global warming to or below 1.5^{0} celcius.

For Scotland, the research and national research capacity supported through the Strategic Portfolio forms a vital component in the Nation's response to these twin crises. Highlights within this report include Scotland's first purpose-built tall tower greenhouse gas observatory; research on estimated greenhouse gas emissions and their mitigation in the agriculture 'smart inventory' for arable, sheep and dairy; new statistical methods that use on farm data to help to predict exotic disease threats to Scotland's livestock sectors; a collaboration with farmers to develop crop species mixtures as a sustainable farming practice; and finally, examining the potential synergies in Scotland with Arctic and near Arctic regions and opportunities from food innovation clustering at local, regional, national and international levels to benefit communities and their local economies.

Looking ahead to COP26, Glasgow will be at the centre of the global climate conversation. SEFARI Gateway, and SEFARI, will be present to showcase these and other Portfolio research innovations and practice changes, and crucially will continue to build new connections and partnerships with sectors and communities in delivering for climate action and Just Transitions for Scotland.

Very best wishes,



Director, SEFARI Gateway

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

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Summary

Theme 1 - Natural Assets

Crop mixtures for sustainable farming using a 'field lab' approach: SEFARI researchers are working with farmers to trial crop species mixtures as a sustainable farming practice that diversifies the cropping system. The research trials over recent years have shown that growing compatible crop combinations can improve crop productivity, reduce the need for chemical inputs, and support beneficial organisms, such as pollinators and natural enemies of pests. To validate these findings in realistic farming conditions, farmers were invited to carry out trials of crop mixtures of their choosing – typically cereals and legumes – selected according to their local growing conditions and downstream value chains. Researchers supported farmers in trial design, management, and data collection, and hosted online workshops and webinars to facilitate practical knowledge sharing with other innovative farmers, agronomists, machinery specialists, processors and policy advisers. In addition, the development of educational resources for schools has been an important outlet for communicating the benefits of crop mixtures for biodiversity conservation and farming sustainability. The successes and challenges of this work are summarised in a podcast recorded for the 'Cereals' agricultural event in July 2021.

Bloomin' Algae app helps to reduce risks to public and animal health from harmful algal blooms: A new version of the Bloomin' Algae app was completed in March 2021 to include real-time maps of harmful algal blooms and provide a more rapid feedback to agencies and recorders. Following testing with SEPA, local authorities and Scottish Water, it was officially released on 12th May 2021 and summarised in presentations and training sessions to agencies. So far, 85 records have been submitted from Scotland with 61% (52 sites) considered correct records of harmful algal blooms and another 20% (17) plausible. This has led to more rapid broadcasting of warning notices by local authorities and landowners (including Scottish Water and NatureScot), reducing risks to public and animal health.

Read Theme 1 achievements in full

Theme 2 - Productive and Sustainable Land Management and Rural Economies

Delivering a sustainable potato industry for Scotland through management of the Potato cyst nematode (PCN): A PCN Working Group comprising more than 50 SEFARI scientists, Scottish Government and industry stakeholders was formed to address the urgent industry need for solutions to PCN management in Scotland where PCN is a major economic burden. Research priorities were identified and a programme of work which draws on Strategic Research Programme (SRP) knowledge and expertise in potato breeding, PCN biology, economic analysis and Integrated Pest Management, working in collaboration with industry partners, was announced by the Scottish Government to coincide with the Potatoes in Practice event. The project is worth more than £2.2M over 5 years and is funded by the Scottish Government through

Climate Change and Greenhouse Gas emission inventory for arable, sheep and dairying: There is still much discussion and argument as to the contribution different farming sectors make to greenhouse gas emissions. Research papers were provided to the Scottish Government on estimated greenhouse gas emission and their mitigation in the agriculture 'smart inventory' for (a) arable (b) sheep and (c) dairy.

Building on these reports and previous submissions on suckler beef a consolidated report on Disaggregating headline Smart Inventory figures for Scottish Agriculture was submitted that provides Scottish Government analysts and policy leads estimates of sectoral contributions (and sources within sectors) to Scottish agriculture's greenhouse gas emission's profile. Researchers also completed a paper for the Scottish Government examining emissions intensity (EI) of Scottish beef compared to dairy-beef and beef produced in other countries providing insights into how Scottish beef production compares to the footprints of competitors and the drivers of these EIs. A further piece of research on greenhouse gas emissions from the Scottish Food and Drink sector was completed for Scotland Food and Drink that examined the EI of Scottish food production and opportunities to mitigate climate change as Scotland transitions to a net zero economy.

Statistical methods using on farm data help to predict exotic disease threats: 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. SEFARI researchers have developed methodology to make use of such data and test it by inferring epidemiological parameters for ASFV using data from outbreaks on 9 farms in the Russian Federation. The methodology performs better than currently available methods, quantifies transmission within-farm and from external sources, and allows combination of data across multiple herds, improving inference. The methodology is flexible enough to be applied to other outbreaks or diseases.

Read Theme 2 achievements in full

Theme 3 - Food, Health and Wellbeing

National Islands Plan Survey: SEFARI researchers have had an important role in the development of the National Islands Plan, which aims to improve life in Scotland's islands. Researchers held the project leadership of the National Islands Plan Survey, designing, distributing and analysing the survey for the Scottish Government. The survey was sent to 20,000 residents of the Scottish islands to collect data on perceptions of key aspects of island life, reflecting the strategic objectives of the National Islands Plan (2019). The researchers authored the final report, released in July 2021, and have produced a visual summary of the results and an online results explorer. The survey has significantly improved the availability of data held about Scotland's islands, for example, a number of the findings appear to contradict assumptions that are sometimes made about Scotland's island residents and will provide important baseline data against which to measure the effectiveness of the Plan. Groups of islanders that were developed as part of the survey will continue to be involved by the Scottish Government in future consultations. Island communities were also involved in a report by the same researchers on responses to COVID-19 in rural and island communities.

Fellowship on the development of Food and Drink opportunities with Arctic Foods Innovation Cluster: A SEFARI Fellowship was set up to identify potential opportunities to engage with food and drink sector partners in the Arctic Region, stimulated by the development of an Arctic Foods Innovation Cluster (AFIC). Key areas of interest for the Fellow included the Highlands and Islands as a food producing region - the opportunities and challenges, and potential synergies with Arctic and near Arctic regions, the identification and comparison of clusters operating at local, regional, national and international levels, and research and innovation (i.e. Scottish food research strengths and innovation). The resulting report (and summary) outlines the economic and policy contexts of the Arctic region, drawing out contrasts and similarities with the Highlands and Islands. Aspects of the values and behaviour of food and drink entrepreneurs are explored using new data from a separate Scottish Government-funded research project. The report concludes by reflecting on innovation and clustering in the food and drink sector in Scotland's Highlands and Islands and suggests avenues for further work and engagement.

Read Theme 3 achievements in full

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Theme 1 - Natural Assets

Work Package 1.1: Soils

Major Achievements

- **Scotland's first purpose-built tall tower (100 metres) greenhouse gas (GHG) observatory:** SEFARI Researchers, in collaboration with Edinburgh University, secured funding from NERC to build a tall tower at the Scottish Government's underpinned Balruddery Farm, near Dundee. The facility will help environmental scientists measure the composition of greenhouse gases, to model GHG changes in Scotland over the coming years and decades.

- **Report on Soil Health commissioned by ClimatexChange (CxC):** This new report assesses the efficacy of thirteen potential indicators of soil health identified in a 2020 CxC review. The report considers the relevance and suitability of these indicators across ten land uses (agriculture uncultivated, open upland habitats, environmentally sensitive areas, grassland, arable, peatlands, forestry, urban, amenity, and transport infrastructure), in the context of identifying potential impacts of climate change and biodiversity loss on soil health. While no single indicator was found to be suitable across all land uses, several were identified as being primary indicators for specific land use types, and seven were found to be extremely important indicators of soil health in more than 50% of the land uses.

- **Report on reuse of waste-water treatment waste:** SEFARI researchers used work funded under the SRP to contribute to a European Environment Agency report on 'Sewage sludge and the circular economy'. The report focuses on options for recovery of energy and nutrients from sewage sludge in the context of the Green Deal and ambitions for zero-pollution. This multi-national report included contributions from academic, industry and policy experts.

Work Package 1.2: Water

Major Achievements

- **Long term monitoring in the Tarland catchment shows rising stream water phosphorus (P) concentrations over the last decade:** An evaluation of the contributions to the decline in water quality due to recycling of streambed P in sediment identified that influential sediment storage zones, in low energy channels in the lower catchment, provide P sources to streamwater that contribute to decadal changes in water quality. This study shows a need for sediment management to maintain Water Framework Directive good ecological condition in streams and the value of such assessment methods to inform effective catchment management.

- **New approach for analysing stream turbidity data (proxy for suspended sediment and pollution) tested:** SEFARI researchers analysed a turbidity time series dataset - recorded every 15 minutes in the Wemyss catchment for over a year - along with two explanatory variables (stage height and rainfall). Turbidity time series are complex and cannot be tackled by traditional simple models. Thus, we developed a new model and approach to analyse the temporal dynamics of turbidity in streams which has the potential to be applied more widely to in-situ sensor applications.

- **Water quality implications of the EU Green Deal reviewed:** The opportunities of the proposed EU Green Deal for meeting the water quality objectives of the Water Framework Directive (WFD) in agricultural landscapes was assessed in a recent review undertaken by SEFARI scientists in collaboration with European researchers. The review found that the reliance on the Common Agricultural Policy poses a risk to meeting water quality improvement objectives. To meet WFD objectives, it is argued that a range of new strategies for understanding and solving water

quality problems, such as better integration of the EU's strategies and scientific evidence, are required.

- **Bloomin' Algae app helps to reduce risks to public and animal health from harmful algal blooms:** A new version of the Bloomin' Algae app was completed in March 2021 to include real-time maps of harmful algal blooms and more rapid feedback to agencies and recorders. This has led to more rapid broadcasting of warning notices by local authorities and landowners (including Scottish Water and NatureScot), reducing risks to public and animal health.

Work Package 1.3: Biodiversity

Major Achievements

- **Crop mixtures for sustainable farming:** SEFARI researchers are working with farmers to trial crop species mixtures as a practice that can reduce chemical inputs and enhance agrobiodiversity. The successes and challenges of this work are summarised in a recent podcast recorded for the 'Cereals' agricultural event in July 2021.

- **Participatory video enables meaningful and transformative interactions with nature:** A newly published paper demonstrates the benefits of using participatory video as a nature engagement tool with young people. In addition to facilitating transformative experiences with nature, the tool increased young people's efficacy, confidence, and sense of empowerment, all of which are necessary to bring about pro-environmental behaviour.

- **Ecological implications of a decline in oak:** SEFARI scientists, working with Forest Research, have recently published a Research Note outlining the implications on biodiversity and ecosystem functioning due to a decline in UK native oak trees, and management

- **Liver fluke risk and agri-environment schemes:** The risk to livestock of grazing saltmarsh habitat to help conserve protected natterjack toad populations on the Solway Firth are being investigated by SEFARI scientists. Results would suggest the fluke risk to livestock is relatively low, but requires careful monitoring. The work has been written up as a case study for the SEFARI website and is currently being incorporated into a Conservation Grazing Guide for Farmers and Land Managers.

- **Increasing resilience of trees and woodlands:** Building on previous SRP funded work, SEFARI researchers have secured NERC funding for a project "(newLEAF)". The project will look at the capacity tree species have for adaptation and whether this can be realised in different situations and timeframes. Announcements of the six successful UK Treescapes projects were made on 9th August and have already generated considerable interest from practitioners and policy-makers.

Work Package 1.4: Integrated Land Use Systems

Major Achievements

- **Stakeholder engagement:** SEFARI researchers have continued to use knowledge and expertise gained during the SRP to engage with natural capital related work beyond the programme. This includes membership of the steering groups on ongoing projects such as the ONS Natural Capital Accounts for Scotland, and specific projects including the Scottish Wildlife Trust's Oceans of Value initiative.

- **Agri-Environmental Schemes for the provision of multiple benefits:** Building on SRP work on the design of Agri-Environmental Schemes (AES) for the provision of multiple benefits, SEFARI researchers contributed to the XVI congress of the European Association of Agricultural Economics in July 2021. This included a session on "How to Promote the Collective Uptake of AESs by Farmers?", and a discussion on "how the CAP can incentivise farmers to adopt greener practices" with a focus on the role of economic experiments to address this. A complementary paper was also published.

- **Integrated land use systems' research:** findings from work conducted under the SRP have been shared through conferences and courses. The Forum Carpaticum was co-organised, with a session on the power of social innovation, and the United Nations Mountain Partnership: Course 21: Course 21 was held, addressing Post-Covid-19 green recovery in rural areas and the role and place of social innovation. Findings on the shared vision of multifunctional land use systems were presented at an online seminar in Guadeloupe and at the International Union of Forest Research Organisation's conference and at European Commission's Director General Agri & European Network for Rural Development events. Several scientific journal articles on social innovation have been published (Barlagne et al 2021; Kluvankova et al 2021; Nijnik et al 2021).

- **Regional Land Use Partnership pilot coordination network:** A two-hour web-based workshop was run with the network and included a presentation on SEFARI catchment partnership work. The meeting was attended by representatives from Scottish Government and Local Authorities. Further discussions on partnership and landscape governance have been had with the Scottish Government.

Theme 2 - Productive and Sustainable Land Management and Rural Economies

Work Package 2.1: Crop and Grassland Production and Disease Control

Major Achievements

- **A new approach to barley breeding:** SEFARI researchers have leveraged funding to refresh the diversity in the barley breeding gene pool and make full use of wild genotypes that carry useful resilience traits. This will enable the development of completely novel and diverse germplasm pools that will have value for future barley breeding, enabling the efficient extraction of value from diverse germplasm in crop improvement programs for complex and multigenic traits. The four-year project is funded by BBSRC and has a value of £677K.
- **Development of high-health high-berry plantlets:** Working with an industry consortium, SEFARI researchers will build on underpinning SRP research to develop novel propagation technologies, addressing significant challenges in the current berry-plant supply chain. The project will help to mitigate quality, yield and health issues that directly affect productivity and profitability in the production of strawberries, raspberries, and blueberries. The two-year project is funded by Innovate UK with an MRP value of £85k.
- **A new mechanism of plant invasion in the potato late blight pathogen is uncovered:** SEFARI researchers, in collaboration with the University of York, have identified a new family of copper-dependent enzymes used by Phytophthora infestans to break down pectin in plant cell walls, providing important insight into how this pathogen is able to invade the host plant. The research was published in the prestigious scientific journal Science. As a direct result of this success, further research is being funded by a BBSRC £1M grant.
- **Knowledge Exchange highlights:** At Arable Scotland 2021 SEFARI researchers participated in the arable conversations sessions to discuss Scotland's commitment to net-zero, sustainable rotations, IPM and new cash crops, using research findings from the SRP. Fruit for the Future and Potatoes in Practice returned to the field with a focus from SEFARI researchers and industry collaborators on current fruit research and new potato varieties, IPM and trade challenges, publicising outcomes of SRP research.

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

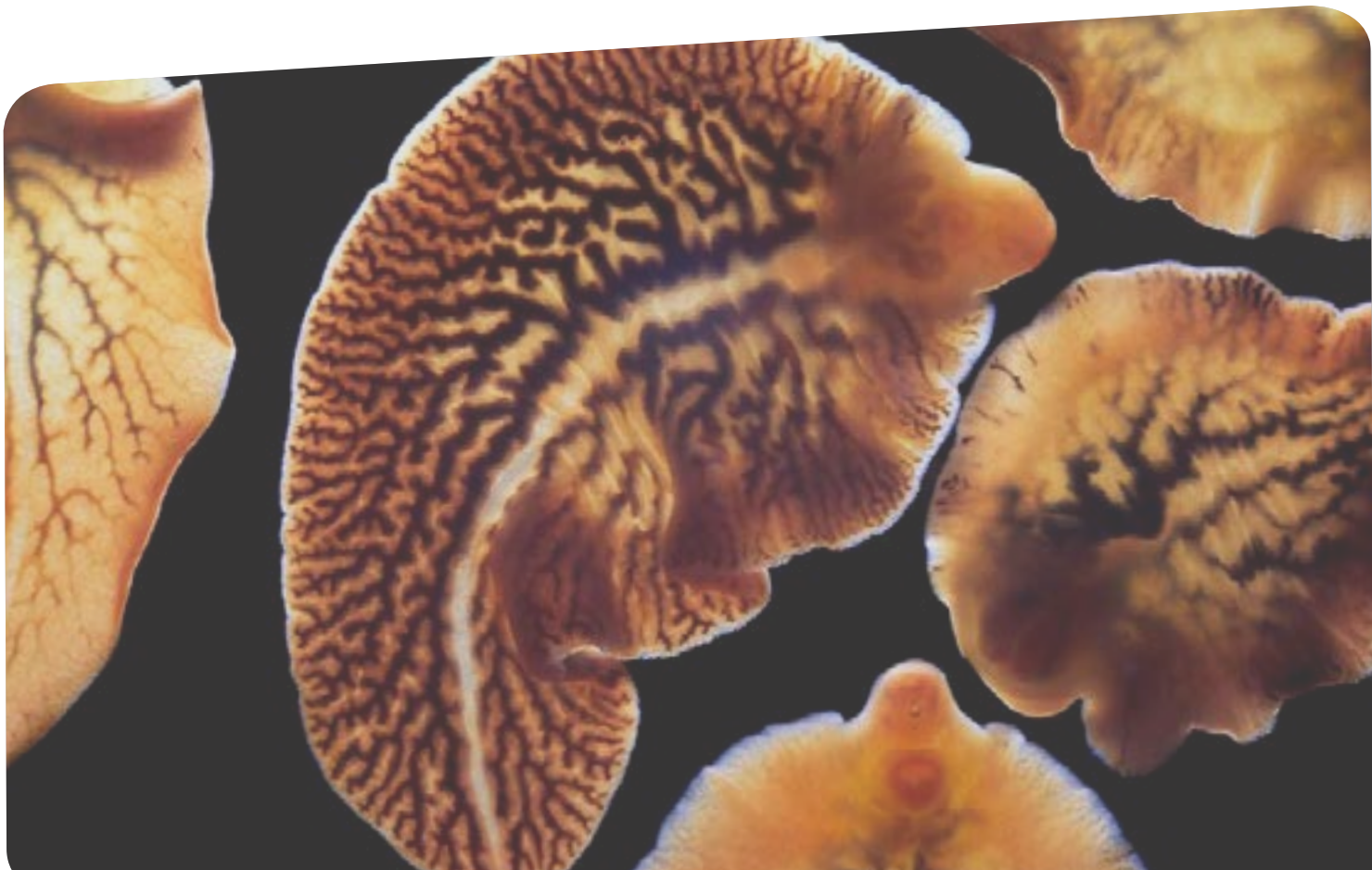
Major Achievements

- **The need for multivalent intestinal parasite vaccines:** During late gestation and early lactation when the natural immunity of ewes to the nematode parasite Teladorsagia circumcincta wanes, it becomes the principal source of parasite egg deposition on pasture. This in turn becomes a major welfare risk to the newborn lambs which can become infected early in life, slowing their growth. Using pasture carrying a mixture of species of parasitic nematodes, we immunised ewes prior to lambing and monitored their immune responses, parasite burden and the growth rates of their lambs. Vaccinated ewes had strong antibody responses against the vaccine and shed up to 52% fewer T. circumcincta eggs than unvaccinated ewes in the 2 months following lambing. However, this effect did not have a significant impact on lamb growth, suggesting that additional parasite species need to be targeted for maximum impact on lamb health. Nematodes of the genus Trichostrongylus typically co-occur with T. circumcincta in temperate regions. We have produced lambs which are immune to Trichostrongylus vitrinus and used their antibodies

to identify immunoreactive proteins from the nematodes as an initial identification of vaccine targets. One protein in particular, similar to one of the T. circumcincta vaccine components, has been selected and produced as a recombinant protein for future combination vaccine studies.

- **Investigating the production effects of liver fluke infection:** Complementing the abattoir study of over 250,00 cattle reported on previously, a comprehensive review of 28 published and unpublished studies of liver fluke (image below), Fasciola hepatica, in sheep and cattle was carried out in an attempt to quantify the production effects of infestation. A meta-analysis using 233 performance comparisons between animals infected with liver fluke with uninfected animals revealed that infected animals had 9% lower daily weight gain resulting in a 6% lower live weight than uninfected animals. Effects of fluke infection on carcass weight were negligible (0.6%) although statistically significant, but effects on total weight gain and milk production were non-significant. In general, effects were larger in studies that reported results from experimental infections rather than observational studies on natural infections, in studies that used young animals, and in studies that measured effects long after initial infection. Our conclusions from this, and the previous study, are that farmers need to be proactive in their fluke control programmes and make use of available information in relation to testing, treatment, quarantine, housing etc. Good practice guidelines are available at the Control of Worms Sustainably (COWS) website.

- **Development of a model of SARS-CoV-2 infection:** In collaboration with partners at the University of Edinburgh, a model of SARS-CoV-2 was developed within the Moredun Research Institute high containment facilities, supported through the underpinning national capacity stream of the RESAS strategic research portfolio, and involved intra-nasal challenge with SARS-CoV-2, of mice carrying the human protein (ACE2), which is targeted by the virus to allow it entry to the cell. The model replicates the changes in the lung seen with human SARS-CoV-2 infections and therefore will be used to determine the effectiveness of novel therapeutics and/or vaccines aimed at controlling SARS-CoV-2 in humans and other susceptible animal species.



Work Package 2.3: Productive and Sustainable Land Management

Major Achievements

- **Data driven approach to understand animal performance on farm:** SEFARI researchers have provided early evidence on digital information that could be used to derive key traits of livestock. Using data driven approaches, researchers showed they could "predict" traits that would otherwise be difficult to record and predict important performance indicators, including feed intake and disease. Results that deploying machine learning approaches to time budget data on cattle could be used to derive feeding behaviour profiles with lower errors that previous methods. However, further work is required to refine methods and improve model robustness. Other research that disease and healthy animals had different time budget profiles and variations within and between animals could be used to help inform on individual and herd health status.

- **Efficiency drivers in EU sheep systems:** European grassland sheep production must be carbon and resource efficient to meet environmental, rural and societal needs. As part of networking projects, Scottish farm data were combined with an EU dataset of labour, carbon and economic data for farm case studies modelling different sheep management strategies. Analyses showed sheep performance recording and artificial insemination are beneficial to farm profitability and environmental footprint. Further ewe prolificacy, breeding management and/or technology adoption can improve environmental and labour efficiency.

- **Cereal varieties for conservation agriculture:** Analysing the yield response of cereal varieties to conventional plough (inversion tillage) and zero or minimum (non-inversion) tillage in trials across 11 years, SEFARI researchers have identified varieties that are differentially adapted to tillage (Agronomy 10, 686; and Agronomy 11, 30). We also observed reductions of over 80% in rust and mildew diseases in conservation compared with conventional tillage crops, facilitating reduced crop protection inputs. Next, we will determine the traits that make the varieties suitable for the low input agronomy of non-inversion tillage, develop tools for breeding such varieties, and develop IPM strategies suitable for net zero carbon crop production systems.

- **Visual Evaluation of Soil Structure (VESS) used to inform policy advice:** VESS was used as part of a Royal Society Evidence Synthesis on soil structure to help inform the Government's Agriculture Bill. SEFARI researchers also helped groups in Finland and Switzerland develop their own modified VESS tools.

- **Testing the long-term effect of fertilisers on soil health:** Research by SEFARI scientists, supplemented with funds from AHDB, studied the impact of different fertiliser treatments on soil properties and crop performance using the 'The Woodlands Field Old Rotation experiment. All fertilised and unfertilised crop types had soil properties with 'good' or 'moderate' soil health status according to the developed soil health scorecard. As expected, phosphorus and potassium status was higher in the fertilised soils, but long-term fertilisation did not have an effect on soil organic matter (SOM), pH or soil structure. SOM levels were highest for fertilised oats and roots, whereas earthworm numbers were greatest in the unfertilised grass ley and lowest in the root crop. As expected, higher yields were attained with fertiliser application for all crop types with the greatest increases seen in hay yields.

Work Package 2.4: Rural Industries

Major Achievements

- **Peatlands and Payments:** Linking with work on improved mapping of the area, depth and condition of peat soils and the rates of GHG emissions for such soils under differing land management regimes, farm structure mapping has been used to quantify the degree of exposure to peatland per businesses. The area, types of peatlands and emissions were summarised for size classes, farm types and regions. The information has been used, working with RESAS analysts, science advisers and policy leads, to inform decision making on how to prioritise peatland restoration to deliver the commitments within the Climate Change Plan.

- **Changes in the distribution of agricultural support from 2014 to 2019:** This research has been conducted to update the information made available to the Agriculture and Rural Development stakeholders' group in 2017 and the Agricultural Strategy Champions in 2018. The analysis has integrated data from the Rural Payment Inspection Division and Census Branch to map both the mix and distribution of payments and the 2014 to 2019 change. The analysis also summarises the changes by region and farm type. The degree and nature of redistribution is quantified and options for looking at linkages between payments and production, natural capital or ecosystem services are being explored.

- **Methodological developments in social research:** Two papers have been published presenting methodological developments in social research. One focuses on how interview questions on the "good farmer" can be complemented by questions on the "good day". The latter question brings out perceptions of well-being, risk and job satisfaction. The two questions enable researchers to elicit data on sensitive issues (e.g. bad farming, social norms, mental health) in a way which is culturally appropriate. The second paper focuses on rural gentrification particularly how the keeping and riding of horses changes the physical and cultural landscape as well as local economic development. The paper breaks new ground for gentrification studies by considering the agency of non-human actors (the horses).

- Agricultural Policy: Researchers continued to support the Scottish Government and Farmer Led Climate Groups, through presence on the Hill Upland and Crofting Group, the Arable Climate Change Group and the Suckler Beef Climate Group Programme Board. A further piece of research provided estimates of how Scottish agricultural support is spread across sectors and geographies (Estimation of sectoral CAP payment 'envelopes' and distribution of agri-environment and forestry support 2019) that improves knowledge of how decoupled support may be allocated across the farming sector (i.e. if payments were to be recoupled). Our researchers have also been working on ex-ante modelling of post-Brexit policy impact on farms and with NatureScot on the assessment of alternative payments under different agri-environment focused farm management practices, such as organic farming, zero tillage and low input system.

Theme 3 - Food, Health and Wellbeing

Work Package 3.1: Improved Food & Drink Production

Major Achievements

- **Food chain waste:** It is estimated that Scottish households throw away 630,000 tonnes of food waste every year. To better understand this, researchers created a database of survey responses on the relationship between household food waste-related behaviours and actual and perceived food insecurity - such as income and price sensitivity - and actual or perceived food availability during the COVID-19 epidemic and following Brexit. Allied to this, a publication addressing dairy industry level waste identified the carbon footprint of food losses, the causes of milk losses, and calculated the emissions associated with these and suggested mitigations that would both improve productivity and reduce GHG emissions.
- **The role of plants in the spread of zoonotic pathogens:** Work on human pathogens and crops was summarised in a SEFARI blog which identified that between a third and a half of all foodborne illnesses are attributed to plant-based foodstuffs and that the social and economic cost of all foodborne disease is £9bn per year. The blog described the organisms responsible for this and their ability to colonise crop plants for the complete plant growth cycle, and this work was further supported by a publication on how the foodborne pathogen, The Shiga Toxin producing Escherichia Coli (STEC), exploits L-arabinose as an abundant metabolite in edible crop plants.
- **Advances in nutrient sources, reformulation and their impacts on health:** Theme researchers published papers on (i) encapsulation of vitamin E in yogurt-based beverage emulsions, biofortification with which increased the antioxidant capability of the yoghurt, a technological approach to food and health that is ready to be adopted by the Scottish dairy industry, (ii) raspberry polyphenols, which may provide beneficial colonic metabolites that protect in colon cancer models, and thus be related to the decreased incidence of colorectal cancer associated with intake of polyphenol-rich fruit and vegetables, and (iii) invasive plants as a valuable alternative protein source and contribute to meeting climate change targets identifying several common Scottish plants, such as gorse, bracken and broom, that could be repurposed as sources of protein and several other health beneficial components such as bioactive phenolics. Aligned with this, funding (£97k) was awarded by the Newton Fund to explore exploitation of the Mezquite tree as a sustainable food source in Mexico.

Work Package 3.2: Healthy Diets and Dietary Choice

Major Achievements

- **New food-based analysis:** Analysis of our National Diet and Nutrition Survey (NDNS+) database shows that variation in nutritional quality, GHGE and cost provides 'food swap' opportunities to improve diets using all three indicators. Based on this, we developed a list of the most nutritious, green and affordable food products. This allows the modelling of foods that optimise healthiness, carbon emissions, price, nutrient profiling and processing level, identifying affordable 'food swaps' that produce greener, fresher and healthier individual shopping lists. We submitted this tool into a recent KTP competition (Mar-21) and our pitch was selected giving us the opportunity to showcase our innovative research to the Food and Drink sector and elicit feedback from the Food and Drink community online.
- **Estimate demand model for ready-to-eat meals:** SEFARI researchers assessed the implications of increased/decreased demand for Scottish-made ready meals on the ready meals subsector and other interrelated sectors. The results suggestthat increased demand for ready meals produced by Scottish companies will expand all sectors of the economy, with the

greatest impact on the ready meals (8.7%) and other food products sectors (2.1%).

- **Food habits in the time of COVID-19:** Leveraging an existing SRP study on dietary habits, our researchers are examining the effect of the COVID-19 pandemic on our food habits. A SEFARI blog presents some of the initial data, indicating that most participants reported only subtle modifications to existing dietary patterns and behaviours rather than radical changes. Subjects were contacted on several occasions during 2021 to build up a longitudinal picture of preserved and evolving dietary habits, and their resilience to shocks to the food supply chain.
- **Publication on relationships between gut health and infections:** SEFARI researchers co-authored a review article on the links between the gut microbiota, host immunity, and infections with the fungal pathogen Candida albicans. The findings are potentially important in understanding the role of diet in human health.
- **Presentations:** Our researchers presented work at (i) the UK Nutrition Society Spring Conference (Mar-21) on gut microbiota metabolism of food-derived mycotoxins and on the dietary influence on functional groups of the gut microbiota, (ii) a webinar on anaerobic culture of the normal human intestinal microbiota (Jun-21), and (iii) the 8th Microbiome R&D & Business Collaboration Forum (May-21) on the continued importance of bacterial culture for gut microbiome research.
- **Public engagement:** SEFARI researchers contributed a series of videos for World Microbiome Day (Jun-21) on the topic of microbiota-directed food formulation.

Work Package 3.3: Food Security

Major Achievements

- **Engagement with food and drink innovation in the Arctic Region:** Based on a SEFARI Gateway Fellowship and SRP 'Local Food' data, a SEFARI researcher published the report Food and Drink Innovation and Clustering in Scotland's Highlands and Islands: review of opportunities for engagement with the Arctic Region.
- **Publications:** A Theme researcher published a paper entitled 'Purchases of meats and fish in Great Britain during the Covid-19 lockdown period', and the blogs 'Upbeat news about the UK organic food market can be misleading' and 'How UK food and drink exports to EU and non-EU countries have evolved over time' in the London School of Economics Business Review. They showed, respectively, that the increase in sales of organic meats during Covid-19 lockdown was due to higher prices and not higher qualities demanded, and that the trends of exports of food and drinks have suffered as a consequence of Covid-19 and Brexit.
- **Presentations:** Theme researchers presented papers to the XVI Congress of the European Association of Agricultural Economists (Jul-21), addressing consumers' preferences and willingness to pay for organic chicken, the impact of restricting the advertising of promotions of foods high in fat, sugar or salt, and 'Food Prices in Scottish Remote Rural Areas: Measuring and Explaining the 'Remoteness Premium'. Presentations to the British Sociological Association addressed interactions between food insecurity, perceived health and social isolation, and provided evidence that the 2017-19 Scottish Health Surveys are likely to have under-reported the prevalence of food insecurity in Scotland.

Work Package 3.4: Communities and Wellbeing

Major Achievements

- **National Islands Plan Survey:** Our researchers prepared the summary for the National Islands plan. An additional visual summary of the results is now available as well as an online results explorer. Island groups that were developed by researchers during the survey are now being mainstreamed by the Scottish Government, e.g. they are being used in the consultation on an Islands Bond and are also being used by the National Registry of Scotland's small area population estimations.
- **Response of Scotland's rural communities to Covid-19:** A report considering the response of Scotland's rural and island communities to Covid-19 was published. The report was covered by BBC Radio Orkney and national print media. A follow-on workshop in June 2021 discussed how the recommendations of the report could be actioned. Presentations including discussion of the effect of the pandemic on migration were delivered at the British Sociological Association Annual Conference, the International Migration Research Network conference (Jul-21; Luxembourg), and the Land Academy conference.
- **Contributing to rural debates:** SEFARI researchers contributed to a podcast discussing the key rural issues to be tackled by the new Scottish Government, and submitted written evidence to the UK Government Scottish Affairs Committee's Inquiry on 'Scotland and the Shared Prosperity Fund'.
- **Promoting engagement to participation in natural environments:** Our researchers contributed to the evaluation of nature-based interventions to promote engagement with nature as part of the Cumbernauld Nature Connections Lottery funded project. The report 'Monitoring outcomes of Cumbernauld Living Landscape volunteers projects' is available upon request (kate.irvine@hutton.ac.uk). A paper was published on the constraints older people face to participate in outdoor recreation.

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